36.311
VSS 2012

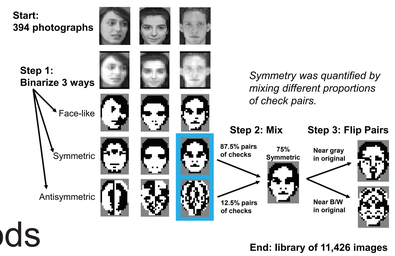
Classification image analysis reveals different cognitive strategies for symmetry and face processing

Rebecca M. Jones, Jonathan D. Victor, Mary M. Conte
Department of Neurology and Neuroscience, Weill Cornell Medical College
rej2004@med.cornell.edu

Introduction

Symmetry and face processing have some common characteristics, but they may rely on different cognitive strategies. We used classification image analysis (Eckstein & Ahumada, 2002) to determine whether subjects used different strategies for upright versus inverted images when making judgments of symmetry or face-likeness. This analysis allowed us to identify parts-based and holistic aspects of processing.

Constructing the Stimuli



Symmetry was quantified by mixing different proportions of check pairs.

Schematic of steps in the generation of the stimulus library from gray level photographs. *For details, see Jones et.al., (2012).*

The first step of the process consists of binarization; this is illustrated for three photographs (top left). Each face is binarized in one of three ways, leading to a maximally face-like image, a maximally symmetric image, or a maximally antisymmetric image (bottom three rows on left).

Next, an image is formed by mixing two of these binarized images, so that a specific level of symmetry is achieved.

At the third step of processing, bilaterally symmetric pairs of checks are flipped in contrast (lower right). This preserves the level of symmetry but can markedly alter face-likeness. If the flipped checks corresponded to original-image pixels that were close to gray (upper arrow), then flipping their contrast results in a face-like image. If the flipped checks corresponded to original-image pixels that were near black or white (lower arrow), then flipping their contrast results in a non-face-like image.

Methods

Observers

N = 6 per experiment; all R-handed
Corrected to normal visual acuity
Practiced (2) and unpracticed (4)

Procedure

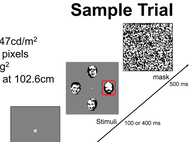
4-AFC
~ 1.5 hrs. practice with feedback
2880 trials/experiment without feedback

Variables

Symmetry: 0.6 - 1.0; partial to fully symmetric
Face-likeness: 1.0 - 4.0; rated least to most face-like in a preliminary expt. (N = 10)
Presentation Time: 100 or 400 ms.
Orientation: upright or inverted

Sample Trial

Contrast: 1.0
Mean luminance: 47cd/m²
Array size: 18X24 pixels
Field size: 9X9 deg²
Binocular Viewing at 102.6cm

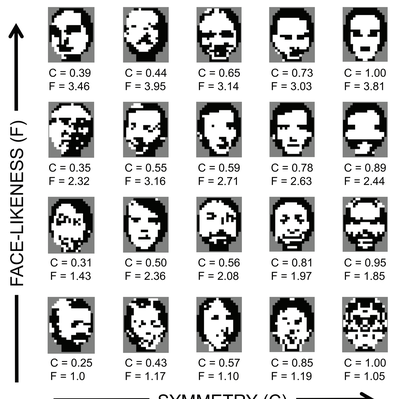


Tasks

In the symmetry task, observers identified the target that was most symmetric among three distractors of equal face-likeness.

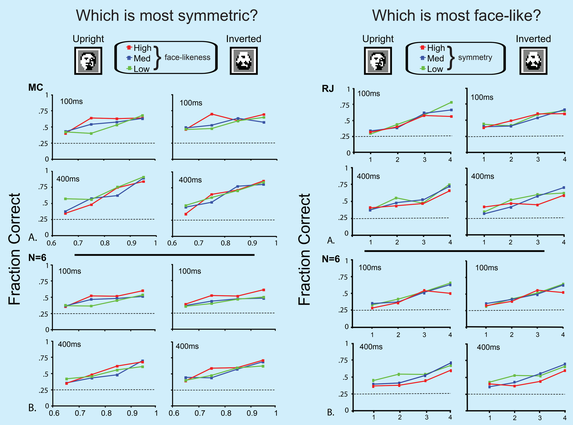
In the face-like task, observers identified the target that was most face-like among three distractors of equal symmetry.

Examples from Stimulus Library



Samples from the stimulus library of 11,426 images. Below each image are its values of symmetry strength (C), ranging from 0 to 1, and face-likeness (F) ranging from 1 to 4. Across the library, face-likeness and symmetry varied independently.

Psychophysical Results



Symmetry and face-likeness interacted in both tasks, but there were no differences between upright and inverted faces.

ANOVA Summary

Which is most symmetric?

Main Effects	F	p
Subject	48.55	<.001
Time	105.09	<.001
Symmetry	159.59	<.001
Face Rating	21.18	<.001
Orientation	5.94	<.05
Significant Two-way Interactions		
Subject X Time	2.90	<.05
Subject X Symmetry	2.77	<.001
Time X Symmetry	12.05	<.001
Subject X Face Rating	2.28	<.05
Face Rating X Symmetry	5.00	<.001
Face Rating X Time	2.03	NS
Significant Three-way Interactions		
Subject X Time X Face Rating	2.71	<.05
Face Rating X Time X Symmetry	3.25	<.05
Face Rating X Symmetry X Orientation	1.51	NS

Symmetry detection was enhanced for face-like objects.

