Symmetry preference in shapes, faces, flowers and landscapes

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Most people like symmetry, and symmetry has been extensively used in visual art and architecture. In this study we compared preference for images of abstract and familiar objects in the original format or when containing perfect bilateral symmetry. We created pairs of images for different categories: male faces, female faces, polygons, smoothed version of the polygons, flowers, and landscapes. This design allows us to compare symmetry preference in different domains. Each observer saw all categories randomly interleaved but saw only one of the two images in a pair. After recording preference, we recorded a rating of how salient the symmetry was for each image, and measured how quickly observers could decide which of the two images in a pair was symmetrical. Results reveal a general preference for symmetry in the case of shapes and faces. For landscapes, natural (no perfect symmetry) images were preferred. Correlations with judgments of saliency were present but generally low, and for landscapes the salience of symmetry was negatively related to preference. However, even within the category where symmetry was not liked (landscapes), the separate analysis of original and modified stimuli showed an interesting pattern: Salience of symmetry was correlated positively (artificial) or negatively (original) with preference, suggesting different effects of symmetry within the same class of stimuli based on context and categorization.

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23   Abstract

24   Most people like symmetry, and symmetry has been extensively used in visual art and

25   architecture. In this study we compared preference for images of abstract and familiar objects in

26   the original format or when containing perfect bilateral symmetry. We created pairs of images

27   for different categories: male faces, female faces, polygons, smoothed version of the polygons,

28   flowers, and landscapes. This design allows us to compare symmetry preference in different

29   domains. Each observer saw all categories randomly interleaved but saw only one of the two

30   images in a pair. After recording preference, we recorded a rating of how salient the symmetry

31   was for each image, and measured how quickly observers could decide which of the two images

32   in a pair was symmetrical. Results reveal a general preference for symmetry in the case of shapes

33   and faces. For landscapes, natural (no perfect symmetry) images were preferred. Correlations

34   with judgments of saliency were present but generally low, and for landscapes the salience of

35   symmetry was negatively related to preference. However, even within the category where

36   symmetry was not liked (landscapes), the separate analysis of original and modified stimuli

37   showed an interesting pattern: Salience of symmetry was correlated positively (artificial) or

38   negatively (original) with preference, suggesting different effects of symmetry within the same

39   class of stimuli based on context and categorization.

40   Symmetry preference in shapes, faces, flowers and landscapes

41   Symmetry is often mentioned in connection with aesthetics and preference (Birkhoff,

42   1933; Osborne, 1986; Ramachandran & Hirstein, 1999). Several studies have demonstrated that

43   observers tend to prefer the more symmetrical version of a given stimulus, using both familiar

44   objects and abstract patterns (Eisenman, 1967; Rhodes, Proffitt, Grady, & Sumich, 1998). Some

45   evidence for symmetry as a general aesthetic principle comes from cross cultural studies (for a

46   recent review see Che, Sun, Gallardo, & Nadal, 2018). In addition to explicit measures, implicit

47   measures have confirmed an association between symmetry and positive valence (Makin,

48   Pecchinenda, & Bertamini, 2012).

49   In this study, we examined the preference for symmetry using a deliberately

50   heterogeneous set of images; specifically, faces (males and females), abstract shapes (smooth

51   and angular), flowers, and landscapes. The aim was to compare the role of perfect bilateral

52   symmetry in the context of multiple categories, and to relate preference to rating of the symmetry

53   salience of the items. For one category (landscapes) the symmetry was about positions of objects

54   (composition) and therefore this is a special case of symmetry that is not within an object.

55   Symmetry in shapes, faces, flowers and landscapes: a brief review

56   Chatterjee has observed that there is a link between the existence of brain regions

57   selective for processing faces (fusiform face area, FFA), bodies (extrastriate body area, EBA)

58   objects (lateral occipital complex, LOC) and places (parahippocampal place area, PPA), and the

59   fact that these are common elements in works of art (Chatterjee, 2014). This, however, raises the

60   question of whether there are general aesthetic principles, such as preference for symmetry,

61   independent of category, or whether aesthetic principles are specific to each category.

62   The early work on symmetry and preference used abstract configurations (e.g. Birkhoff,

63   1933; Eisenman, 1967). It is well established that preference for symmetry correlates with the

64   salience of abstract symmetry. Jacobsen and Höfel (2003; Höfel & Jacobsen, 2007) used black

65   and white patterns and recorded visual evoked potentials. They found preference for reflectional

66   symmetry and strong activation in visual areas. Makin, Helmy and Bertamini (2018) compared

67   preference for abstract patterns where salience had been determined by formal measures of

68   perceptual goodness (van der Helm & Leeuwenberg, 1996), discrimination speed and amplitude

69   of the visual evoked brain response (Makin et al., 2016). Results were straightforward: measures

70   of salience correlated with preference ratings. The more perceptually obvious the symmetry, and

71   the larger the neural response, the more people liked it. Moreover, the results were similar in

72   samples from UK and Egypt.

73   Other work has shown that implicit preference for symmetry is closely related to how

74   quickly symmetry can be discriminated (e.g. Makin et al., 2012; Makin, Pecchinenda, &

75   Bertamini, 2012). Despite this strong link, it is also known that preference for symmetry varies

76   with several factors, in particular with age and sex (Humphrey, 1997) and with training (Eysenck

77   & Castle, 1970). Although, importantly, symmetry preference is stable in the context of category

78   learning (Rentschler, Jüttner, Unzicker, & Landis, 1999). Moreover, McManus (2005) has

79   argued that there is always a tension between symmetry and asymmetry, in the sense that the best

80   balance may not be achieved by perfect symmetry.

81   The literature on the attractiveness of faces is vast (for a review, see Rhodes, 2006). The

82   universality of this preference in humans is supported by cross-cultural and developmental

83   studies (e.g., Perrett, May, & Yoshikawa, 1994). Symmetry contributes to beauty for both males

84   and females faces, with evolutionary psychologists highlighting the role of symmetry in

85   signalling mate quality and health (e.g., Gangestad & Thornhill (1997); Watson & Thornhill

86   (1994). Evidence in support of the link between facial symmetry and health is mixed (for a

87   negative finding see Pound et al., 2014) and even chicken prefer more symmetrical human faces

88   (Ghirlanda, Jansson & Enquist, 2002). There is an alternative position that argues that preference

89   for symmetry is a by-product of how information is processed by neural systems (Enquist &

90   Arak, 1994; Enquist & Johnstone, 1997). This alternative view has been highlighted recently by

91   Ryan: "'preferences for symmetry in sexual traits may have nothing to do with good genes of the

92   courter but more with how the brains of the choosers work" " (Ryan, 2018, p.68). However, it

93   should be noted that these two positions are not mutually exclusive.

94   Little (2014) has argued that symmetry preference is domain specific and stronger in the

95   case of faces. This is consistent with an evolutionary view claiming that symmetry is an index of

96   the ability of an organism to cope with developmental stress and thus an index of mate quality. In

97   support of this view it has been reported that preference for symmetry in faces is stronger for

98   upright than for inverted faces (Little & Jones, 2003). The study by Little (2014) compared

99   responses to human faces, primate faces, and abstract art images. They reported strongest

100   preference for symmetry in human faces. However, the faces were discrete objects while the

101   abstract patterns used were patches of colour that did not form a single object. It is known that

102   symmetry is more salient in the case of other grouping factors (i.e., within rather that between

103   objects; e.g. Bertamini, 2010). Recently, Vessel, Maurer, Denker and Starr (2018) found strong

104   inter-individual agreement (i.e., shared taste) for faces and to a lesser extent for landscapes, and

105   low agreement for architecture and in particular for artworks. This suggests the possibility that

106   there are different mechanisms, and different factors affecting symmetry preference for different

107   categories of objects. For faces symmetry may be linked to attractiveness, and possibly mate

108   quality. At the other extreme we have bilateral symmetry between objects, such a physical layout

109   of different objects, it is possible that symmetry is not a predictor of preference.

110   Flowers are interesting stimuli for different reasons. The growth process may explain

111   some of the symmetry present in flowers, just as in leaves and other biological features. In

112   addition, flowers have evolved to be salient visual stimuli and attractive to insects in particular,

113   as this is their function. Bumblebees for example show an innate preference for bilateral

114   symmetry in flowers (Rodríguez et al., 2004). In a recent study, Hůla and Flegr (2016) asked

115   observers to rate the beauty of 52 common wildflowers. Flower with radial symmetry and low

116   complexity were rated as the most beautiful. The authors note that these are more prototypical as

117   flowers. There was also a preference for more coloured flowers (in particular for blue). Although

118   most flowers possess a degree of symmetry, just as for human faces, this symmetry is not

119   perfect. It is possible therefore to modify the images to create flowers with perfect bilateral

120   symmetry.

121   Landscapes have been studied in terms of preference, although in some cases they have

122   been selected as rich stimuli but without a specific interest in what makes landscapes special.

123   Rapid categorization of scenes is possible, for example in terms of openness, and is probably

124   based on coarsely localized information (Oliva & Torralba, 2001) and colour (Oliva & Schyns,

125   2000). With respect to preference, the biophilia hypothesis suggests that preference for open

126   space with sparse vegetation and water may reflect the characteristics of the environment

127   familiar to our common African ancestors (Wilson, 1984). In one study, Falk and Balling (2010)

128   found evidence for this hypothesis by presenting participants with diverse types of landscapes

129   (see also Orians & Heerwagen (1992)). Using functional magnetic resonance imaging, Yue,

130   Vessel and Biederman (2007) found that viewing scenes independently rated as preferred, was

131 associated with greater activation in the parahippocampal cortex, but not in the lateral occipital

132 complex (LOC). As in other studies, the category scenes included a variety of settings, some

133 outdoors and some indoors. For the purpose of our study by landscape we mean an outdoor scene

134 with views extending in the distance.

135   Landscapes are unlike single objects in important ways. A body that is subject to growth

136 will contain some degree of symmetry, but a natural landscape is shaped by multiple physical

137 processes. It is unlikely that hills, boulders or trees will be located in a symmetrical pattern. This

138 can be contrasted with non-natural, highly constrained scenes of towns or gardens. Our study is

139 therefore the first that allows a direct comparison of the strength of preference for symmetry in

140 landscapes as compared to other categories. As noted above there are good reasons to expect

141 symmetry to be closely associated with objectness, and therefore to have a different function

142 within rather than between objects.

143   The current study

144   We selected images of faces (males and females), abstract shapes (smooth and angular),

145 flowers, and landscapes. Observers were asked for ratings of beauty in the context of multiple

146 categories. For each item we had two versions, one had perfect bilateral symmetry and the other

147 had a much lower degree of regularity. We will us the terms original and bilateral symmetry

148 respectively. Examples of the stimuli are provided in Figure 1. The images as well as the raw

149 data are available on Open Science Framework (osf.io/9qz6p).

150   Each observer, however, never saw both versions of a given item. Perfect symmetry is

151 rare in nature, and there is some evidence in the case of faces that when it appears artificial then

152 less symmetrical faces may be preferred in some cases (Zaidel & Hessamian, 2010). Therefore,

153   although we predict a preference for symmetry, preference may depend both on its salience (how

154   easy it is to see) and on how artificial it may appear.

155   In a second phase of the study observers rated how symmetrical each image appeared

156   (rating of symmetry salience) and in a third phase they discriminated which of the pair was the

157   symmetrical version as quickly as possible (response time was recorded). The aim was to test

158   preference for symmetry in a context of multiple categories, without drawing attention to

159   symmetry as the key variable. We will analyse the link between preference and observer ratings

160   of the salience of the symmetry in the pattern. This correspondence could provide support for the

161   view that preference is linked to the tuning of the visual system (Enquist & Arak, 1994;

162   Ramachandran & Hirstein, 1999; Redies, 2007).

163   People may like what they find easy to perceive, providing a direct link between

164   perception and emotion. Leder, Belke, Oebert and Augustin (2004) formulated a model of visual

165   aesthetic judgment, where symmetry is placed, among other factors, within the early perception

166   analysis stage. Symmetry is an optimal stimulus for the human visual system to process, and

167   observers may like it for this reason. Alternatively, the link between preference and fluency may

168   work in a more indirect way because of the positive associations with fluency of processing. This

169   latter idea is known as fluency hypothesis (Reber, Schwarz, & Winkielman, 2004). A recent

170   proposal is that fluency as an amplification role, in the sense that it amplify the pre-existing

171   valence of a stimulus (Albrecht & Carbon, 2014).

