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Study of Fusiform Gyrus of Brain to Explore Autism

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Abstract

Autism is a complex disorders of brain development. Now it is a great concern to the present world. It is a neuro-developmental disorder that occurs in the early age of a child. It impairs a child's ability to communicate and interact with others. It also includes restricted repetitive behaviors, interests and activities. These issues cause significant impairment in social, occupational and other areas of functioning. Recent studies show abnormal inter-regional connectivity of brain at functional level in autistic patients. To investigate the causes of autism, fusiform gyrus of brain is responsible for face processing tasks has been studied for the control and autistic individuals. In pursuing the work, functional magnetic resonance imaging (fMRI) images of fusiform gyrus for control and autistic patients are considered as input images for behavior analysis. Three categories of faces that is, familiar faces, stranger faces and combination of both familiar and stranger faces are considered. The proposed approach, different edge detector operators such as Sobel, Roberts, Prewitt are investigated to find edge map of fMRI images. In this work a new edge detector operator has been proposed. The study described a new approach of edge finding with an aim to find better edge map of fMRI images. Then extract the activation area in fusiform gyrus using thresholding and these images are applied for segmentation. After segmentation the values of activation areas for both control and autistic individuals are calculated using the binarization method. All values of activation areas are compared for both control and autistic individuals. Finally, it has been observed that fusiform gyrus regions are hypoactive in patients with autism than in control. Results obtained are highly satisfactory to be encouraged.

Keywords: *Autism, Autistic Spectrum Disorders (ASD), Fusiform Gyrus, Functional Magnetic Resonance Imaging (fMRI).*

I. Introduction

Autism is an invasive developmental disorder which includes abnormal development and function of the brain. Autistic people have decreased social communication skills and restricted or repetitive behavior or interest. However, the most obvious signs of autism and symptoms of autism tend to emerge between 2 and 3 years of age. It is part of a spectrum disorders characterized by a triad of symptoms, including deficits in all aspects of social reciprocity; pragmatic communication deficits and language delays; and an assortment of behavioral problems, such as restricted interests, sensory sensitivities and repetitive behaviors (APA, 1994). The causes of autism remain unknown, many studies have concerned a variety of developmental genes, environmental factors such as exposures to viruses or toxins during pregnancy are hypothesized to contribute but none have been decisively identified. It is a developmental neural disorder, which is known as autistic spectrum disorders (ASD) (Volkmar *et al.*, 2004). The worldwide prevalence of ASD is about 6 per 1,000, with about four times as many males as females (B. Cohen *et al.*, 1994). It affects information processing in the brain by altering nerve cells and their synapses. However, the real cause of autism occurrences is not well understood yet (Kanwisher *et al.*, 1999). Autism has a strong genetic basis, although the genetics of autism are complex and it is unclear whether ASD is explained more by rare mutations, or by rare combinations of common genetic variants (Schultz, 2005). In rare cases, autism is strongly associated with agents that cause birth defects (Pierce *et al.*, 2001), (Pierce *et al.*, 2004). Autism is characterized by ASD first appears during infancy or childhood, and generally follows a steady course without remission and establishes by age two or three years (Dalton *et al.*, 2005). Autistic people understand both surroundings and human behavior uniquely since they react in an abnormal way to input stimuli makes problematic human engagement, restricted interests and inability in the environmental generalization

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(Johanson *et al.*, 1996). A key feature of normal social functioning in humans is the processing of faces, which allows people to identify individuals and enables them with the capacity to understand the mental state of others (B. Cohen *et al.*, 1994). It is well recognized from functional magnetic resonance imaging (fMRI) studies that the fusiform gyrus is consistently active when normal humans view faces (Kanwisher *et al.*, 1999). Patients with autism can perform face perception tasks but there is strong evidence that the fusiform gyrus, as well as other cortical regions supporting face processing in controls, is hypoactive in patients with autism (Bolte *et al.*, 2006). It has been proposed that the failure to make direct eye contact may explain the observed hypo-activation of the fusiform gyrus in face perception tasks in autism (Dalton *et al.*, 2005). This review will specifically focus on face perception deficits in autism, describing current literature on abnormalities in the fusiform face area and the amygdala. It will be argued that an abnormality early in development in the amygdala can give rise to later social perceptual deficits in face identity and facial expression perception. There is evidence that the fusiform gyrus receives input from the visual cortex and provides the major input into an extended system consisting of cortical regions and sub-cortical regions such as amygdala indicating that the altered function of the fusiform gyrus in patients with autism. Three categories of faces that is, familiar faces, stranger faces and combination of familiar and stranger faces are considered for examine of fusiform gyrus from fMRI images. The proposed approach has been implemented in Matlab. The fMRI images are taken as the input image and detect the edge of these images using different edge detection operators and calculate the value of activation area in fusiform gyrus of brain for control and autistic individuals. The results obtained after segmentation is taken as input for binarization operation and compared to the control based on the calculated value of activation area of fusiform gyrus of brain.