Which is most face-like?

Main Effects	F	p
Subject	9.51	<.001
Time	15.54	<.001
Symmetry	24.80	<.001
Face Rating	229.95	<.001
Orientation	0.21	NS
Significant Two-way Interactions		
Subject X Time	1.30	NS
Subject X Symmetry	1.14	NS
Time X Symmetry	2.87	NS
Subject X Face Rating	1.09	NS
Face Rating X Symmetry	4.20	<.001
Face Rating X Time	7.49	<.001
Significant Three-way Interactions		
Subject X Time X Face Rating	0.95	NS
Face Rating X Time X Symmetry	5.33	<.001
Face Rating X Symmetry X Orientation	0.42	NS

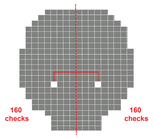
Face detection was reduced for highly symmetric objects.

In both experiments, the interaction between symmetry detection and face-likeness was similar for upright and inverted faces, indicated by the absence of a significant three-way interaction for Face Rating x Symmetry x Orientation.

Classification Image Analysis

Each image was reduced to a set of 160 binary values, indicating whether each check in the left half of the image matched, or mismatched, the luminance of the check in the mirror-image position in the right half.

Logistic regression was carried out in SPSS (binary LR; $p < 0.05$ stepwise entry; $p < 0.1$ stepwise removal).

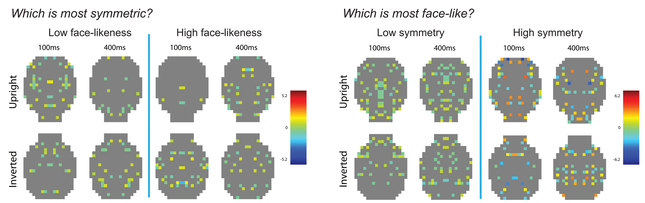


Pixel-by-pixel approach: Independent variables were the 160 binary values derived from each pixel pair.

Region of interest approach: Independent variables were the averages of the pixel-based binary values from each of four horizontal strips that subdivided the image.

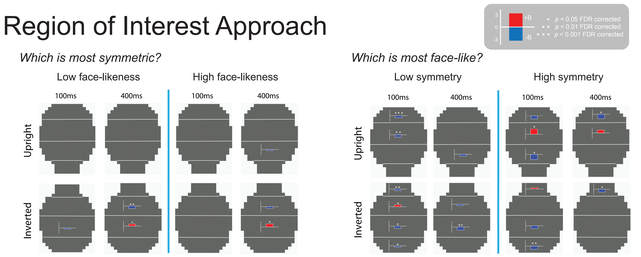
Logistic regression yielded a coefficient, B, for each independent variable, indicating its contribution to the probability that the image was correctly selected.

Pixel-by-Pixel Approach



Pixel-by-pixel analysis for two tasks. The color code indicates the logistic regression coefficient (positive: symmetric checks increased the probability of selecting the target; negative: symmetric checks decreased the likelihood of detecting the target). Only checks with significant ($p < 0.05$, False Discovery Rate (FDR)-corrected) regression coefficients are shown.

Region of Interest Approach



Region of interest analysis for two tasks. Each histogram graph represents the logistic regression coefficient of the given region (Red: positive B values; Blue: negative B values).

Pixel-by-Pixel Summary

- The number of checks that contributed to the subjects' decision was greater for the face-likeness task (average 22 check pairs per condition) than for the symmetry task (average 13 check pairs per condition). This suggests that a more distributed strategy was used for the face-like task than for the symmetry task.
- In the symmetry task, the largest cluster of checks was a 7-check cluster positioned over the eyes, seen in the low face-like, 100ms, upright condition ($p = 0.02$ for a cluster of this size). No such cluster was seen when faces were inverted. This suggests that for rapid assessment of symmetry, strategy depended on image orientation.
- In the face-like task, the largest cluster of contiguous checks (8 checks) was on the midline, and it occurred for the low symmetry, 100ms, upright condition ($p = 0.04$ for a cluster this size). No such cluster was seen when faces were inverted. This suggests that for rapid assessment of face-likeness, strategy depended on image orientation.

Region of Interest Summary

- In the symmetry task, observers utilized all regions of the image with equal weight.
- In the face-like task, symmetry in the eye regions was positively correlated with selecting a target as more face-like, but this was only for upright images.

Conclusions

- We used classification image analysis at two scales, pixel-by-pixel and region of interest, to probe the strategies observers used when making symmetry or face-likeness judgments.
- The two classification image analyses demonstrated that observers utilized different strategies for upright and inverted faces – even though overall performance was identical.
- The classification image analyses suggest an interaction between the holistic and parts-based processing levels: specific parts-based analysis is more prominent in the upright faces, than in the inverted ones.

References

Eckstein, M.P., & Ahumada, A.J., Jr. (2002). Classification images: a tool to analyze visual strategies. *Journal of Vision*, doi:10.1167/2.1.i.

Jones, R.M., Victor, J.D., & Conte, M.M. (2012). Detecting symmetry and faces: Separating the tasks and identifying their interactions. *Attention, Perception, & Psychophysics*, doi: 10.3758/s13414-012-0273-4.

Supported by NIH EY7977