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On Methods for the Analysis of Indefinite Stimuli Perception Characteristics: an fMRT Study of Gender-Specific Differences

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Comparative identification of cerebral regions activated in men and women during perception of indefinite images was carried out by fMRT and psychological testing. Nine men and nine women aged 20-26 years took part in the study. The volunteers examined simple geometric figures, slightly structurized images (tables from Rorschach's test), and images of impossible figures. Activation in the cerebellum and visual cortex (bilateral) was more pronounced in women in response to all types of images and less so in the right *G. temporalis medius*. The right frontal regions (*G. precentralis*, *G. frontalis superior*, *G. frontalis medius*) were also stronger activated in women in response to indefinite stimuli.

Key Words: *indefiniteness; indefinite stimuli; functional magnetic resonance tomography (fMRT); visual paradigm; gender-specific differences*

Numerous data on the cerebral correlations of perception of indefiniteness have been acquired. The tasks associated with this phenomena activate *G. cinguli* and *Operculum* [6,7], left *G. frontalis inferior* [8] or the temporal and right frontal lobes [10]. Low tolerance of indefiniteness is associated with close functional relations of *G. cinguli anterior*, *Insula*, and *Striatum* [4]. As the problems with an element of the indefiniteness are rather complex, they involve additional activation of the prefrontal cortex [5]. This hypothesis is supported by the data indicating that a trend to avoid the indefiniteness negatively correlates with the volume of the grey matter in the lateral prefrontal cortex [9]. The information allowing reduction of the indefiniteness degree is processed in the *G. temporalis inferior* [8]. However, we failed to find the data on the gender-specific differences.

We attempted detection of specific local activation of the brain in men and women performing a visual test with definite and indefinite stimuli.

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MATERIALS AND METHODS

The study was carried out in 9 men and 9 women aged 20-26 years. The volunteers had no history of severe neurological and mental disorders or contraindication to MR studies. No individuals with significant loss of vision were included in the group. All volunteers signed informed consent to participation in the study. The study was carried out in accordance with the Helsinki Declaration.

A single fMRT study (block design) was carried out in all participants. The duration of a block was 5 shots, 3.5 sec each. During the "relaxation" blocks, the volunteers were shown a black cross on a white monitor to fix the vision in order to prevent unnecessary movements of the eyes. During experimental blocks, the monitor presented visual stimuli from one of three sets: 1) simple geometric figures of the same color; 2) Rorschach test tables, containing an indefiniteness in the form of understructurized image; and 3) complex impossible volumic figures. Five stimuli from each set were presented (Fig. 1).

Functional MRT studies were carried out on an 1.5 T Achieva Nova Dual magnetic resonance tomo-

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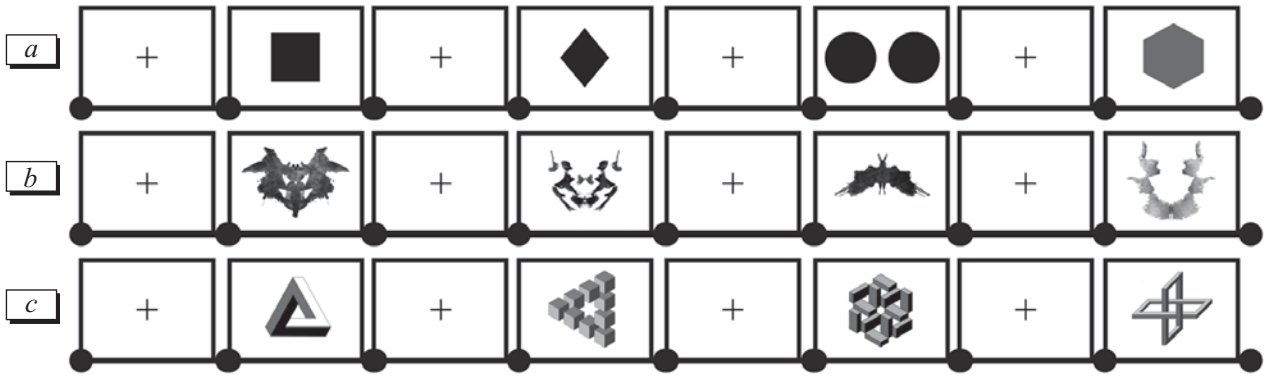