II. Fusiform Gyrus

The fusiform gyrus is a part of the human visual system that, it is speculated, is specialized for facial recognition. It is located in Brodmann Area 37. It is also known as the (discontinuous) occipitotemporal gyrus (NN, 2004). Other sources have the fusiform gyrus above the occipitotemporal gyrus and underneath the parahippocampal gyrus. There is still some dispute over the functionalities of this area, but there is relative consensus on the following:

1. processing of color information
2. face and body recognition
3. word recognition
4. number recognition
5. within-category identification

Some researchers think that the fusiform gyrus may be related to the disorder known as prosopagnosia, or face blindness. Research has also shown that the fusiform face area, the area within the fusiform gyrus, is heavily involved in face perception but only to any generic within-category identification which is shown to be one of the functions of the fusiform gyrus (McCarthy *et al.*, 1997). Fusiform gyrus has also been involved in the perception of emotions in facial stimuli (Radua *et al.*, 2009). Figure 1 shows the fMRI of fusiform gyrus of brain for the control and autistic individuals which clearly indicates the differences among them (Consider three types of faces- all faces, familiar faces and stranger faces) (K. Pierce *et al.*, 2008).

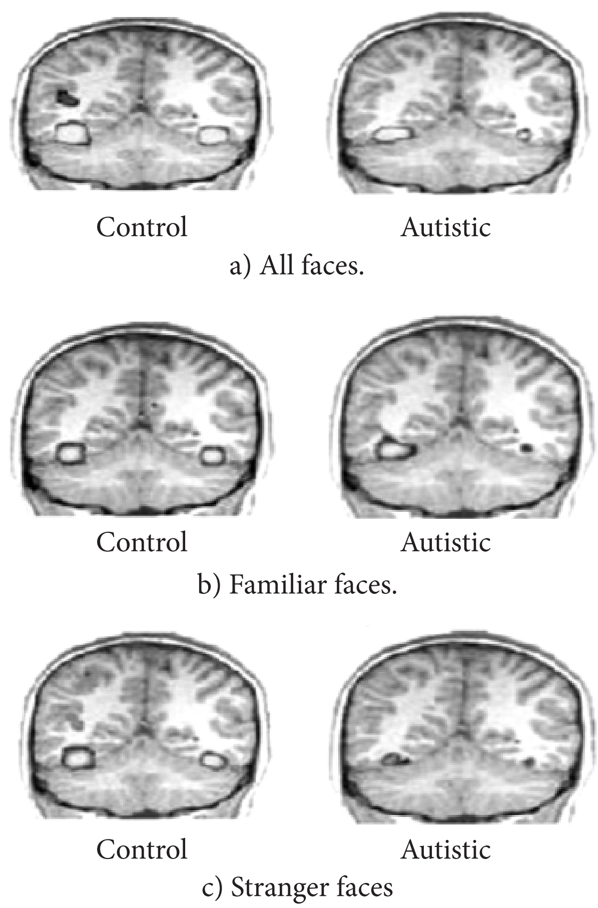


Figure 1: fMRI of fusiform gyrus both of control and autistic for a) all faces, b) familiar faces and c) stranger faces.

III. Material and Methods

In carrying out the work fMRI scan images of the fusiform gyrus of brain for control and autistic individuals are taken as input. Three categories of faces that is, familiar faces, stranger faces and combination of both familiar and stranger faces are considered of fusiform gyrus from fMRI images as input. Detect the edge of activation area in fusiform gyrus of input images using Roberts, Prewitt and Sobel operators.