172   Despite the extensive literature on preference for symmetry, the relationship between

173   salience and preference for symmetry in different domains requires more exploration. There is no

174   guarantee that preference in one domain will generalize to other domains (Makin, 2017).

175

176   **Methods**

177   **Participants**

178   Forty-two individuals (8 male, 34 female) took part in the study and were recruited from

179   the University of Liverpool student community. The age range was 18-24 and six were left

180   handed.

181

182   **Stimuli**

183   There were six sets of ten pairs of images. For each set, ten images were the original

184   versions (partly symmetrical but without perfect vertical bilateral reflection) and ten images had

185   perfect vertical symmetry. The sets were: male faces, female faces, angular shapes, smooth

186   shapes, flowers, landscapes. All images were in greyscale. We used a black background and the

187   images appeared within a square region of 500 pixels, except for the landscapes that had a height

188   of 500 pixels and a width of 800 pixels.

189   Faces: we used, with permission, some of the images from a classic paper on preference

190   for symmetry: Rhodes, Proffitt, Grady, and Sumich (1998). There were ten males and ten

191   females faces, either as veridical images of human faces or as manipulated images to contain

192   perfect bilateral symmetry, thus generating new images of the ten individuals.

193   Abstract shapes: Points were selected from a circle to create a polygon. For more details

194   on the procedure, see Palumbo, Ruta and Bertamini (2015) and Bertamini, Palumbo, Gheorghes

195   and Galatsidas (2016). Around the polygon there were always 20 convex and 16 concave

196   vertices (total 36). The radius of the underlying circle could vary randomly by 54% in length

197   making the polygon irregular. Symmetrical versions were created by using the left side of the

198   polygon and setting the vertices on the right side by reflection. There were two categories of

199   abstract shapes, one was the original polygons and we refer to these stimuli as Angular (ten

200   pairs). A second set was created by using a cubic spline that made the contour smooth. We refer

201   to this set as Smooth (ten pairs).

202   Flowers: the flower stimuli were from taken from a study by Hůla and Flegr (2016). In

203   this study, people rated 52 flowers for beauty. Results found a preference for blue colour and for

204   radially symmetrical flowers. We selected the following species: Epipactis palustris; Euphrasia

205   rostkoviana; Impatiens noli-tangere; Lathyrus tuberosus; Limodorum abortivum; Melittis

206   melissophyllum; Mimulus moschatus; Ophrys apifera; Pisum sativum; Tropaeolum majus;

207   Veronica beccabunga; Viola biflora; Viola reichenbachiana. Starting from the original images we

208   removed colour and manipulated symmetry to obtain ten pairs of images. One set had the

209   original image of the flower and the other had perfect bilateral symmetry.

210   Landscapes: Images of outdoor scenes were downloaded from the internet. We used the

211   keyword "landscape" on Google image search with a setting of "free to use share or modify".

212   Starting from the original images we removed colour and manipulated vertical symmetry to

213   obtain ten pairs of images. As for the other categories, one set had the original image of the

214   landscape and the other had perfect bilateral symmetry.

215   In summary, for all stimuli (with exception for the abstract shapes) symmetry

216   corresponded to an artificial manipulation, as opposed to the original, natural version. This

217   allowed us to test whether the presence of perfect symmetry would automatically predict higher

218   preference, even in objects - and arrangements of objects - that are not perfectly symmetrical by

219   nature.

220   **Procedure**

221   The experiment had approval from The Health and Life Sciences Research Ethics

222   Committee (Psychology, Health and Society) at the University of Liverpool (Ref: Bertamini:

223   0540). All participants were given information and signed a consent form before the start of the

224   study.

225   Each participant was tested individually in a quiet room. They completed three phases

226   always in the same order. First participants rated the beauty of each image using a mouse to

227   control a rating scale (1 = not at all, 10 = very beautiful). Second, they used a similar rating scale

228   to rate how "clear" and "salient" the symmetry was in the images (1 = not at all, 10 = very

229   salient). The question was phrased as follows: "You will be presented with the same images

230   again. You will need to indicate how 'obvious' or 'salient' is the symmetry in each image (from

231   not at all at very salient)".

232   The last phase had a different format, participants saw a pair of images and selected the

233   more symmetrical of the two. They were asked to respond with one of two keys ('a' and 'l') as

234   quickly as possible. The presentation of the stimuli and the recording of the responses was

235   controlled by a program in Python using the PsychoPy software (Peirce, 2007). Distance from

236   the screen was not enforced, but at a natural distance of approximately 57 cm all stimuli were 10

237   deg of visual angle in height. The three tasks are shown in Figure 2.

238   There were two versions of the procedure. We had ten pairs of images for each category,

239   one original and one with bilateral symmetry. Therefore, 60 images were selected so that for

240   each category there were five original and five bilaterally symmetrical items. These 60 items

241   were used for one version (A) of the experiment. In another version (B) the total number was the

242   same but for each item we used the symmetrical image (if the original was used in set A) and

243   vice versa. This ensured that for each participant a given face, flower and so on was only

244   presented in one version (either original or symmetrical). This difference between set A and B

245   applies to rating of preference and salience, and not for the discrimination task in which the pair

246   was presented on the screen. Upon completion, participants were asked whether or not they had

247   any strategy throughout the study.

248

249   **Analysis**

250   In all the analyses, we split the categories into groups. We tested the results for faces by

251   including male and female as a category. Similarly, we tested the results for abstract shapes by

252   including angular and smooth as a category. This is because we were interested in sex and in

253   angularity as possible factors affecting preference. We did not have similar factors for flowers

254   and for landscapes.

255   All of the analyses in the present work used generalised linear mixed-effects models

256   implemented in the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015) in *R* version 3.3.3

257   (R Core Team, 2018). The dependent measures of these analyses were subjective ratings of

258   beauty or symmetry, or the response times in the discrimination task. A standardisation

259   procedure was applied to these scores, which involved subtracting the mean from the individual

260   ratings, and then dividing each score by the standard deviation. The mean and standard

261   deviations used to standardise the scores were derived from each individual participant rather

262   than the whole sample. All models included symmetry (symmetric/original) as an effect coded

263   fixed factor. Stimulus type was also included in the analyses for faces (male/female) and abstract

264   shapes (angular/smooth), but not for the flower or landscape analysis. The initial random effects

265   structure represented the maximal model (Barr, Levy, Scheepers, & Tily, 2013). For all analyses,

266   we included participant as a random intercept, together with item (the different images) and

267   version (set A and set B), each with fully crossed random slopes for symmetry and stimulus type.

268   We have no theoretical interest in these variables and we treat them therefore as random factors.

269   The model was simplified until convergence was reached where necessary. Log likelihood-ratio (

270   χ^2) comparisons were obtained through the sequential decomposition of the model (Bates et al.,

271   2015), which provided confirmatory tests for the predictors. The marginal and conditional R^2

272   effect sizes are also reported as measures of the variance explained by the model with the

273   random effect structure included (conditional R^2) and excluded (marginal R^2) from the

274   calculation (Johnson, 2014; Nakagawa & Schielzeth, 2013; Nakagawa, Johnson, & Schielzeth,

275   2017).

276

277   **Results**

278   **Preference (beauty ratings)**

279   Before standardisation, beauty score was highest for landscapes (M=74.813; SE=1.046)

280   and lowest for angular shapes (M=30.629; SE=0.884). For smooth shapes it was 33.737

281   (SE=0.942). For males and females faces it was respectively: 32.724, 42.993 (SE=0.85, 0.971).

282   Finally, for flowers it was 51.578 (SE=1.1).

283   Similarly, the standardised beauty score was highest for landscapes (*M*=1.343; *SE*=0.043)

284   and lowest for angular shapes (*M*=-0.622; *SE*=0.036). For smooth shapes it was -0.476

285   (*SE*=0.038). For males and females faces it was respectively: -0.498, -0.059 (SE=0.036, 0.04).

286   Finally, for flowers it was 0.285 (SE=0.047). Mean values are plotted in Figure 3.

287   The maximal model that converged for the faces stimuli contained random intercepts for

288   participant, item, and version, but no random slopes. The model revealed that the standardised

289   beauty ratings for faces with perfect bilateral symmetry were significantly higher than for

290   original faces ($\beta = 0.0462$, $SE = 0.0202$, $\chi^2 = 4.26$, $p = .039$). Furthermore, there was a

291   significant effect of stimulus type ($\beta = -0.2216$, $SE = 0.0202$, $\chi^2 = 110.7$, $p < .001$), as higher

292   ratings of beauty were given to female faces than male faces. There was also a marginal

293   interaction between symmetry and stimulus type ($\beta = -0.0354$, $SE = 0.0202$, $\chi^2 = 3.06$, $p = .080$),

294   as a larger decrease in beauty ratings were observed for original female faces than original male

295   faces, compared to their symmetric counterparts. This model accounted for 10.31% of the

296   variance in the data without the random-effects, but 38.93% when they were included ($R^2_m =$

297   0.1031; $R^2_c = 0.3893$).

298   The maximal model that converged for abstract shapes also only included the random

299   intercepts for participant, item, and version. This revealed that the standardised beauty ratings

300   were significantly higher for symmetrical than original shapes ($\beta = 0.1399$, $SE = 0.0188$, $\chi^2 =$

301   52.09, $p < .001$). Furthermore, there was a significant effect of stimulus type ($\beta = -0.0764$, $SE =$

302   0.0188, $\chi^2 = 16.34$, $p < .001$), as higher ratings of beauty were given to smooth shapes than

303   angular shapes. There was no interaction between symmetry and stimulus type ($\beta = -0.0114$, SE

304   $= 0.0188$, $\chi^2 = 0.37$, $p = .543$). This model accounted for 5.37% of the variance in the data

305   without the random-effects, but 40.01% when they were included ($R^2_m = 0.0537$; $R^2_c = 0.4001$).

306   In the case of flowers, the maximal model consisted of the random intercepts for

307   participant, item, and version. This model did not confirm higher beauty ratings for symmetrical

308   flowers ($\beta = -0.0155$, $SE = 0.0357$, $\chi^2 = 0.19$, $p = .664$), and accounted for 0.03% of the variance

309   in the data without the random-effects, and 32.51% when they were included ($R^2_m = 0.0003$; R^2_c

310   = 0.3251). It is worth noting that in the original study by (Hůla & Flegr, 2016), beauty was

311   mainly linked with radial symmetry of flowers and not bilateral symmetry.

312   The maximal model for the landscapes data also consisted of random intercepts for

313   participant, item, and version. Conversely, this analysis data showed higher beauty ratings for the

314   original images (β = -0.0845, SE = 0.0299, χ^2 = 7.93, p = .005) and explained 1.06% of the

315   variance in the data without the random intercepts and 45.88% when they were included (R^2_m =

316   0.0106; R^2_c = 0.4588).

317

318   **Salience (symmetry ratings)**

319   Ratings of salience of symmetry were analysed in the same way as ratings for beauty. In

320   all of the models, the maximal random-effects structure that converged included the random

321   intercepts of participant, item, and version, with no random slopes.

322   The non-standardised salience score was highest for flowers (mean=66.875; SE=1.736)

323   and lowest for smooth shapes (mean=51.496; SE=2.068). For angular shapes it was 51.924

324   (SE=2.023). For males and females faces it was respectively: 58.247, 61.344 (SE=1.708, 1.682).

325   Finally, for landscapes it was 58.906 (SE=2.035). Mean values are plotted in Figure 4.

326   The standardised salience score was highest for flowers (mean=0.267; SE=0.05) and

327   lowest for smooth shapes (mean=-0.216; SE=0.06). For angular shapes it was -0.21 (SE=0.059).

328   For males and females faces it was respectively: -0.001, 0.089 (SE=0.049, 0.047). Finally, for

329   landscapes it was 0.036 (SE=0.06).

330   The model for faces revealed that the standardised salience ratings were significantly

331   higher for symmetric faces than original faces (β = 0.6382, SE = 0.0195, χ^2 = 646.94, p < .001).

332   Furthermore, there was a significant effect of stimulus type (β = -0.0468, SE = 0.0195, χ^2 = 5.9,

333   p = .015), as higher ratings of symmetry were given to female faces than male faces. There was

334   also an interaction between symmetry and stimulus type (β = 0.0645, SE = 0.0195, χ^2 = 10.9, p

335   < .001), because there was little difference in salience for male and female faces when they were

336   symmetrical, but a larger difference for the original stimuli. This is reasonable given that there

337   was more variability in symmetry in the original faces. This model accounted for 56.73% of the

338   variance in the data without the random-effects, and 60.53% when they were included (R^2_m =

339   0.5673; R^2_c = 0.6053).

