Computer analysis of monochromatic drawings by mentally healthy people and patients with schizophrenia

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Computer analysis of monochromatic drawings by mentally healthy people and patients with schizophrenia

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This paper presents the results of a comparative computer analysis of monochromatic drawings by mentally healthy subjects and patients with schizophrenia. The contours of the images were distinguished in each of the drawings, after which the following characteristics were calculated: the total length of all the contours of the image, the mean size of the image, and the ratio of the total length of the contours to the mean size. The spatial-frequency spectra of the images were also computed. It is established that the mean size of the drawings and the relative length of the contours in the drawings by the patients with schizophrenia are less than in those of the healthy subjects—i.e., the drawings of the patients with schizophrenia are less detailed. Moreover, these drawings are characterized by a certain rise of the spectrum in the region of medium spatial frequencies. As shown by a computer experiment, on the basis of an analysis of twenty arbitrarily chosen drawings by the patients with schizophrenia, a positive diagnosis can be delivered in 92% of all the cases. When the same sample of drawings by healthy subjects is analyzed, the probability of an incorrect diagnosis was 6.5%. The resulting data are regarded as evidence of dysfunction when there is schizophrenia of the magnocellular system, which provides a global analysis of the images and an increase of the internal noise level of the visual system.

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INTRODUCTION

The capability of the brain to create an objective picture of the surrounding world, needed for adaptive behavior, often happens to be damaged by various pathological states, especially by psychopathology. There is currently very little known about how people with mental disorders perceive the world. There is a well-known hypothesis that the structural–functional organization of the visual system is evolutionarily adapted and coordinated with the statistical properties of the natural visual medium.[1] Works of art, as well as ordinary simple drawings, are a reflection of the surrounding medium; therefore, it can be expected that the main statistical characteristics of such images will be close to those for natural scenes.[2] Therefore, an analysis of the statistical characteristics of works of art and of drawings by people with mental illnesses can be used to investigate defects of visual perception, in particular, those due to schizophrenia. The data of numerous studies are evidence of a deficit of contrast sensitivity accompanying schizophrenia.[3–11] As a whole, patients with schizophrenia demonstrate a falloff of contrast sensitivity in the range of low spatial frequencies,[8–11] to which the most sensitive neurons are those of the magnocellular system, which provides a global analysis of the images of scenes.[6,12–17] The interaction of the mechanisms of global and local analysis of the images of scenes ensures the integrity of the perception and its objectivity. It is logical to assume that the dysfunction of one or both mechanisms accompanying schizophrenia reduces the statistical characteristics of drawings, which are a product of the activity of the brain.

The goal of this paper is to demonstrate an approach to the investigation of the breakdowns of visual perception that accompany schizophrenia by computer-analyzing monochromatic drawings by mentally healthy subjects and patients with schizophrenia.

OBJECTS AND METHODS OF THE STUDY

Eighty-one mentally healthy subjects (34 ± 12 yr) and seventy-seven patients (38 ± 13 yr) of the psychoneurological clinic with a range of F20.0 in the MKB-10 classification—paranoid schizophrenia—participated in the study. All the patients were in stable condition. The task of each subject was to draw the face of a person on a single sheet of paper and a complete person on a second sheet. All the drawings were made using a black marker with the same size of nib on a sheet of paper of the same size (0.5 format A4). The time for drawing was unlimited. The resulting drawings were scanned, and the size of the scanning region of each drawing was 5100×3500 pixels. In order to exclude from the images low-contrast details not associated with the drawing (elements of the paper texture, spots, etc.), the image was binarized after scanning. The edges of the contours in the binarized images contain fine irregularities, which can result in increased contour lengths when the images are processed. To eliminate these irregularities, each image was reduced to a size of 512×351 pixels by

FIG. 1. Demonstration of the discrimination of the contours (the boundaries of dark regions) of images.

means of a scaling algorithm that uses a Lanczos filter.[18] The boundaries of dark regions (features and regions with continuous coloring) were then distinguished in each image (Fig. 1). An algorithm similar to Canny's well-known algorithm[19] was used to search for the boundaries. Since there was no noise component in the images being processed, preliminary convolution of the image with a Gaussian kernel, ordinarily used in algorithms for distinguishing edges to suppress high-frequency noise, was not used in our case. The thresholds T_1 and T_2 used in Canny's algorithm for the gradients were selected to be different: $0.02G_{\max}$ and $0.01G_{\max}$, where $G_{\max}$ is the maximum brightness gradient in the image being processed. The contours discriminated in the image were chains of points with a step of one pixel.

The following parameters were then computed for each image: the total length of all the contour chains in the image in pixels, the mean size of the image in pixels, and also the ratio of the total length of the chains to the mean size. To compute the mean size D of the contour image, the coordinates of its centroid were first calculated (by averaging the coordinates of the points of all the contours along the X and Y axes), and then the mean distance of the points of the contours from this centroid was computed, equal to

$$D = \frac{2}{N}\sum_{i=1}^{N}\sqrt{(x_i - x_0)^2 + (y_i - y_0)^2},$$

where N is the overall number of points in the contours, x_0, y_0 are the coordinates of the centroid, and x_i, y_i are the coordinates of the ith point of the contour.