Roberts Operator

The Roberts operator is given by the equations:

$$G_x = W_9 - W_5$$

$$G_y = W_8 - W_6$$

(a)

-1	0
0	1

(b)

0	-1
1	0

Figure 2: (a) Roberts Mask for Horizontal Direction (b) Roberts Mask for Vertical Direction

Prewitt Operator

Consider the arrangement of pixels:

W_1	W_2	W_3
W_4	W_5	W_6
W_7	W_8	W_9

The Prewitt's operator is given by the equations:

$$G_x = (W_7+W_8+W_9) - (W_1+W_2+W_3)$$

$$G_Y = (W_3+W_6+W_9) - (W_1+W_4+W_7)$$

(a)

-1	-1	-1
0	0	0
1	1	1

(b)

-1	0	1
-1	0	1
-1	0	1

Figure 3: (a) Prewitt Mask for Horizontal Direction (b) Prewitt Mask for Vertical Direction

Sobel Operator

The Sobel operator is given by the equations:

$$G_x = (W_7+2W_8+W_9) - (W_1+2W_2+W_3)$$

$$G_Y = (W_3+2W_6+W_9) - (W_1+2W_4+W_7)$$

Where, W1 to W9 are pixels values in a sub image as shown in Figure 4.

(a)

-1	-2	-1
0	0	0
1	2	1

(b)

-1	0	1
-2	0	2
-1	0	1

Figure 4: (a) Sobel Mask for Horizontal Direction (b) Sobel Mask for Vertical Direction

New Operator

The Sobel operator is given by the equations:

$$G_x = (W_7+3W_8+W_9) - (W_1+3W_2+W_3)$$

$$G_Y = (W_3+3W_6+W_9) - (W_1+3W_4+W_7)$$

Where, W1 to W9 are pixels values in a sub image as shown in Figure 5.

(a)

-1	-3	-1
0	0	0
1	3	1

(b)

-1	0	1
-3	0	3
-1	0	1

Figure 5: (a) New Mask for Horizontal Direction (b) New Mask for Vertical Direction

Extract the activation area in fusiform gyrus using thresholding. Then these images are applied for segmentation. After segmentation, the values of activation areas for both control and autistic individuals are calculated using the binarization method. That is the image having only two values either black or white (0 or 1). Here 256x256 jpeg image is a maximum image size. The binary image can be represented as a summation of total number of white and black pixels. Area of an image is the total number of the pixels present in the area which can be calculated in the length units by multiplying the number of pixels with the dimension of one pixel:

Image, I = Σ 255w
=0Σ 255H
=0[f(0) + f(1)]
f (0) = white pixel (digit 0)
f (l) = black pixel (digit 1)

Pixels = Width (W) X Height (H)
= 256 X 256

No_ of_ white pixel P = Σ 255w
=0Σ 255H
=0[f(0)]

Where, P = number of white pixels (width*height)

Finally, the calculated activation values are used for comparing the surroundings of fusiform gyrus to show the graphical representation for both control and autistic. The proposed work is implemented using Matlab.

IV. Results and Discussion

The work is performed for the calculation of activation areas in fusiform gyrus of control and autism individuals. In carrying out the work fMRI scan images of the control and autism are taken as input and the corresponding images are produced by edge detection methods (Roberts, Prewitt, Sobel and New operator). Than using New operator, the edge detected images apply for thresholding and these produced images are consider for segmentation. After segmentation the activation areas of fusiform gyrus are calculated using binarization operation. The images of the input and produced output for the control and the autistic individuals are shown separately.

Figure 1 shows the input images of the fusiform gyrus of brain both of control and autistic for all faces, familiar faces and stranger faces.

Simulated images for all, familiar and stranger faces

Roberts Operator

To detect the neural pathway surrounding the fusiform gyrus area of brain, Roberts operator is used for the control and the autistic in. Figure 6 shows the processed images of the control and autistic for all, familiar and stranger faces.