340   The maximal model for abstract shapes revealed that the standardised beauty ratings were

341   significantly higher for symmetrical than original shapes (β = 0.9511, SE = 0.0171, χ^2 =

342   1239.09, p < .001). There was no significant effect of stimulus type (β = -6e-04, SE = 0.0171, χ^2

343   = 1.6e-03, p = .968) and no interaction between symmetry and stimulus type (β = -0.0204, SE =

344   0.0171, χ^2 = 1.42, p = .233). This model accounted for 77.21% of the variance in the data

345   without the random-effects, but 79.96% when they were included (R^2_m = 0.7721; R^2_c = 0.7996).

346   In the case of flowers, the model confirmed higher symmetry salience ratings for

347   symmetrical flowers (β = 0.6227, SE = 0.0279, χ^2 = 309.63, p < .001). This model accounted for

348   49.74% of the variance in the data without the random-effects, and 63.11% when they were

349   included (R^2_m = 0; R^2_c = 0.6311).

350   Finally, in the case of landscapes the model revealed higher symmetry salience ratings for

351   symmetrical images (β = 0.997, SE = 0.0218, χ^2 = 717.41, p < .001). This model accounted for

352   81.92% of the variance in the data without the random-effects, and 83.86% when they were

353   included (R^2_m = 0.8192; R^2_c = 0.8386).

354   In summary, for all categories more symmetrical images were rated as more symmetrical.

355   People produced ratings of symmetry salience also for images that were perfectly symmetrical.

356   This variability reflects subjective evaluation of symmetry or possible additional symmetry

357   present independently of the bilateral symmetry manipulation.

358

359   **Speeded Discrimination**

360   The response time necessary to discriminate which of two images was symmetrical was

361   analysed in the same way as ratings for beauty and salience. The only important difference is that

362   here the factor Position refers to the order of the images in the pair. Position symmetry means

363   that symmetry was on the left (and original on the right) and Position original means that original

364   was on the left (and symmetry on the right). The maximal model that converged contained

365   random intercepts for participant, item, and version, with no random slopes.

366   Before standardisation, response time was fastest for smooth shapes (mean=0.888;

367   SE=0.017) and slowest for female faces (mean=1.294; SE=0.037). For angular shapes it was

368   0.893 (SE=0.019). For males faces it was 1.23 (SE=0.037). For landscapes it was 1.041

369   (SE=0.017) and for flowers it was 1.078 (SE=0.026). Similarly, the standardised response time

370   was fastest for smooth shapes (mean=-0.231; SE=0.046) and slowest for female faces

371   (mean=0.304; SE=0.067). For angular shapes it was -0.229 (SE=0.05). For male faces it was

372   0.066 (SE=0.054). For landscapes it was 0.068 (SE=0.049) and for flowers it was 0.046

373   (SE=0.058). Mean values are plotted in Figure 5.

374   The model revealed that there was no difference in response time when the symmetrical

375   image was presented to the left or to the right ($\beta = 0.0263$, $SE = 0.0388$, $\chi^2 = 0.45$, $p = .503$).

376   There was a significant effect of stimulus type ($\beta = -0.1187$, $SE = 0.0388$, $\chi^2 = 9.36$, $p = .002$),

377   as faster responses were given to male faces than female faces. There was no interaction between

378   symmetry and stimulus type ($\beta = 0.0308$, $SE = 0.0388$, $\chi^2 = 0.63$, $p = .426$). This model

379   accounted for 1.35% of the variance in the data without the random-effects, and 1.73% when

380   they were included ($R_m^2 = 0.0135$; $R_c^2 = 0.0173$).

381   The model for abstract shapes revealed that there were faster responses when the

382   symmetrical image was presented to the left ($\beta = 0.0856$, $SE = 0.0306$, $\chi^2 = 7.79$, $p = .005$).

383   There was no significant effect of stimulus type ($\beta = 5.30\text{e-}05$, $SE = 0.0306$, $\chi^2 = 1.1\text{e-}05$, $p =$

384   .997) and no interaction ($\beta = 0.0471$, $SE = 0.0306$, $\chi^2 = 2.38$, $p = .123$). This model accounted

385   for 1.22% of the variance in the data without the random-effects, but 4.03% when they were

386   included ($R_m^2 = 0.0122$; $R_c^2 = 0.0403$).

387   In the case of flowers, the model did not confirm any difference whether symmetry was

388   on the left or the right ($\beta = 0.0079$, $SE = 0.0513$, $\chi^2 = 0.02$, $p = .878$). This model accounted for

389   < 0.01% of the variance in the data without the random-effects, and 5.82% when they were

390   included ($R_m^2 = 0.00006$; $R_c^2 = 0.0582$).

391   Finally, for landscapes as for flowers there was no difference in response time ($\beta =$

392   0.0128, $SE = 0.0445$, $\chi^2 = 0.08$, $p = .774$). This model accounted for 0.02% of the variance in the

393   data without the random-effects, and 3.62% when they were included ($R_m^2 = 0.0002$; $R_c^2 =$

394   0.0362).

395   In summary, for all categories the speeded discrimination was fast and accurate, and

396   differences between categories small. The only additional information was the finding of easier

397   discrimination between symmetrical and original male faces compared to female faces. This

398   pattern is different from that seen for beauty rating: symmetry affected beauty ratings equally for

399   male and female stimuli, with a trend for a stronger modulation for female rather than male

400   faces.

401

402   **Relationship between Beauty and Salience**

403   We analysed to what extent the beauty rating reflected the salience of the symmetry in

404   the images. From our first set of analyses we can already see that the category for which

405   symmetry had the strongest effect on beauty rating was that of abstract patterns, and the

406   symmetry for these images was very high. However, symmetry salience was high also for

407   landscapes and here this factor contributed to rating the images as less beautiful. This suggests

408   that symmetry can be used in different ways in different contexts.

409   Here we ask a different question. Within each category, were images rated as more

410   symmetrical also the images rated as more beautiful in the same category? Therefore, we used

411   salience rating as a predictor. We analysed symmetry (original images and images with perfect

412   bilateral symmetry) as a factor. Note that in the first case, symmetry varied among the original

413   objects, such as faces, and in the second case there was perfect bilateral symmetry, but people

414   reported subjective differences in perceived symmetry.

415   Unlike previous analyses here all the categories are entered in the same analysis. To

416   compare them we used a set of pre-planned contrasts. In particular we analysed the difference

417   between landscapes and flowers in one contrast, in another we combined these two to form a

418   new Nature category and compare this to the category of faces. Finally, in another contrast we

419   tested the group of novel stimuli (smooth and angular abstract stimuli) against the familiar

420   objects (faces, flowers and landscapes). The relationship between beauty and salience ratings is

421   represented graphically in scatterplots in Figure 6.

422   For consistency with previous analyses, we entered subject, item and version as random

423   factors. The model revealed that there was an overall effect of salience in predicting preference (

424   $\beta = 0.1312$, $SE = 0.0383$, $\chi^2 = 5.68$, $p = .017$). Other main effects not related to salience were as

425   follows: Beauty ratings were higher for landscapes than flowers ($\beta = -0.448$, $SE = 0.0648$, $\chi^2 =$

426   295.48, $p < .001$), for nature (landscapes/flowers) than faces ($\beta = -0.4584$, $SE = 0.0389$, $\chi^2 =$

427   617.4, $p < .001$), and for real-world stimuli (landscapes/flowers/faces) than abstract shapes ($\beta = -$

428   0.2438, $SE = 0.0221$, $\chi^2 = 549.77$, $p < .001$). Many of these main effects also interacted with

429   symmetry and salience. The difference in beauty ratings between abstract stimuli and the other

430   types was smaller for symmetrical than the original stimuli ($\beta = -0.0565$, $SE = 0.0222$, $\chi^2 = 4.3$,

431   $p = .038$). Also, increased salience led to a smaller difference in beauty ratings between nature

432   (landscapes/flowers) and faces ($\beta = 0.0364$, $SE = 0.0403$, $\chi^2 = 19.99$, $p < .001$), but a larger

433   difference between landscapes and flowers ($\beta = -0.0007$, $SE = 0.0623$, $\chi^2 = 7.62$, $p = .006$) and

434   familiar stimuli and abstract shapes ($\beta = -0.0149$, $SE = 0.0211$, $\chi^2 = 9.65$, $p = .002$).

435   Beauty ratings for familiar shapes (faces, flowers, landscapes) were more strongly

436   affected by symmetry than unfamiliar abstract shapes ($\beta = -0.0565$, $SE = 0.0222$, $\chi^2 = 4.3$, $p =$

437   .038). Critically, beauty ratings were higher for symmetrical stimuli, but only when this

438   symmetry was salient, as shown by a significant interaction between symmetry and salience ($\beta =$

439   -0.1069, $SE = 0.032$, $\chi^2 = 5.39$, $p = .020$). Finally, there was a three-way interaction between

440   salience, symmetry, and the contrast between nature (landscape/flowers) and face stimuli ($\beta =$

441   0.1015, $SE = 0.0403$, $\chi^2 = 5.78$, $p = .016$), which appears to be due to beauty ratings increasing

442   for faces as the salience of their symmetry increases, but increasing or decreasing with salience

443   for the nature items depending on symmetry. This model accounted for 47.22% of the variance

444 in the data without the random-effects, and 50.15% when they were included ($R^2_m = 0.4722$; $R^2_c =$

445 0.5015).

446 These effects are hard to visualise. Therefore, in Figure 6 we also present two additional

447 plots. These highlight in particular how symmetry salience could be linked in very different ways

448 to beauty rating depending on which set of stimuli we are analysing: the original or the

449 symmetrical set.

450

451 **Symmetry Preference in Individuals**

452 In the previous section we analysed whether the individual images that were perceived as

453 more symmetrical were also rated as more beautiful. Here we turn to the question of whether,

454 across the stimuli, individuals who liked symmetry did so in a consistent manner. Specifically,

455 we examined whether beauty ratings for symmetrical and original stimuli were consistent across

456 the different categories. For each individual, we computed average beauty response for each

457 category, and separately for the symmetrical and original items. These were different items, but

458 within a category we took the difference between the two averages. Therefore, the new value

459 represents how much more the symmetrical stimuli were rated compared to the original stimuli

460 (per person and per category).

461 Figure 7 shows a scatterplot matrix in which each dot is a person. The two axes are two

462 categories, and thus people in the top right quadrants liked symmetry in both categories (say,

463 they liked both symmetrical faces and symmetrical landscapes). People in the bottom left

464 quadrants disliked symmetry in both categories, and in the other two quadrants we have

465 inconsistent liking responses.

466   Table 1 shows the correlations that correspond to the patterns of Figure 7. Both the table

467   and the figure show weak consistency in what individuals liked. In many cases they liked

468   symmetry for one category but not for another. Some of these is not surprising, for example

469   comparing abstract shapes and landscapes many participants are in the top left quadrant because

470   they disliked symmetry in landscapes and liked it in abstract shapes. Some other cases are more

471   surprising, like the total absence of consistency for symmetry in faces and in flowers. Here liking

472   symmetry in one category had no relationship with liking symmetry in the other.

473   In the Supplementary materials we also report a second smaller study (N=25). The

474   procedure and the aims were the same but there were two important changes. One was that in

475   this study observers saw both the original and the bilateral symmetry versions of the items. The

476   other change was that we included colour version of the images in addition to the greyscale

477   versions. The results were consistent with the results of our main study, thus supporting the

478   generality and robustness of the findings.

479

480   **Conclusions**

481   Human preference for symmetry and regularity is a well-known phenomenon. In this

482   study we used a simple rating task with images that were manipulated to introduce perfect

483   bilateral symmetry around the vertical axis. Vertical bilateral symmetry is the most salient type

484   of symmetry (Royer, 1981), and is a non-accidental propriety associated with objectness

485   (Bertamini, 2010; Bertamini, Friedenberg, & Kubovy, 1997). Human faces are a special example

486   of bilateral symmetry and attractiveness ratings increase as symmetry increases (Rhodes et al.

487   1998). In this study we compared different categories of images, including faces, and also

488   images of landscapes which are not characterised by bilateral symmetry in nature.