Histograms of the distribution were constructed for each of the characteristics, and the mean values were also calculated.

The tilt angle of the amplitude spectrum of the image in a logarithmic coordinate system was used as the spatial-frequency characteristic. Since the original spectrum of the image is two-dimensional, before computing the slope, it was converted to one-dimensional by averaging the cross sections, whose orientation covered 360° (with a 1° step). The resulting averaged cross section of the spectrum was then approximated by a straight line, using the method of least squares, and the tangent of the angle between this line and the horizontal axis was computed. The tangent of the angle served as the characteristic degree of the slope of the spectrum.

RESULTS AND DISCUSSION

The mean length of the contours in the pictures equalled $(4.6 \pm 2.9) \times 10^3$ pixels in the drawings by healthy subjects and $(3.1 \pm 2.0) \times 10^3$ pixels in those of the patients with schizophrenia—i.e., a difference of a factor of 1.5. Obvious evidence of the recorded differences is the difference in the distributions of the contour lengths in the drawings by the patients with schizophrenia and the mentally healthy subjects (Fig. 2). The histogram of the distribution of the contour lengths in the drawings by the patients with schizophrenia is shifted toward lower lengths.

The difference in the contour lengths can reflect either a difference in the mean sizes of the drawings or a difference in the number of details. In order to estimate the contribution of these two factors, the distributions and the mean values of the picture sizes were calculated (Fig. 3), as well as the relative contour lengths—i.e., the ratios of the contour lengths to the picture sizes (Fig. 4). The last parameter makes it possible to roughly estimate the degree of detail of the drawings, regardless of their size.

The mean size of the drawings is 182 ± 51 pixels in the group of healthy subjects and 159 ± 66 pixels in the patients with schizophrenia—i.e., they differ by a factor of 1.15 (Fig. 3).

The mean value of the relative contour lengths was 23 ± 9.0 in the drawings by healthy subjects and 17.8 ± 6.0 in the drawings by patients with schizophrenia—i.e., they differ by a factor of 1.34. The histograms of the distribution of the relative contour lengths in the drawings by the patients with schizophrenia are shifted toward lower values (Fig. 4), as is the distribution of the contour lengths. The drawings by the patients with schizophrenia accordingly differ from those by the mentally healthy subjects by less pronounced detail. The reduced detail of the drawings by the patients with schizophrenia by comparison with those by the mentally healthy subjects is

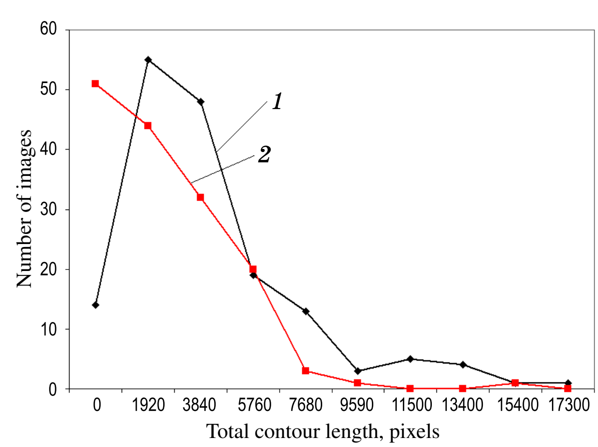

FIG. 2. Distribution of contour lengths in drawings by patients with schizophrenia (2) and healthy subjects (1).

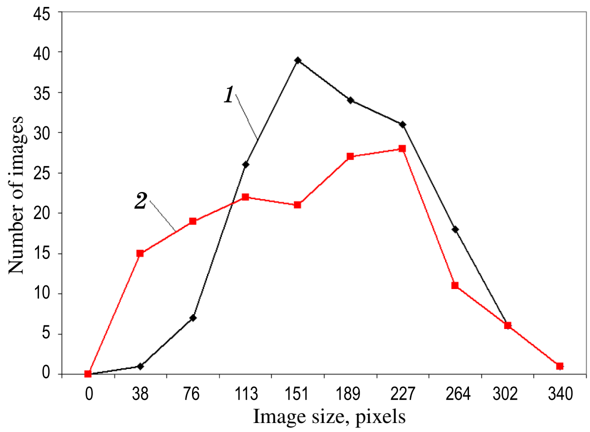

FIG. 3. Distribution of sizes of drawings for patients with schizophrenia (2) and healthy subjects (1).