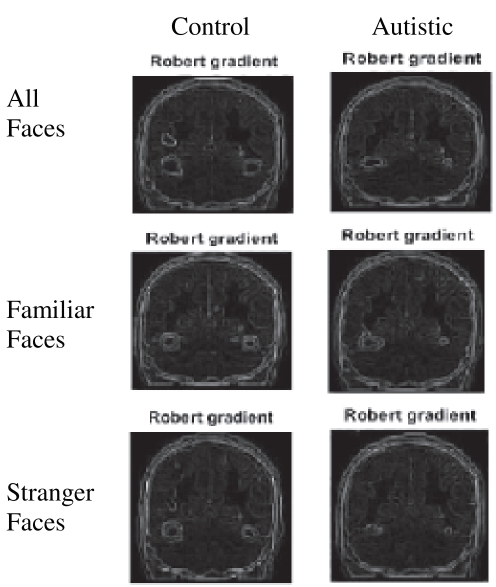


Figure 6: Processed images of the fusiform gyrus using Roberts operator of control and autistic for all faces, familiar faces and stranger faces.

Prewitt Operator

To detect surrounding edge of the fusiform gyrus area of brain, Prewitt operator is used for the control and the autistic in. Figure 7 shows the processed images of the control and autistic for all, familiar and stranger faces.

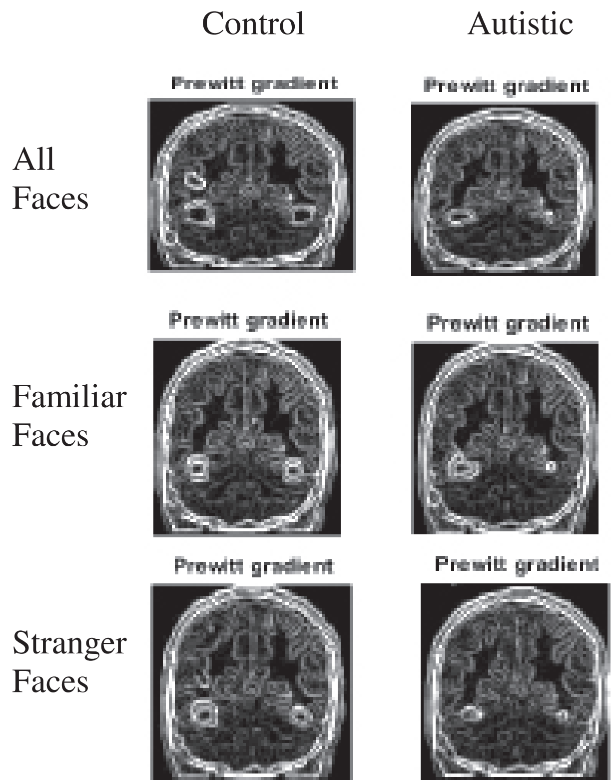


Figure 7: Processed images of the fusiform gyrus using Prewitt operator of control and autistic for all faces, familiar faces and stranger faces.

Sobel Operator

To detect the neural pathway surrounding the fusiform gyrus area, sobel edge detection operator is used for the control and the autistic. Figure 8 shows the processed images.

Comparing the produced images, it is clearly visualized that the edges for the control are sharply observed which indicates that the neural pathways for the control are more effective surrounding the fusiform gyrus than autistic.