489   For each specific stimulus we created a pair of images, one was the original and the other

490   the symmetrical manipulation (perfect bilateral symmetry). Each observer only saw one item

491   from a given pair. We refer to the two as symmetrical and original, however, original stimuli did

492   possess some degree of symmetry, as is the case for human faces. Therefore, here by

493   symmetrical stimuli we mean stimuli with perfect bilateral symmetry.

494   We asked what the effect of mixing very different categories of objects would be, and

495   how symmetry preference would relate to symmetry salience in the context of these different

496   categories. We included faces (males and females), abstract shapes (polygons and smoothed

497   polygons), flowers and landscapes. Landscapes are special in that bilateral symmetry here would

498   appear unfamiliar and artificial. The rating for beauty was followed by a second task in which

499   participants rated the salience of symmetry. Finally, they performed a speeded task in which they

500   had to discriminate which of the images in a pair was more symmetrical.

501   From the ratings of beauty, we can confirm some expected effects. Observers preferred

502   the more symmetrical abstract objects. Independently of symmetry, observers preferred smooth

503   shapes over angular shapes, confirming previous findings for preference for abstract shapes

504   (Bertamini et al., 2016). Probably because within abstract shapes the angularity was a salient

505   factor, this effect was strong. Moreover, observers preferred the more symmetrical faces, in line

506   with previous results (e.g. Little & Jones 2003; Rhodes et al. 1998). This preference however did

507   not apply to flowers. This may appear inconsistent with what reported by Hůla and Flegr (2016).

508   Note, however, that Hůla and Flegr had found a particular preference for flowers with naturally

509   occurring radial symmetry. The symmetry we introduced was an artificial bilateral reflection.

510   Moreover, Hůla and Flegr only used images of actual flowers while we compared original and

511   modified versions of the flowers.

512   For landscapes the effect of symmetry reversed compared to faces and abstract shapes,

513   and there was a preference for the original landscape over the one with bilateral symmetry. This

514   suggests that context and categorical classification of images are important. There is no doubt

515   that the landscape images had aesthetic value. Most participants rated landscapes as beautiful

516   (compared to the other categories) as shown in Figure 3. It is likely that introducing perfect

517   symmetry in a natural context was perceived as artificial and unnatural, and consequentially it

518   was disliked. This effect may be similar to that observed for computer generated faces (Zaidel &

519   Deblieck, 2007).

520   The fact that perfect (artificial) symmetry was not preferred in flowers and disliked in

521   landscapes, suggests that symmetry in the image is not a sufficient factor per se to elicit

522   preference, especially in the natural environment. In the case of flowers, the study by Hůla &

523   Flegr (2016) found that beauty was related to radial symmetry. They also had ratings of

524   prototypically and therefore they could show that what was judged beautiful was related to what

525   was perceived as the more prototypical image of a flower. For a prototypical wildflower radial

526   rather that bilateral symmetry is the most important factor. In the case of landscapes this was the

527   only category in which symmetry was not associated with an object but rather with a layout of

528   features and objects. In other words, for landscapes symmetry is about composition. However,

529   despite the fact that for landscapes there was a tendency to dislike symmetry, it is remarkable

530   that within the set of symmetrical images of landscapes the higher ratings of beauty were given

531   to those rated as more symmetrical. We consider this surprising result when discussing the

532   correlation between salience and beauty.

533   Natural landscapes are unlikely to be symmetrical, but often humans manipulate the

534   landscape and introduce regularities. This is clearly the case for landscaped gardens in particular

535   starting with the Italian Renaissance style (Leon Battista Alberti, 1404-1472, wrote a book about

536   architecture that talks extensively about gardens). A recent study, however, has found that the

537   restorative power of gardens was higher for informal rather than formal gardens (Twedt, Rainey,

538   & Proffitt, 2016).

539   In a second analysis we tested ratings of symmetry salience as a predictor of beauty

540   ratings. Overall, we confirmed this link, as it was already observed for faces in the original paper

541   by Rhodes et al. (1998). However, the comparison of the different categories revealed a complex

542   pattern (Figure 6). While previous work has already established a positive relationship between

543   symmetry salience and symmetry preference for abstract patterns (Makin et al., 2012), this did

544   not generalize to landscapes.

545   The experiment used images in greyscale, and a design that avoided presenting both

546   original and modified versions of an item to a given observer. Colour is likely to contribute to

547   beauty. In a follow-up study we included some of the categories (abstract, flowers, landscapes)

548   in both colour and greyscale. We report this experiment in the supplementary materials. It

549   confirmed that ratings for beauty were higher in the case of colour images, but it also confirmed

550   and supported the other results without interactions with colour (see Figure 1S).

551   In terms of general preference for symmetry in some individuals and not others we did

552   not find much evidence that strong symmetry preference in one category implied strong

553   preference in another category. Individual differences have recently been studied in the context

554   of visual illusions. Grzeczkowski et al. (2017) asked the question of common factors in a sample

555   of over one hundred participants. If these common factors exist, a person susceptible to one

556   illusion should be susceptible to other illusions as well. They looked at the correlations between

557   the strength of six illusions but could only confirm a correlation between two of them

558   (Ebbinghaus and Ponzo). They came to the conclusion that, in terms of visual perception,

559   individuals are unique.

560   We highlight two novel aspects of the results. First the role of symmetry varies between

561   categories, as we have seen, and landscape with bilateral symmetry were liked less than the

562   original images of landscapes. We argue that bilateral symmetry is associated with objects and

563   not images with a layout of multiple objects (trees, mountains etc.). However, this first

564   consideration has to be interpreted keeping in mind a second aspect of the data. Within the

565   original images salience and beauty ratings were negatively correlated. However, within the new

566   symmetrical images of landscapes there was a preference for the more symmetrical images

567   (more precisely those where symmetry was more salient, and ratings of subjective symmetry

568   higher). Although we do not have self-reports on this, it is probable that observers were not

569   aware of this effect of symmetry on their responses, as all images were presented interleaved in a

570   random order. We suggest that symmetry was not related to beauty for landscapes because

571   variation in the layout is a positive quality of a complex landscape. But symmetry was related to

572   beauty for artificial landscapes because these were treated as if they were patterns, or objects,

573   and therefore more similar to the other categories of stimuli.

574   The context effects that we report are further evidence of how difficult it is to attribute

575   preference to specific factors. Philosophers have expressed scepticism (e.g., Dickie, 1962), but

576   even within empirical aesthetics problems have been noted (Holmes & Zanker, 2012), and one

577   problem is particular is known as the Gestalt nightmare: having a preference for symmetry and

578   for blue does not mean that we can sum these preferences to predict responses to blue

579   symmetrical stimuli (Makin, 2017). Although strong claims have been made about the existence

580   of a "single neural currency" for aesthetics (Skov & Nadal, 2018), it would be a mistake to

581   conclude from the existence of common reward mechanisms that fixed, objective factors are

582   monotonically contributing to reward, or to preference. Our observed context effects are

583   consistent with other context effects reported. For example, for faces there are both assimilation

584   and contrast effects (Wedell, Parducci, & Geiselman, 1987). More generally, the nature of

585   human choices is known to be multi-dimensional (Tversky & Shafir, 1992). In evaluating visual

586   preference, we found that symmetry can play both a positive and a negative role even within the

587   same study and for the same category of objects. The critical factor that can reverse the effect of

588   symmetry is its association with an object: bilateral symmetry is expected to be a within-object

589   property and is only judged as beautiful in that context.

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Figure 1

Figure 1

Examples of images from each of the six categories. The top row shows the original images that differed in level of symmetry. The second row shows perfect bilateral symmetry. For faces this was a morph of left and right sides and for all other categories was based on the left side only. The unoccluded faces can be seen in the original paper (Rhodes, Proffitt, Grady, & Sumich, 1998) here: www.doi.org/10/ddzs8x

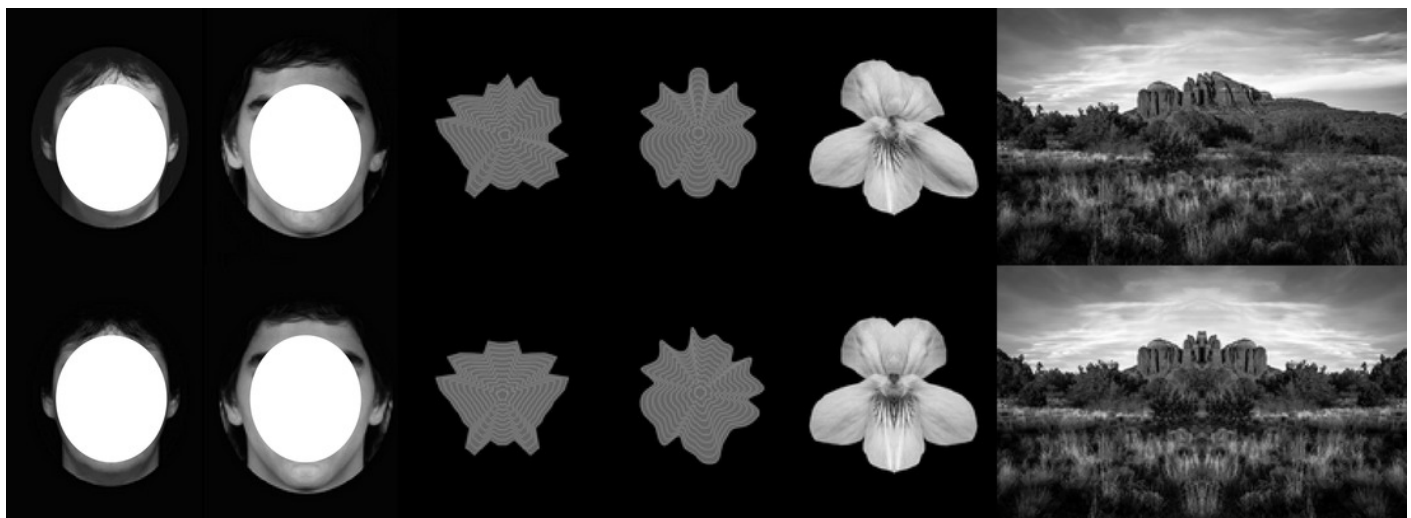
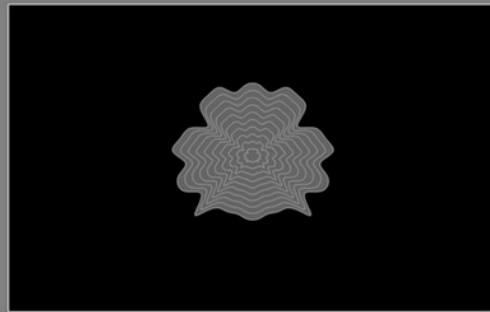



Figure 2

Figure 2

An illustration of the three tasks: beauty rating, followed by salience rating, followed by speeded discrimination. The stimuli were the same for the three tasks but were presented in different random order. The unoccluded faces can be seen in the original paper (Rhodes, Proffitt, Grady, & Sumich, 1998) here: www.doi.org/10/ddzs8x

Welcome to the Experiment.
You will be presented with several images. You will need to indicate how much you like each image (from not at all to very beautiful). First, you will have some practice trials without the actual images to familiarize with the rating scale.
Press space to start with the practice.