Fig. 1. Alternation of the "work" blocks with the test images in the monitor and "relaxation". *a*) Geometrical figures; *b*) Rorschach tables; *c*) impossible images.

graph (Phillips). The main working T2*-weighed images were obtained by SshEPI (Single-shot Echo Planar Imaging) with 4×4×4 mm voxel and TR/TE 3500/50 msec. The reference anatomical image was obtained by T1 TFE (Turbo Field Echo) method with 1×1×2 mm voxel. The image in the monitor was presented with the use of a head pick-up-and-transmission coil with an oblique mirror.

The results were processed and fMRT images acquired using FEAT 6.00 software (FMRI Expert Analysis Tool), a part of FSL (FMRIB's Software Library). The processing procedure included coordination of the mutual location of shots, image normalization by the standard form (MNI space), and Gauss' function leveling with an isotropic nucleus of 8 mm. Individual data were analyzed by the method of common linear model using unilateral *t* test. Based on individual activation maps, the group maps were designed in accidental effect model suggestion.

Clusters of reliably activated and deactivated voxels were distinguished in group maps (voxels with z>3.7 and clusters significant at $p<0.05$ with multiple comparison correction were selected). The male group>female group and the female group>male group contrasts were analyzed for each of the three visual tasks.

RESULTS

In general, men and women demonstrated similar activation patterns. Both exhibited activation of the occipital zones, including the Broadman zone (BZ) 19 when performing the visual tests. Rather small areas were involved in processing of the simple figures, while the processing of the indefinite images of both types involved larger areas of the occipital cortex. In addition, visual perception of indefinite stimuli was associated (in both groups) with deactivation of the median cortical structures: *G. cinguli*, *Precuneus*, *Cuneus*, *et al*. Hence, both groups exhibited involvement of the visual system under conditions of suppressed default mode network (DMN), this trend was more manifest for more complex indefinite images.

TABLE 1. Gender-Specific Differences in Perception of Simple Geometrical Figures

Location	Peak *t* test values	Coordinates of peak in MNI space	Number of voxels
Female group>male group			
R_Cuneus, L_Precuneus, R_G. occipitalis superior, R_Precuneus, L_G. occipitalis superior, BA 7, 19	6.54	12 -80 40	1046
R_Cerebellum VI, R_Cerebellum Crus I, R_G. lingualis, BA 18	8.57	14 -84 -16	881
R_G. occipitalis medius	6.35	34 -72 0	343
R_G. parietalis superior, R_G. parietalis inferior, R_G. angularis, BA 40, 7	6.05	38 -62 56	234
L_Cerebellum Crus I, L_G. lingualis, BA 18	5.91	-12 -84 -18	193
Male group>female group			
R_Planum temporale	5.03	58 10 -34	107

Note. Here and in Table 2: R – right, L – left.

TABLE 2. Gender-Specific Differences in Perception of Rorschach Tables

Location	Peak *t* test values	Coordinates of peak in MNI space	Number of voxels
Female group>male group			
R_G. occipitalis superior, R_Cuneus, L_Precuneus, R_Precuneus, BA 7, 19	6.75	14 -80 40	1509
R_G. parietalis superior, R_G. parietalis inferior, R_G. angularis, BA 40, 7	6.47	38 -62 56	380
R_Cerebellum VI, R_Cerebellum Crus I, R_G. lingualis, BA 18	8.3	12-80 -16	360
R_Cerebellum VI, R_Cerebellum Crus I	7.94	38 -62 -30	307
R_G. frontalis superior, R_G. precentralis, BA 6	6.12	38 -6 66	192
R_G. frontalis medius, R_G. frontalis superior	4.72	26 50 34	164
L_G. precentralis, BA 6	4.92	-22 -12 76	119
L_Cerebellum Crus I	5.56	-12 -84 -16	97
Male group>female group			
R_Planum temporale, R_G. temporalis medius, BA 21	5.22	56 10 -34	205
R_G. occipitalis inferior, BA 18, 19	4.99	48 -88 -10	123
BA 17, 18	6.17	6 -102 -10	104