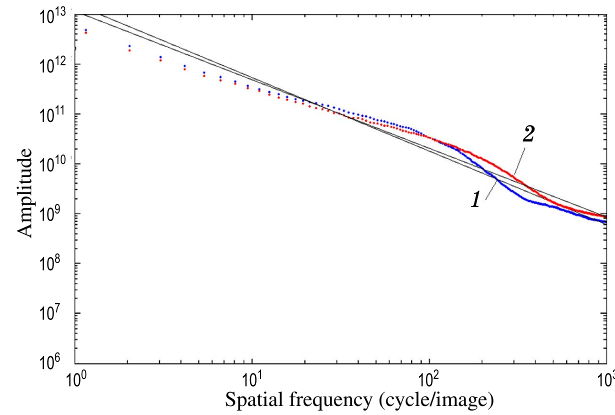

FIG. 5. Averaged spectra of drawings by healthy subjects (1) and patients with schizophrenia (2).

probably the result of dysfunction of the magnocellular system, which provides a global description of the visual field.

The results of applying the spatial-frequency (spectral) approach to the analysis of the drawings by the mentally healthy subjects and the patients with schizophrenia is evidence of differences of the spectral characteristics of the drawings by the groups being compared. The mean tangent of the tilt angle of the spectrum was −1.23 for the drawings by the healthy subjects and equalled −1.30 for the drawings by the patients with schizophrenia. That is, the tangent of the tilt angle of the spectrum of the drawings by the healthy subjects is somewhat smaller than in the patients with schizophrenia (Fig. 5). The drawings by the patients with schizophrenia were also characterized by strengthening of the amplitude spectrum of the images in the range of medium spatial frequencies. In this connection, the results of Ref. 20 are of interest, which described the spatial-frequency characteristics of the scenes that gave people a feeling of anxiety. These images also had a rise in the middle of the spatial-frequency range.

Starting from the results of the research that we carried out earlier,[7–11], the resulting data can be regarded as evidence of schizophrenia-associated dysfunction of the magnocellular system, which provides global analysis of the images of the scenes and an increase of the internal noise level of the visual system.

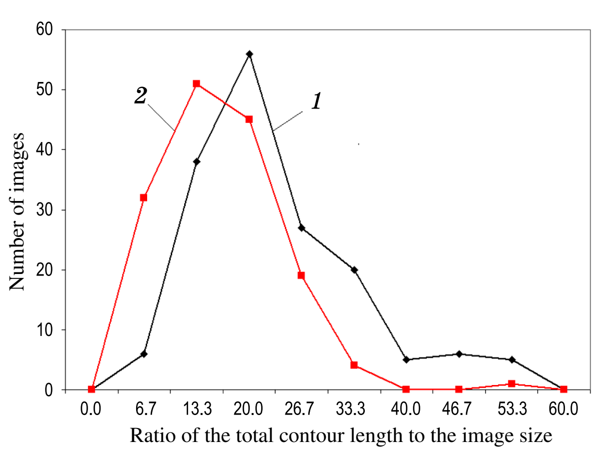

FIG. 4. Distribution of relative contour lengths in drawings by patients with schizophrenia (2) and healthy subjects (1).

An advantage of the method that we used for analyzing monochromatic drawings, by comparison with a similar approach to the analysis of pictures[21] made by artists suffering from schizophrenia, is that the conditions of the study are maximally unified. There is no influence on the statistical characteristics of the drawings from differences in the drawing technique, the imaged scenes, the instrument used for drawing, or the size of the region of the drawing.

The question arises of whether this difference in the characteristics of the drawings can be used for purposes of diagnosis. The mean value of the total contour length in the drawings by healthy subjects equals 4636 pixels. It is possible to choose a threshold value for the contour length—say 3709 pixels—and to assume that, if the medium contour length in a set of drawings by a subject is below this threshold, it may be concluded that illness may be present.

To check this assumption, the following computational experimental was carried out: Ten drawings were selected in random order from an initial set of drawings for a given group of subjects (sick or healthy). The mean contour length over the sample was computed for them and was compared with the threshold of 3709 pixels. If the mean contour length was lower than this threshold, a positive "diagnosis" was issued. The experiment was repeated 10,000 times. If the sample was taken from the figures of the sick subjects, a positive diagnosis was rendered in 85% of all the cases. The same analysis of the samples from the drawings by healthy subjects showed a probability of incorrect diagnosis of 15% of the cases. If the volume of the sample was increased from ten to twenty drawings, the probability of correct diagnosis increases to 92.0% and that of erroneous diagnosis decreases to 6.5%.

It should be pointed out that these results cannot be considered a suitable diagnostic method. It must be taken into account that the changes described in this article in the character of the drawings may be specific not only for schizophrenia. Moreover, it is possible that such changes of the drawings will not be observed at early stages of the illness.

CONCLUSION

The approach to the analysis of monochromatic drawings considered in this investigation showed that drawings by patients with schizophrenia are less detailed than those of mentally healthy subjects and have an increase of the spectrum in the region of medium spatial frequencies. These data are regarded as evidence of schizophrenia-associated dysfunction of the magnocellular system, which provides global analysis of images and increases the internal noise level of the visual system.

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