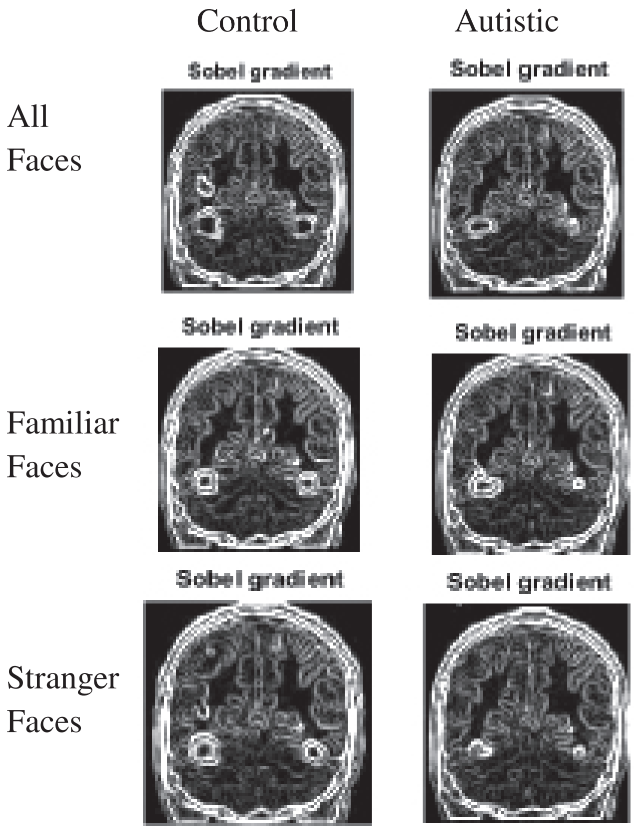
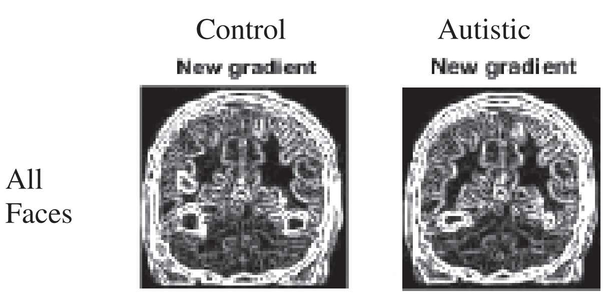


Figure 8: Processed images of the fusiform gyrus using Sobel operator of control and autistic for all faces, familiar faces and stranger faces.

New Operator

To detect the neural pathway surrounding the fusiform gyrus area, sobel edge detection operator is used for the control and the autistic. Figure 9 shows the processed images.

Comparing the produced images, it is clearly visualized that the edges for the control are sharply observed which indicates that the neural pathways for the control are more effective surrounding the fusiform gyrus than autistic.



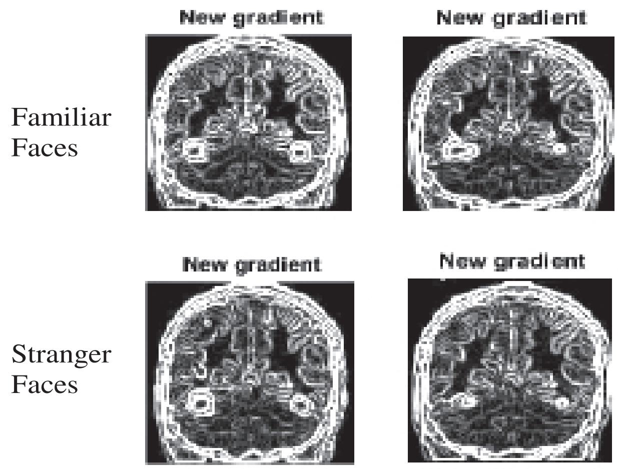


Figure 9: Processed images of the fusiform gyrus using New operator of control and autistic for all faces, familiar faces and stranger faces.

Performance Evaluation

Table 1: Subjective fidelity scoring scales

Quality	Comparison
A – Very good	+ 3 Very high
B – Good	+2 High
C – Fair	+1 Medium
D – Poor	- 1 Less
E – Bad	- 2 Much less

Table 1 shows the subjective fidelity scoring scales that used for comparing different operator's performance. The new operator's performance for edge detection in image is evaluated subjectively against the different operators (Sobel, Robert and Prewitt).

Table 2 shows the performance for evaluating contrast for all input images of comparing different operators (Sobel, Robert, Prewitt and New). The performance of New operator is very good from all operators to consider table 1 scoring scales.

Table 3 shows the performance for detecting edge map of different operators (Sobel, Robert, Prewitt and New) for all input images. The edge map performance of New operator from all operators is also very good.

Table 4 shows the performance for noise contents of different operators (Sobel, Robert, Prewitt and New) for all input images. The processed images have much less noise contents using New operatoir from all operators.

It has been shown that the new operator performs better than all these operators under almost all scenarios.