As for differences between the groups, activation of the parieto-occipital cortical regions, mainly right, and of a part of the cerebellum was stronger in women in response to geometrical figures (Table 1). Hence, the females used a larger scope of secondary and associative visual regions, and the sensorimotor and speech zones, which could indicate a greater "loading" of spatial thinking and semantical processing of images with the use of inner speech.

Gender differences observed in processing of the Rorschach test tables, were generally close to those described in perception of the geometrical figures. However, the differences in the right occipital region augmented during perception of the indefinite images. In addition, some frontal structures of the right hemisphere were stronger activated in females during demonstration of under-structurized images (Table 2). These results could indicate the most active use of the resource involved in processing of spatial information and on higher intensity of integrative processes in *G. frontalis superior*, "classifying" the sensory data.

The location of gender-specific differences was similar during perception of the impossible figure images (Table 3). The number of voxels in the detected clusters was even higher, which suggested the still greater differences in the use of the cognitive resource.

The clusters in which the cerebral activity in women is lower than in men (lingual and visual regions, including 3B 17, 18, and 19) indicates that the results are ambiguous. The difference in the *Planum temporalis* involvement, caused by a significant deactivation of this region in women, is particularly interesting. This formation is characterized by exceptional structural and functional asymmetry; its deactivation in the right hemisphere can reflect the reciprocal interhemispheric interactions.

In our study, the processing of visual information in women with emphasis on the spatial component proved to be more "energy-consuming". This result were at discrepancy with the data obtained for the mental motor rotation of volumic figures [1,3], indicating a greater right-hemispheric activation in men or the absence of gender-specific differences. The involvement of the speech zones presumably indicated a specific strategy of information processing, which was in line with the data on better values of female volunteers in some verbal tests [3].

These differences were even stronger for the indefinite images tests (which poorly correlated with previous data [2], according to which the visual perception of Rorschach spots required no extra resource in comparison with geometrical figures). However, the stimuli of categories 1, 2, and 3 differed by the indefiniteness degree and by the complexity of images, in case with category 3 by the presence of volume and hence, by greater requirements to spatial thinking. Presumably, it is desirable to use more complex category 1 images in further studies.

An additional difference in the right frontal cortex can be due to more intense integration of sensory information in women. Presumably, this reaction is the response to a stimulus of high indefiniteness [10].

TABLE 3. Gender-Specific Differences in Perception of "Impossible" Figures

Location	Peak *t* test values	Coordinates of peak in MNI space	Number of voxels
Female group>male group			
R_G. occipitalis superior, R_Cuneus, L_Precuneus, R_Precuneus, R_G. occipitalis medius, BA 7, 19	7.41	22 -70 36	1981
R_Cerebellum VI, R_Cerebellum Crus I, R_G. temporalis inferior	8.45	38 -62 -30	656
R_Cerebellum VI, R_Cerebellum Crus I, R_G. lingualis, BA 18	8.28	14 -84 -16	404
R_G. parietalis superior, R G. parietalis inferior, R G. angularis, BA 40, 7	6.32	38 -62 56	367
R_G. frontalis superior, R_G. precentralis, BA 6	6.45	38 -6 66	247
L_Cerebellum Crus I	5.7	-8 -84 -22	138
L_G. precentralis	5.39	-22 -12 76	111
R_Cuneus, BA 18	6.51	18 -102 12	106
Male group>female group			
R_Planum temporale, R_G. temporalis medius, BA 21	5.24	58 10 -34	148
R_G. occipitalis medius, R_G. angularis, BA 39	4.82	48 -70 32	125

The study has demonstrated good prospects of perceptive problems presentation for neurovisualization studies of human reactions in indefinite situations, including the detection of gender-specific differences in these responses.

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