Localization differences between face symmetry and abstract symmetry perception within the high-level visual cortices

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Abstract:

Symmetry perception of high-level and abstract visual elements is a process that we take granted for. Localization of facial and abstract symmetry patterns may differ due to biologically relevant factors. To investigate localization differences within the high-level cortices LOC, OFA, FFA and DLPFC, we used images consisting of original and symmetrical faces and phase scrambled patterns generated from these. Based on the behavioral responses and the fMR-adaptation paradigm, we found that patch symmetry was mainly processed in OFA bi-laterally and in the LO2 compartment of LOC, with right hemispheric dominance. On the other hand, facial symmetry was associated with the face selective network in the right hemisphere, although LH areas were also active. Our findings support specialized symmetry processing for faces.

Keywords: face symmetry, pattern symmetry, fMRI

Introduction

Symmetry perception facilitates rapid and automatic processing of visual similarities or disparities (Treder, 2010). Enhanced symmetry perception along the vertical axis is driven by biological processes such as survival and mating: animals prefer more symmetric individuals, due to the assumption that symmetry indicates healthiness (B. C. Jones et al., 2001; Rhodes et al., 2007). Humans exhibit strong sensitivity for detection of vertical symmetry. For instance, when simulated face-alike pictures with variable degrees of symmetry are generated, asymmetry detection is observed to be more precise than identity detection (Anderson & Gleddie, 2013) and higher levels of face-likeness improves symmetry detection accuracy (Jones, Victor & Conte, 2012). Hence localization differences within the brain might be observed for face symmetry versus general symmetry perception. Given the involvement of lateral occipital cortex (LOC) in both high-level and abstract symmetry percepts (Sasaki et al., 2005), we wanted to explore how symmetry is processed within the sub-areas of LOC as well as within the ROIs of the well-known face network, for face pictures and for abstract pictures.

Methods

Data Collection

Stimuli 36 face pictures (18 F, 18 M) were selected from a database created for studying facial symmetry perception (Yildirim, 2010). The face pictures in this database were standardized in terms of pose, expression, brightness, contrast, and texture. Each original picture had a symmetric counterpart. The symmetric images had significantly less entropy (mean:3.85, stdev:0.05) than the original ones (mean:4.05, stdev:0,04). In addition, for each image, a phase scrambled abstract image was created (Fig 1).

Participants All participants consented to participate. Twenty healthy participants (9M, 11F) evaluated the symmetry of the chosen pictures behaviorally. Fourteen participants (9M, 5F) were admitted to a 1-back working memory test conducted as an fMRI experiment.

Data Acquisition A block design 1-back fMRI task with multiple conditions (i.e. Patch symmetry, face symmetry and face perception) was executed. The face symmetry condition was run utilizing an fMR adaptation (fMR-a) paradigm (Grill-spector, Henson, & Martin, 2006) in which the neuronal response was habituated using original faces and then only a single attribute of the stimulus –symmetry- was changed in the following block. The patch symmetry and face perception conditions were standard block designs. MR data acquisition was done with a 3-Tesla Siemens MAGNETOM Trio System MR scanner at the UMRAM center, in Ankara. MRI and fMRI images were collected via standard high-resolution T1-weighted Mprage and T2*-weighted gradient-echo planar imaging parameters (4 runs were collected for fMRI).

Data Analysis

Data Processing Brainvoyager QX software package (Goebel, 2012) was used for data analysis. After standard pre-processing, one subject was excluded due to artifacts. The conditions were paired to determine 3 contrasts: patch symmetry, face symmetry and face localization. Statistical significance was corrected with FWE at a threshold of p=.005.

Time Series Analysis fMRI time series were extracted for the face symmetry condition for five anatomically defined ROIs using the Talairach stereotaxic space: LO1/LO2 compartments of the LOC (Larsson & Heeger, 2006) for shape processing, OFA/FFA (Nichols, Betts, & Wilson, 2010) for face processing and DLPFC (Weissman et al., 2008) for 1-back working memory processing.

fMRI map comparisons The number of voxels that exceeded the statistical activation threshold within each ROI were counted for each subject and for each contrast. These are tabulated for the chosen ROIs, separately for RH and LH. Then the Excel function _xlfn.CHISQ.TEST for 2d arrays was used to calculate the statistical significance of the differences between face versus patch symmetry and face symmetry versus face perception.

Results

Behavioral results

During symmetry judgment, reaction time for original images *(M*=1508.49*, S.E.*=28.82*)* were found to be significantly shorter than the symmetrical images *(M*=1786.33*, S.E.*=42.56*)*, although the information in the symmetric images were less based on the entropy measurement. This might be because the symmetric faces were considered to be a bit uncanny.