Table 2: Performance for evaluating contrast of different Operators

Operators For Comparison	All faces		Familiar faces		Stranger faces	
	Control	Autism	Control	Autism	Control	Autism
Sobel	B	B	B	B	B	B
Roberts	C	D	C	D	C	D
Prewitt	B	C	B	C	B	C
New	A	A	A	A	A	A

Table 3: Performance for edge map of different operators

Operators For Comparison	All faces		Familiar faces		Stranger faces	
	Control	Autism	Control	Autism	Control	Autism
Sobel	B	B	B	B	B	B
Roberts	C	D	C	D	C	D
Prewitt	B	C	B	C	B	C
New	A	A	A	A	A	A

Table 4: Performance for noise contents of different operators

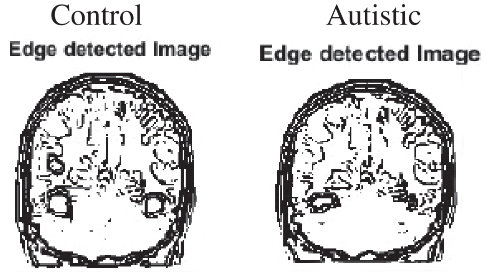
Operators For Comparison	Contrast		Edge Map		Noise Contents	
	Controls	Autism	Controls	Autism	Control	Autism
Sobel	-1	-1	-1	-1	-1	-1
Roberts	+1	+2	+1	+2	+2	+1
Prewitt	-1	+1	-1	+1	-1	+1
Proposed	-2	-2	-2	-2	-2	-2

Thresholding

Figure 10 shows the result of thresholding which gives the accurate edge detected images using new operator of the fusiform gyrus of brain for control and autistic for all faces, familiar faces and stranger faces.

Control Autistic

All Faces



Familiar Faces

Stranger Faces

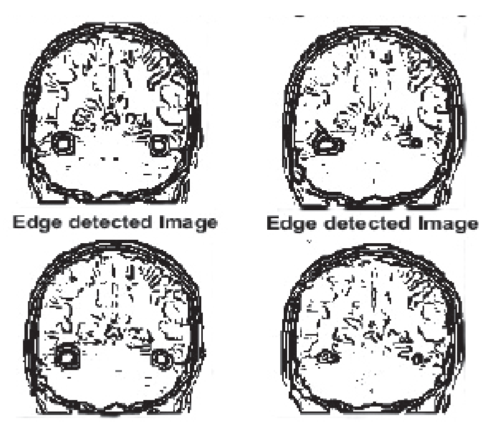


Figure 10: Edge detected images of the fusiform gyrus of brain for control and autistic using thresholding.

Image Segmentation

It has been observed that Sobel edge detection operator is computationally more expensive compared to Prewitt and Robert's operator. It means using Sobel operator the edge detection of fusiform gyrus of brain is very clear from Roberts and Prewitt operators. Consider processed images using Sobel operator for extraction fusiform gyrus area of brain both control and autistic using segmentation methods. Figure 11 shows the segmented images for both control and autistic individuals. It also shows extracted activation area of fusiform gyrus of brain for both control and autistic individuals.

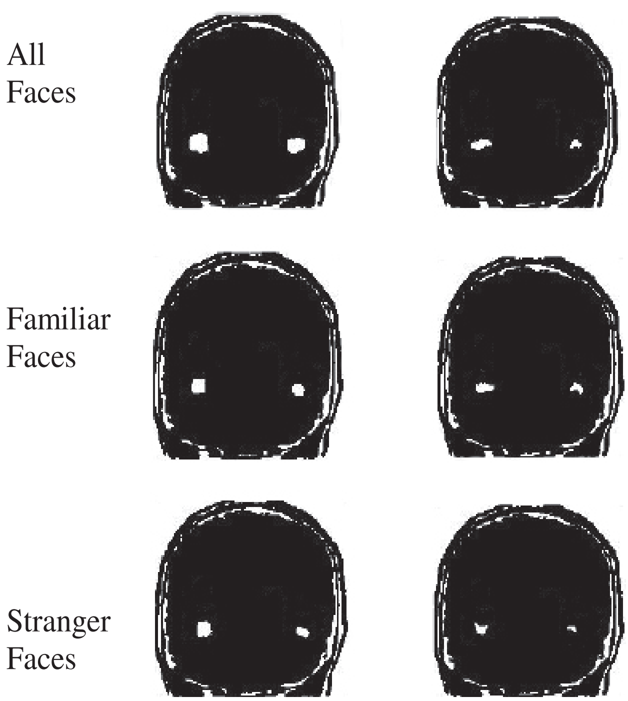


Figure 11: Segmented images of the fusiform gyrus of brain of control and autistic for all faces, familiar faces and stranger faces.