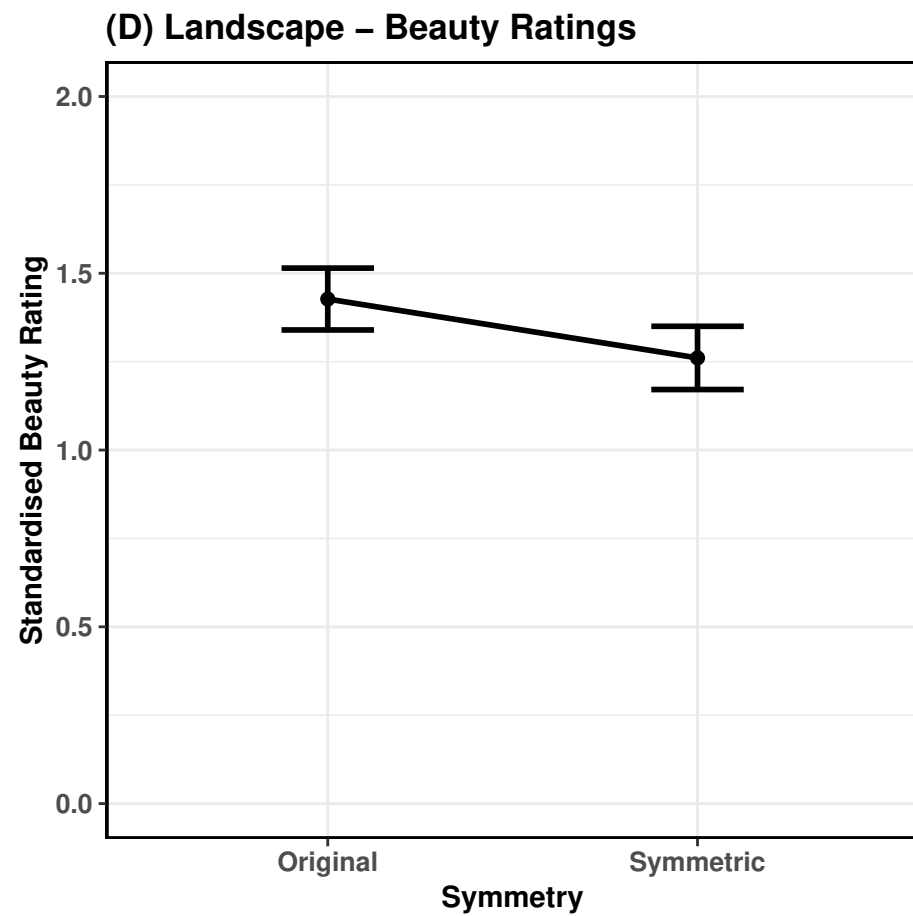
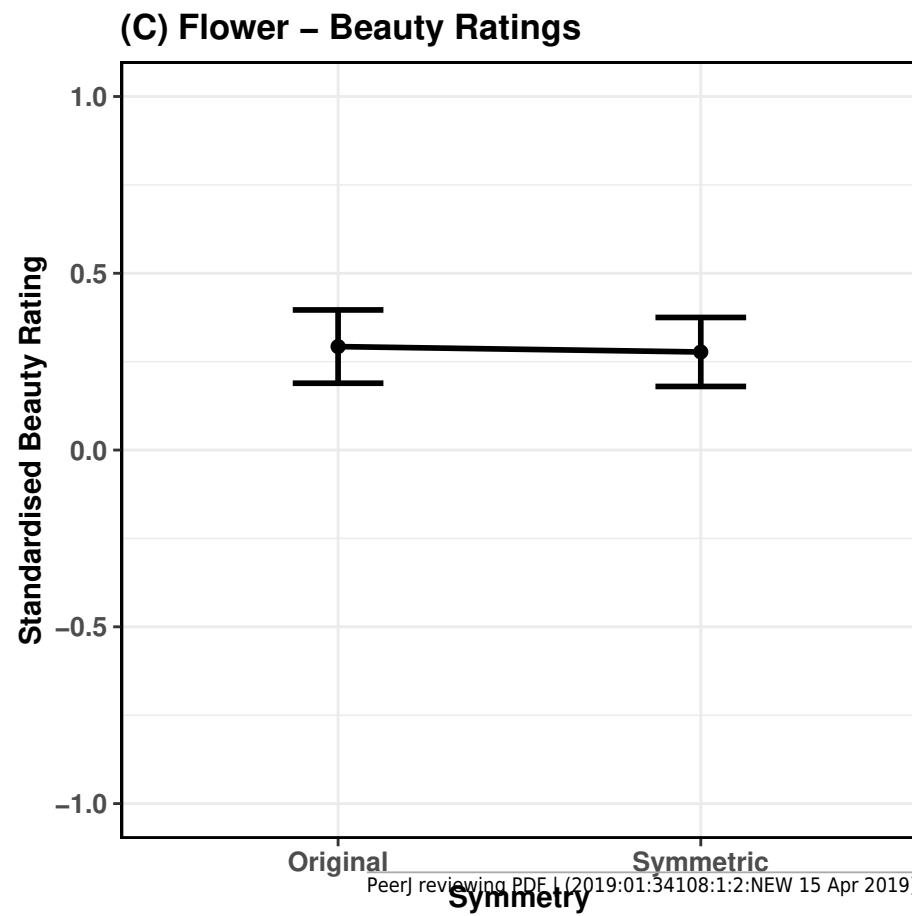
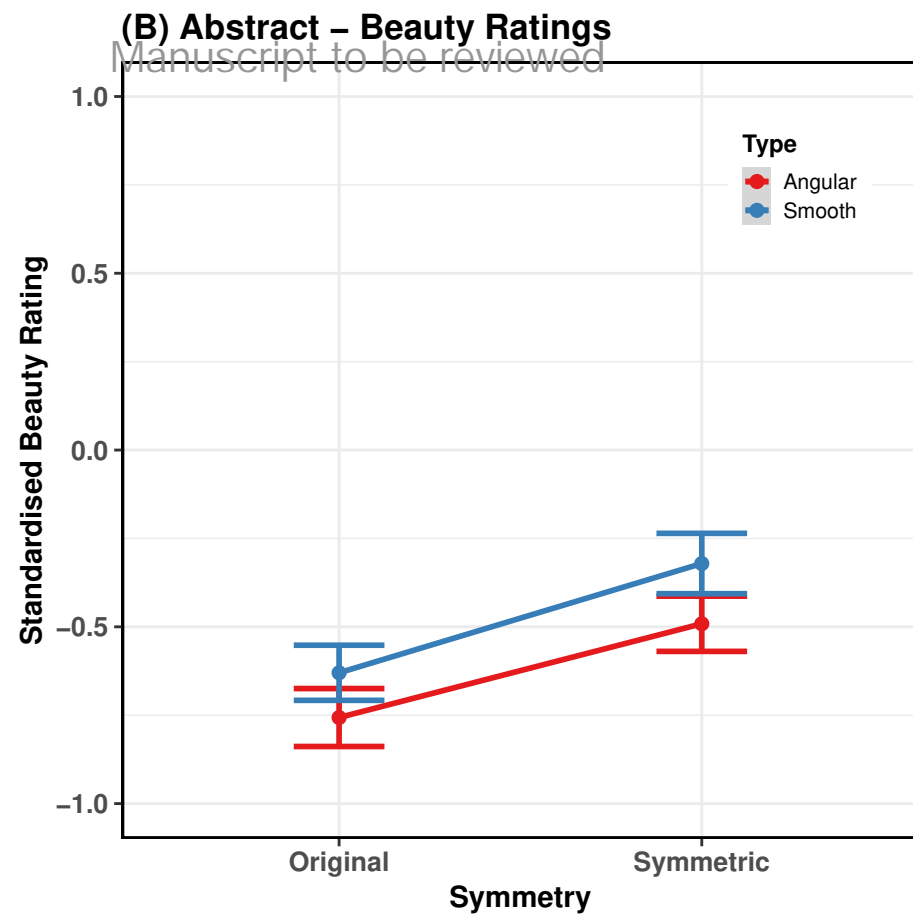
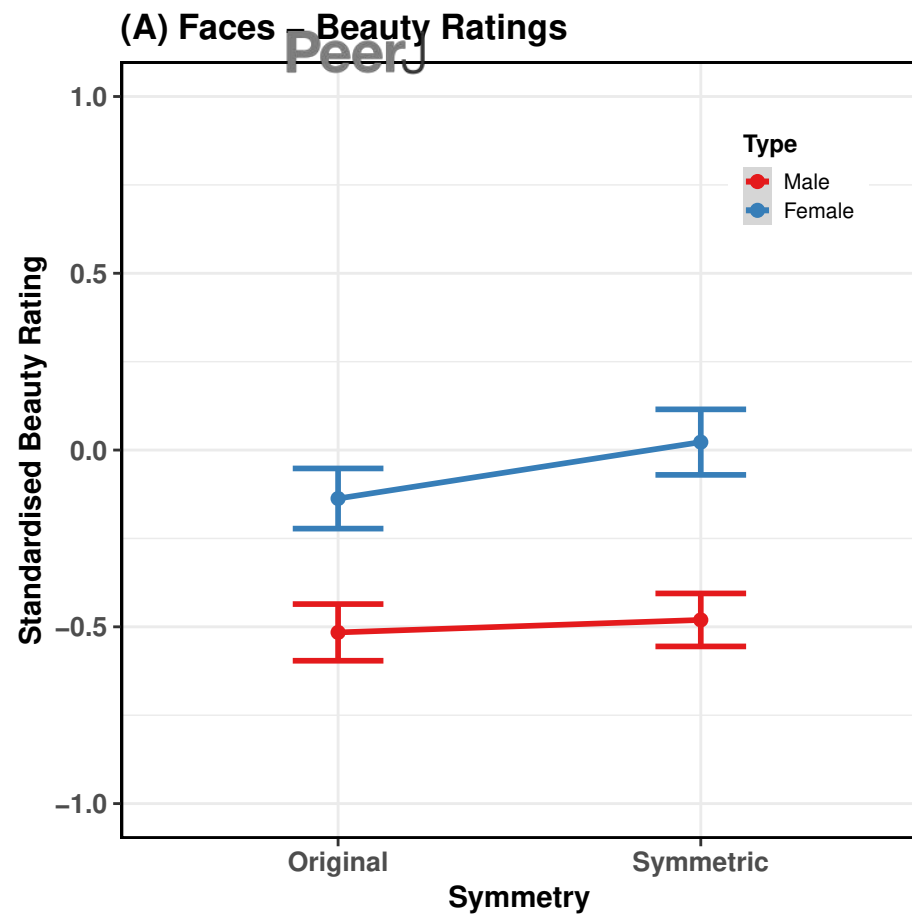
Rate Beauty

You will be presented with the same images again.
You will need to indicate how 'obvious' or 'salient' is the symmetry in each image (from not at all at very salient).
Press space bar to start.'