Face symmetry adaptation results

Slopes of the regression lines in the adaptation time series for all of the ROIs were either negative or flat for the original faces and the slopes of the regression lines for the time series of the symmetric faces were positive, with moderate to high R^2 values (0.55-0.96), as well as significant p values; indicating statistically significant release from adaptation when face symmetry was being processed.

Localization differences in fMRI maps

The localization of the three contrasts are shown in Figure 2 (orange: face symmetry, blue: patch symmetry and magenta: face perception). The number and percentage of voxels within the ROIs is provided in Table 1, such that for each contrast, 100% indicates the entire number of voxels that are activated inside the extracted ROIs within both RH and LH. The localization differences between the three contrasts within the ROIs were significant, as revealed by the Chi-Sq tests for Face symmetry versus Patch symmetry perception ($p<6.1*10^{-20}$) and for Face symmetry versus face perception ($p<3.4*10^{-8}$).

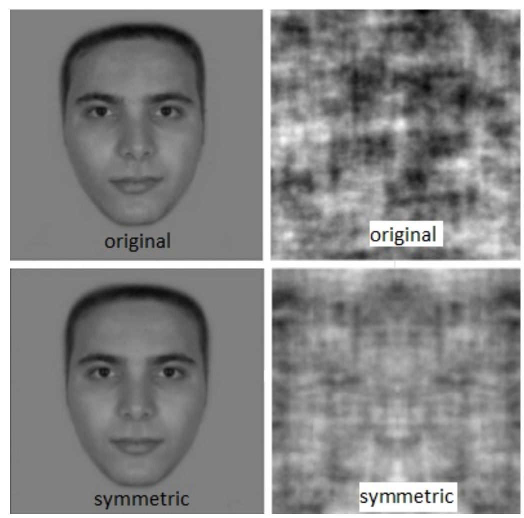

Figure 1: Stimuli.

Table 1: Voxel Distributions

	LH					
	Face Symmetry Voxel Count	%	Face Perception Voxel Count	%	Patch Symmetry Voxel Count	%
LO1	1885	5	10477	7	6739	9
LO2	4214	11	19578	14	12948	18
DLPFC	4808	13	3864	3	776	1
FFA	2354	6	11382	8	1718	2
OFA	3925	10	15320	11	8312	12
	RH					
	Face Symmetry Voxel Count	%	Face Perception Voxel Count	%	Patch Symmetry Voxel Count	%
LO1	1284	3	13972	10	9673	14
LO2	3494	9	24202	17	17488	24
DLPFC	5470	14	4394	3	2037	3
FFA	5703	15	15024	11	2259	3
OFA	5034	13	23916	17	9592	13

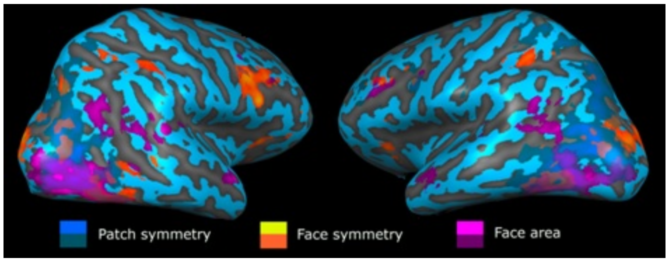

Figure 2: fMRI activity maps.

Conclusion

Mechanisms rooted in biology might be responsible for higher-level processes specialized for symmetry perception. Using block design and fMR-a paradigms, we were able to show that the neuronal populations allocated to the face and abstract symmetry percepts had similarities such as RH dominance and comparable ratios of the responding populations within the sub-areas of LOC. The representation of symmetry was larger in LOC2 compared to LO1 for both face and abstract symmetry perception. However, there were also significant localization differences justified by the ChiSQ test: 1) The contribution of FFA was not important for patch symmetry but important for face symmetry perception, 2) The contribution of DLPFC was enhanced for face symmetry but almost negligible for patch symmetry perception. These differences can be explained considering the role of FFA and DLPFC in face perception. Since FFA is specialized in face processing, its recruitment is not crucial in pattern symmetry processing. On the other hand, DLPFC is known to participate in configural face processing.

Future research involving simultaneous eye-tracking and neuroimaging may shed new light onto the role of the extended networks in face and abstract symmetries. The role of the extended areas in symmetry perception may bring extra highlights into the symmetry processing models to be implemented.

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