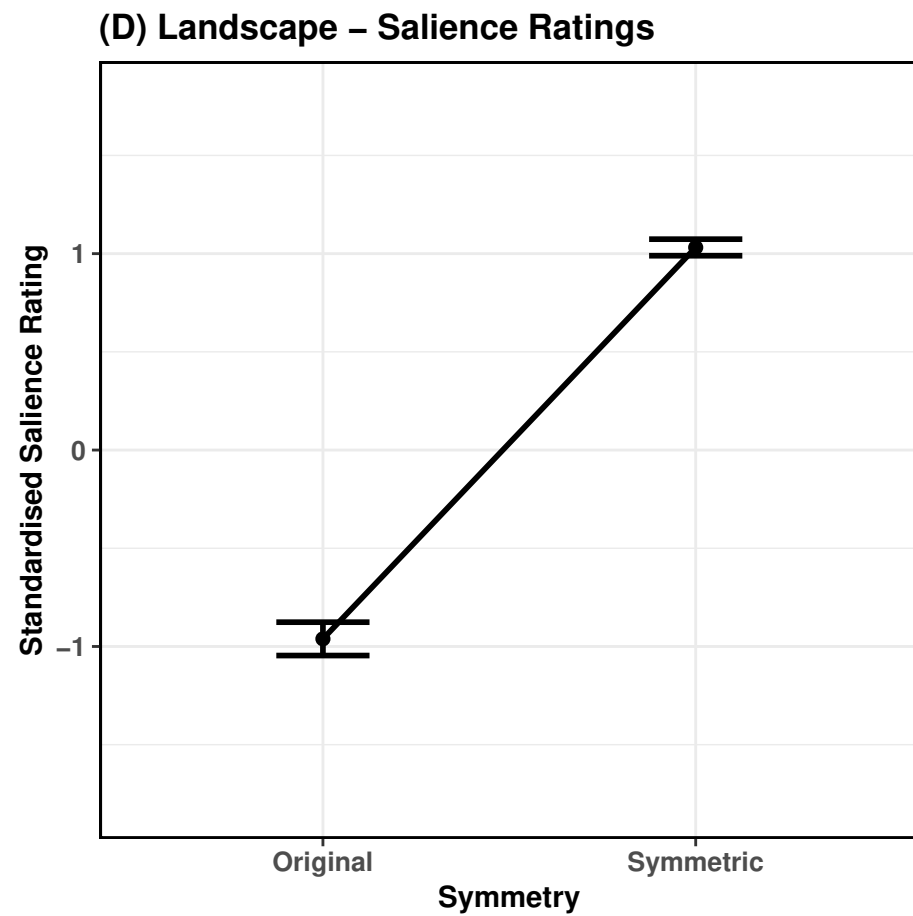
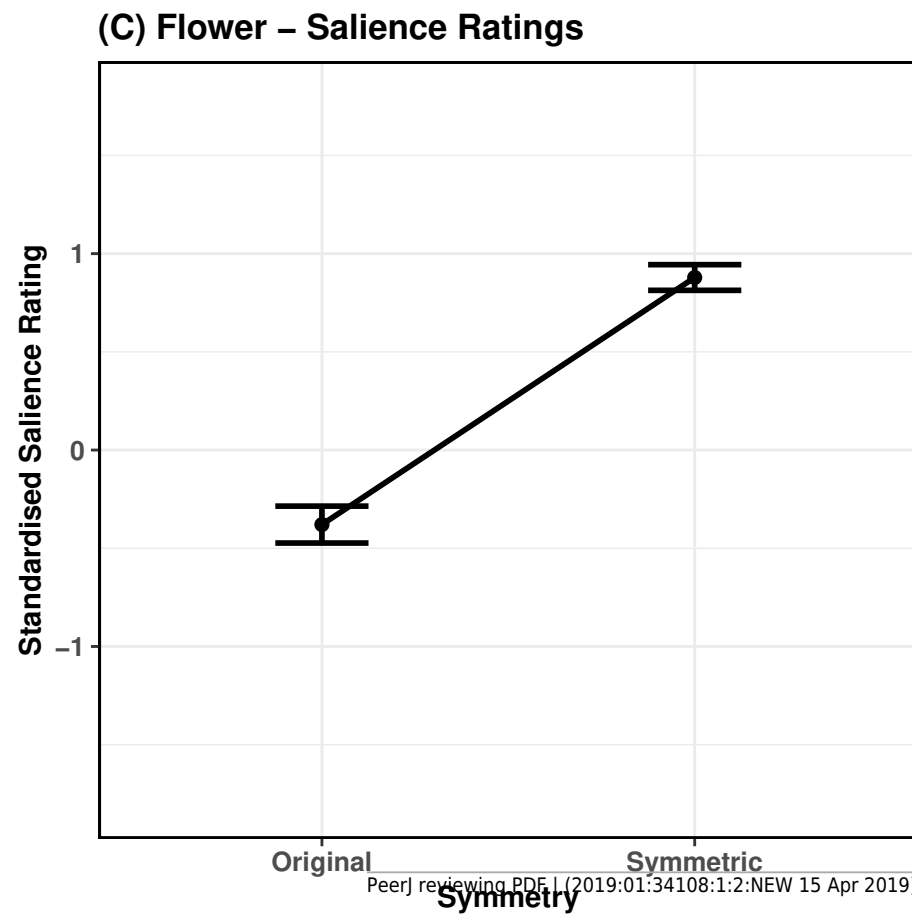
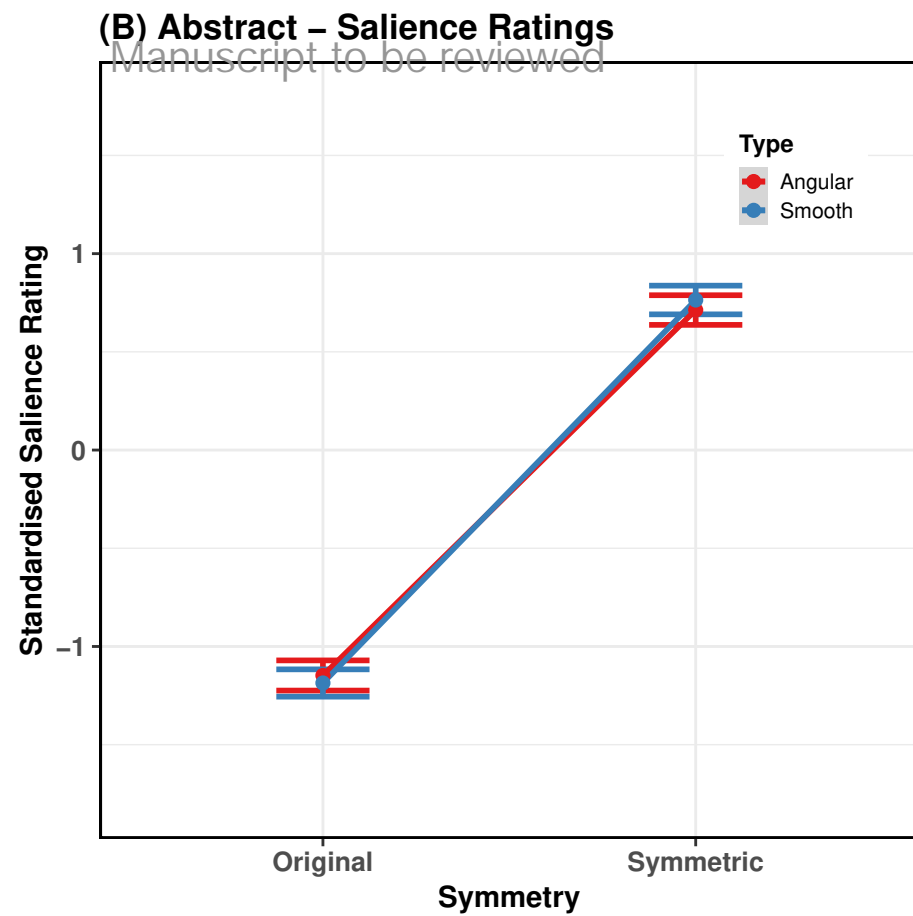
Rate Symmetry

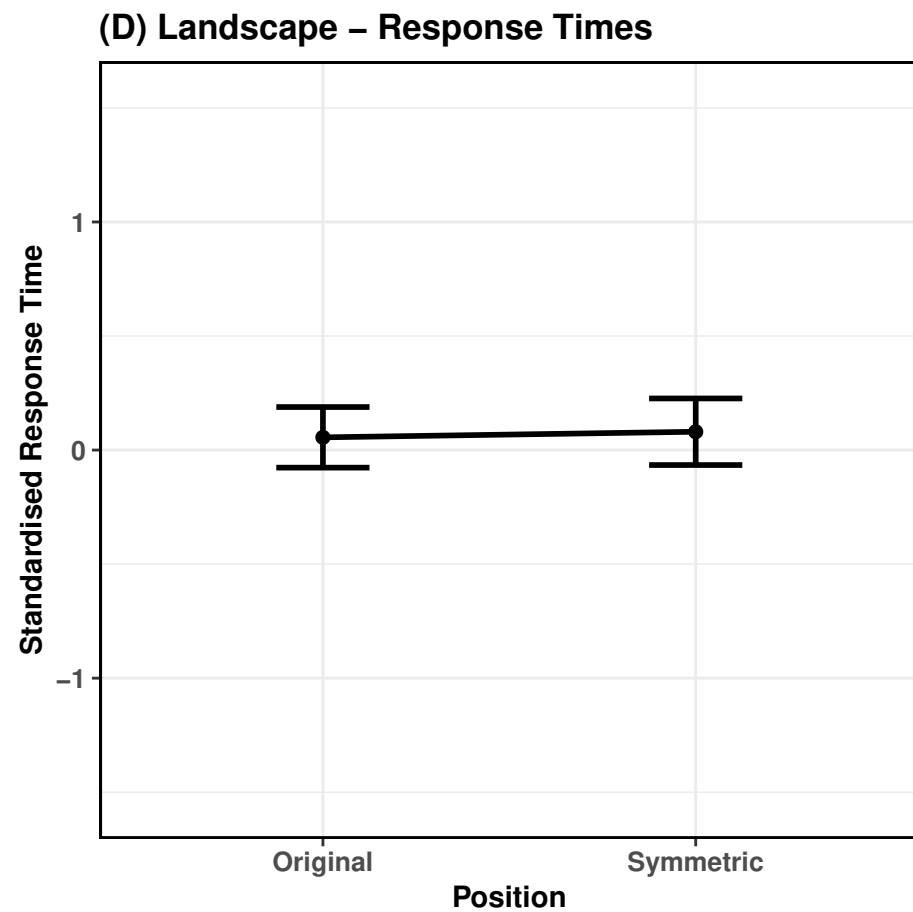
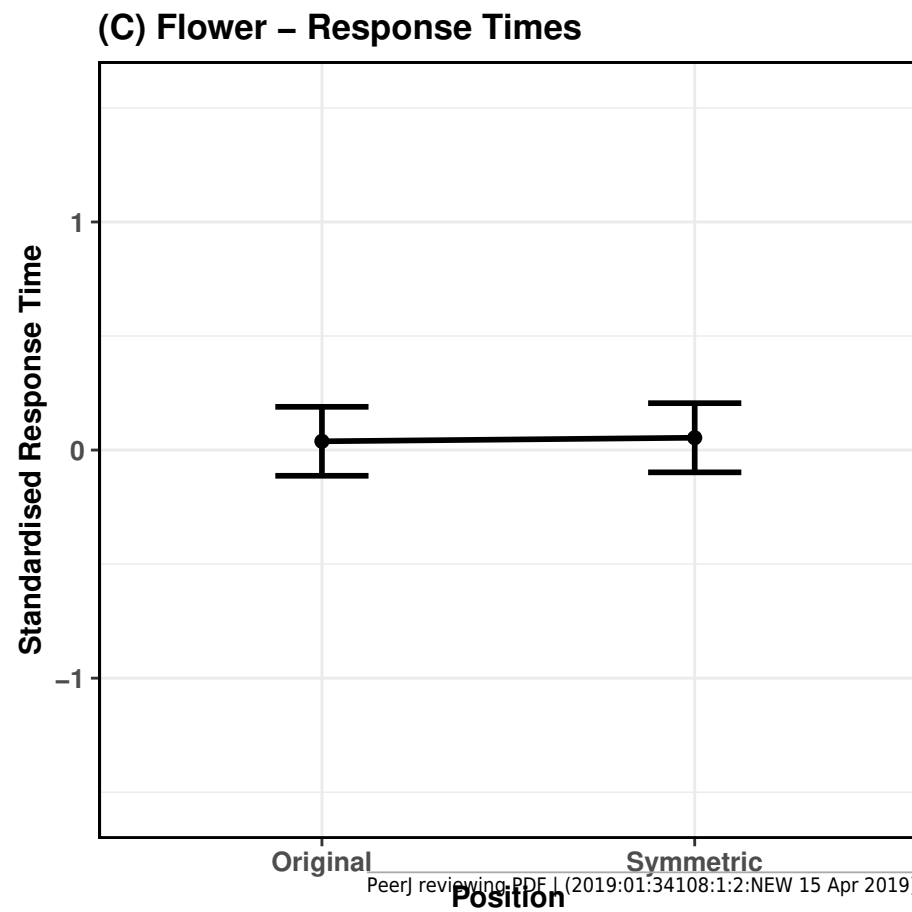
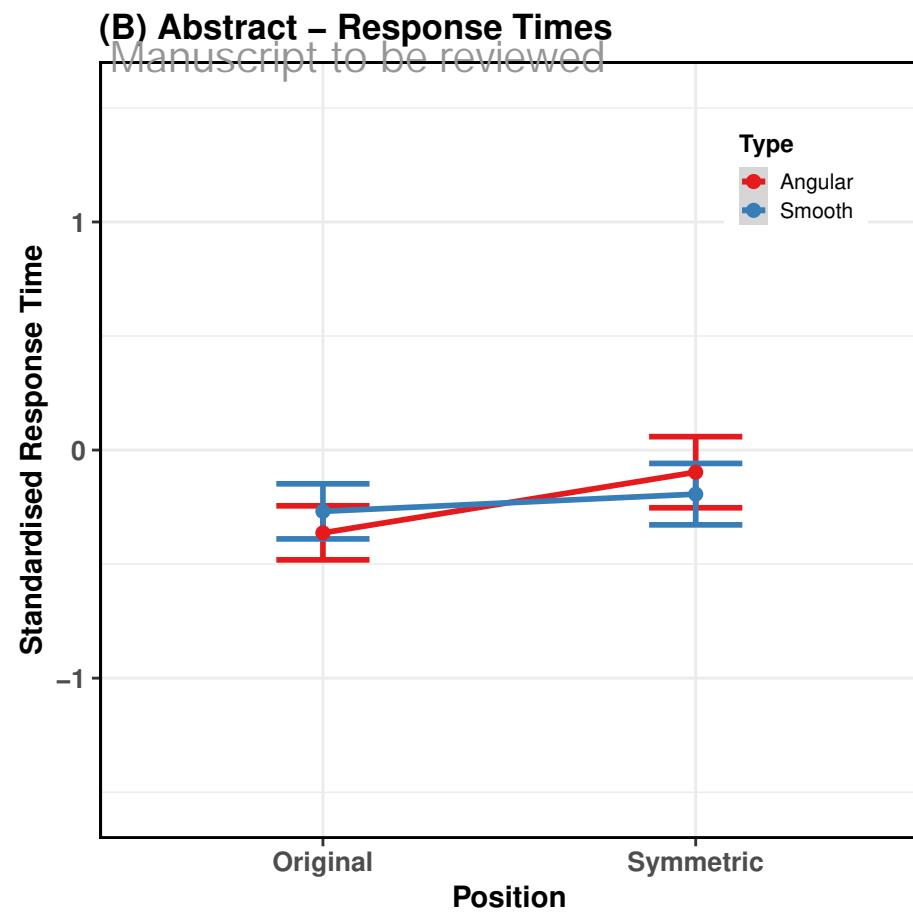
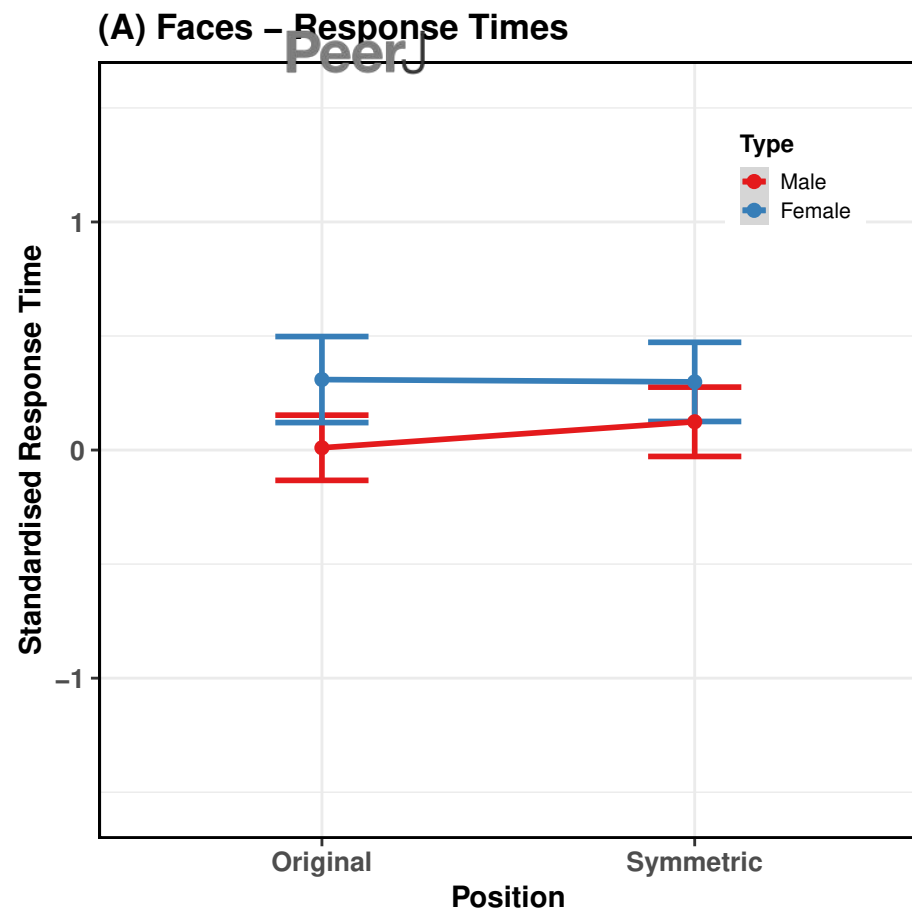
You will be presented with pairs of images.
You will need to indicate which is more symmetrical (if left press 'z' if right press 'm').
For this task you need to go as FAST as you can without making errors.
Press space bar to start.

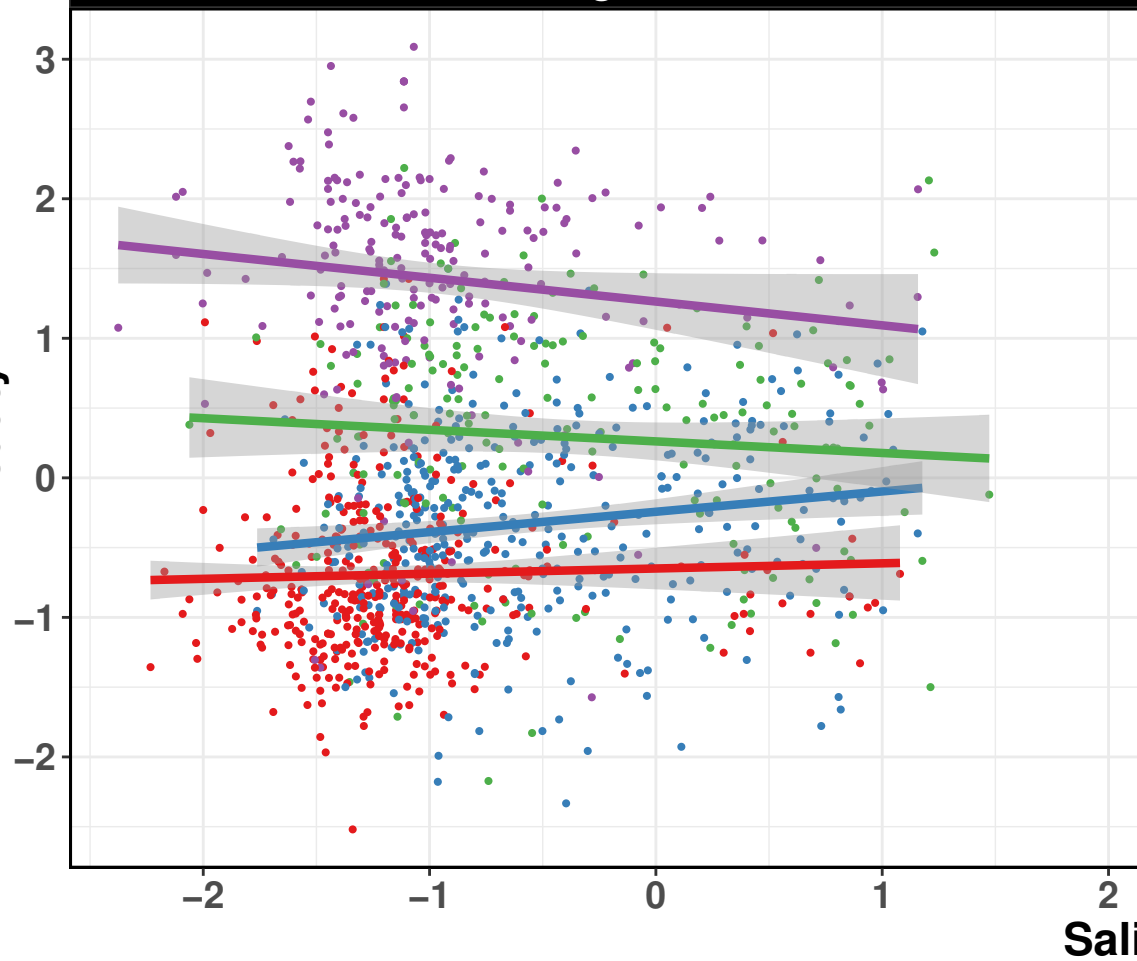
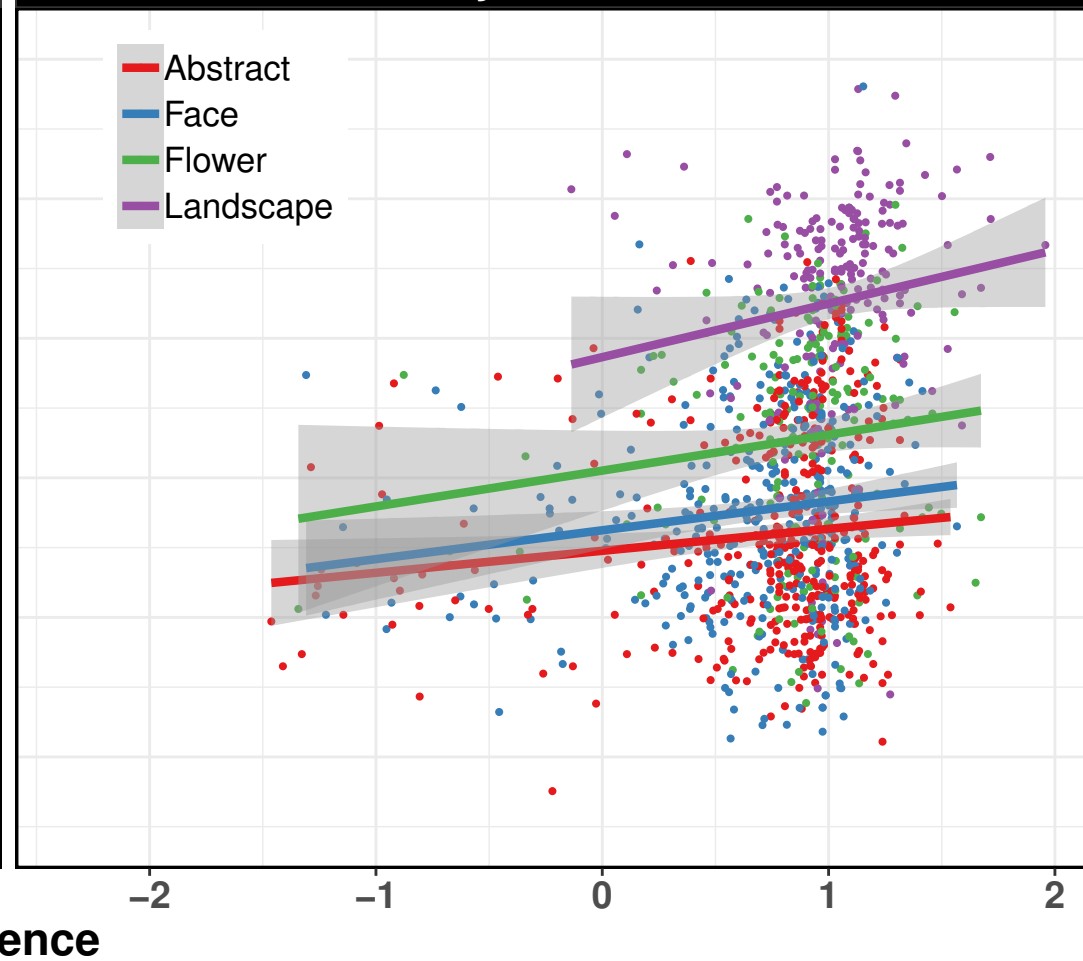
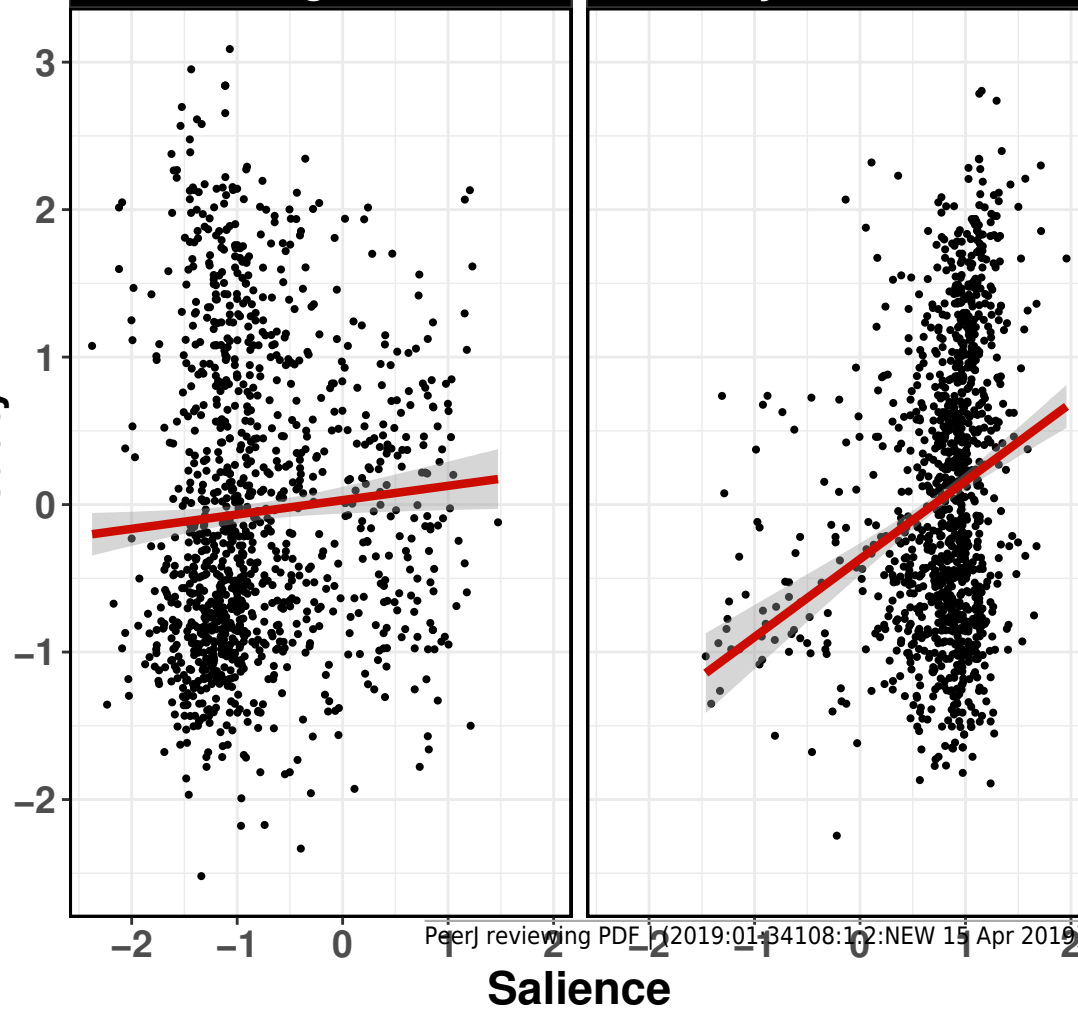
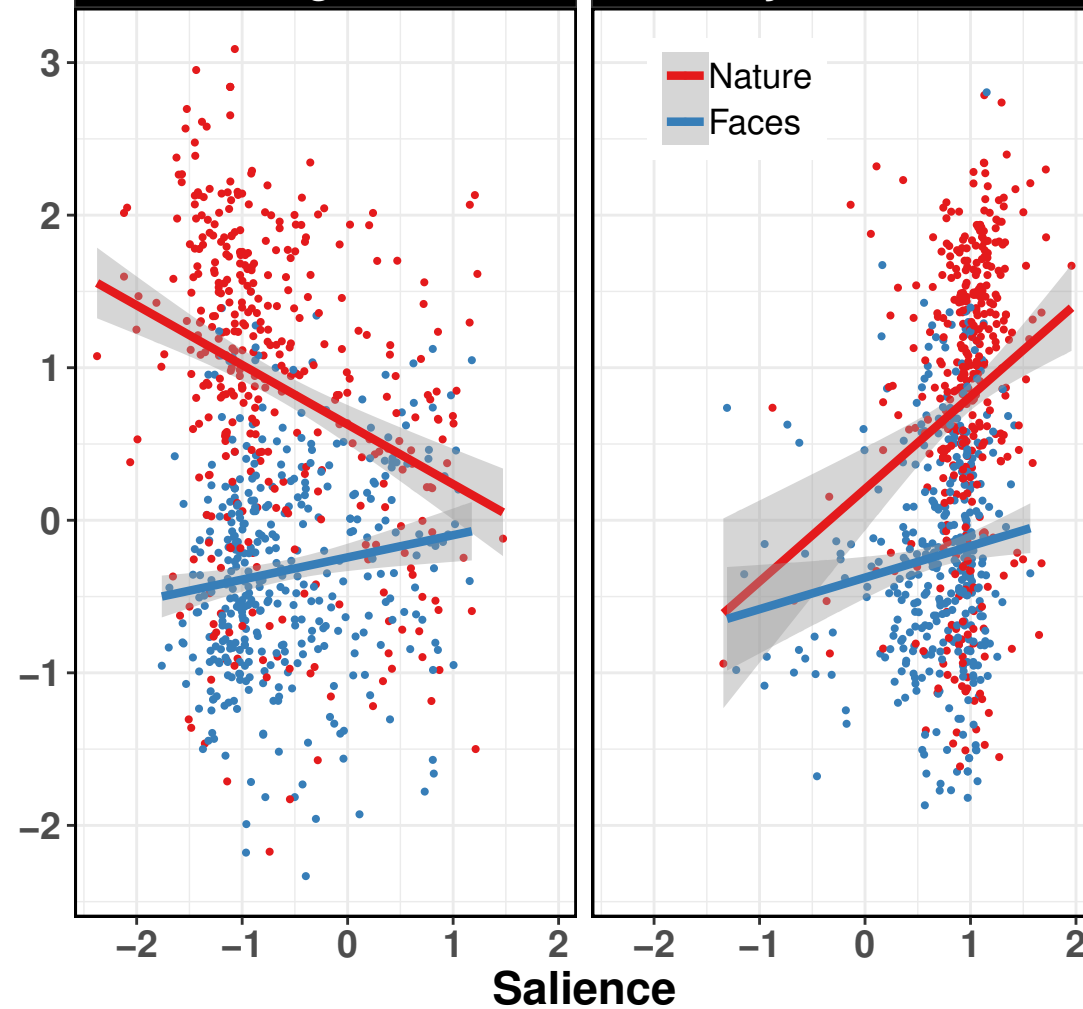
Choose Left or Right

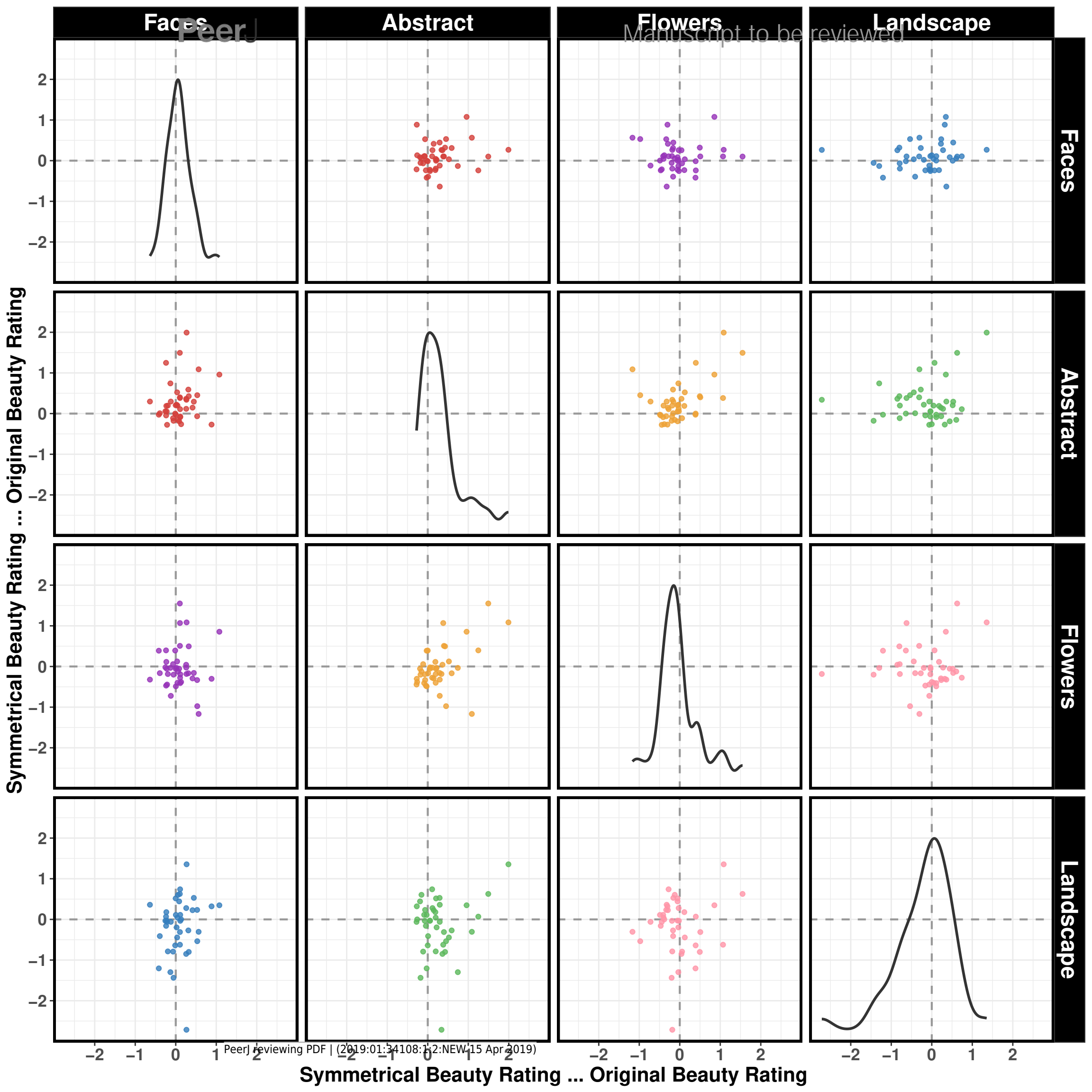
Beauty ratings

Mean rating for the beauty task, comparing original stimuli and stimuli with bilateral symmetry (x axis). The panels are organised by category and match the way the statistical analyses have been carried out. Error bars represent the standard error adjusted for the model random effects structure. The scale has the same range in the panels but is shifted upwards in the last one.

Salience ratings

Mean rating for the symmetry salience task, comparing original stimuli and stimuli with bilateral symmetry (x axis). The panels are organised by category and match the way the statistical analyses have been carried out. Error bars represent the standard error adjusted for the model random effects structure.

Speeded discrimination time

Mean speeded discrimination task, comparing original stimuli and stimuli with bilateral symmetry (x axis). The panels are organised by category and match the way the statistical analyses have been carried out. Error bars represent the standard error adjusted for the model random effects structure.

Relationship between ratings of symmetry and rating of beauty.

Relationship between ratings of symmetry (salience) and rating of beauty. The regression lines match the way the statistical analyses have been carried out. In all graphs, the left panel is for the original stimuli and the right panel for stimuli with bilateral symmetry. The main graph at the top (A) shows all four categories using different colours. To highlight some important relationships the two additional panels combine some of the data. Panel B shows the overall link between salience and beauty. Panel C shows how this relationship is different in different categories and in particular for the nature stimuli (flowers and landscapes).

Relationship of preference in one category and preference for another category.

Scatterplot matrix to show how preference for symmetry for one category relates to preference for another category. Preference for bilateral symmetry is measured as the difference Symmetry - Original. Each point is an individual. People in the top right quadrants liked symmetry in both categories, people in the bottom left quadrants disliked symmetry in both categories, and in the other two quadrants we have inconsistent liking responses.

Correlations for symmetry preference across participants.

Correlations for symmetry preference across participants.

1   Table 1. Correlations for symmetry preference across participants.

Stimuli Type	Term	Beta	SE	t	p	R^2
Faces	(Intercept)	0.05 [-0.08, 0.18]	0.07	0.69	= .492	0.0703
	Abstract	0.18 [-0.13, 0.49]	0.16	1.12	= .264	
	Flowers	-0.08 [-0.37, 0.16]	0.14	-0.61	= .544	
	Landscape	0.06 [-0.11, 0.19]	0.08	0.72	= .473	
Abstract	(Intercept)	0.28 [0.15, 0.43]	0.07	4.02	< .001	0.2998
	Faces	0.28 [-0.21, 0.77]	0.25	1.11	= .265	
	Flowers	0.45 [0.04, 0.87]	0.21	2.13	= .033	
	Landscape	0.07 [-0.14, 0.3]	0.11	0.61	= .545	
Flower	(Intercept)	-0.17 [-0.28, -0.06]	0.05	-3.14	= .002	0.2581
	Abstract	0.55 [0.13, 1.03]	0.23	2.39	= .017	
	Faces	-0.16 [-0.67, 0.36]	0.26	-0.61	= .544	
	Landscape	0.03 [-0.15, 0.24]	0.10	0.25	= .801	
Landscapes	(Intercept)	-0.24 [-0.48, 0.01]	0.12	-1.93	= .053	0.0474
	Abstract	0.19 [-0.4, 0.87]	0.32	0.60	= .547	
	Faces	0.25 [-0.29, 0.79]	0.28	0.92	= .359	
	Flowers	0.06 [-0.34, 0.55]	0.23	0.26	= .793	