Calculation activation area of fusiform gyrus

Consider segmented processed images for calculating the values of activation area fusiform gyrus of brain of control and autistic for all faces, familiar faces and stranger faces.

Table 5: Indicated activation area and calculated values of both control and autism for all faces.

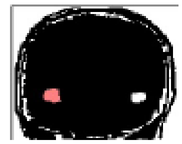
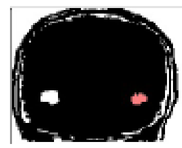
For All faces		**Area in pixels**
Control	 Left side	219
	 Right side	154
Autistic	 Left side	102
	 Right side	47

Table 6: Indicated activation area and calculated values of both control and autism for familiar faces.

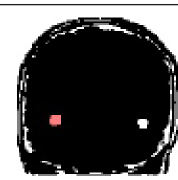
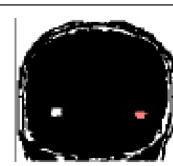
For Familiar faces		**Area in pixels**
Control	 Left side	107
	 Right side	76
Autistic	 Left side	92
	 Right side	54

Table 7: Indicated activation area and calculated values of both control and autism for stranger faces.

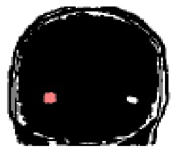
For Stranger faces		Area in pixels
Control	 Left side	126
	 Right side	63
Autistic	 Left side	65
	 Right side	26

Table 5 shows activation area is indicated as pink color for left and right sides of fusiform gyrus of brain both of Control and Autistic for all faces. The values are calculated for indicated area of fusiform gyrus. For left side, the values are 219 (in pixels) for Control and 102 (in pixels) for Autistic. For right side, the values are 154 (in pixels) for control and 47 (in pixels) for autistic. From these calculated values, it is observed that the values for left and right sides of Autistic are smaller than Control.

Table 6 shows also activation area is indicated as pink color for left and right sides of fusiform gyrus of brain both of control and autistic for familiar faces. The values are calculated for indicated area of fusiform gyrus. For left side, the values are 107 (in pixels) for control and 92 (in pixels) for autistic. For right side, the values are 76 (in pixels) for control and 54 (in pixels) for autistic. From the result values, it is observed that the values for left and right sides of autistic are also smaller than control but the difference of values are very close.

Table 7 shows also activation area is indicated as pink color for left and right sides of fusiform gyrus of brain both of control and autistic for all faces. The values are calculated for indicated area of fusiform gyrus. For left side, the values are 126 (in pixels) for control and 65 (in pixels) for autistic. For right side, the values are 63 (in pixels) for control and 26 (in pixels) for autistic. From these calculated values, it is observed that the values for left and right sides of autistic are smaller than control.

From the calculating values, it has been observed that the values of activation area for autistic are smaller than control. The compared results are shown in Figure 12, Figure 13 and Figure 14 with graphical representations.

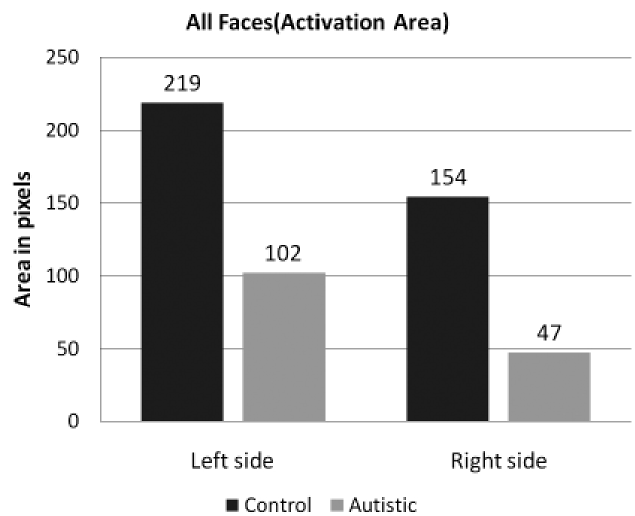


Figure 12: Graphical representation of both control and autistic for all faces.

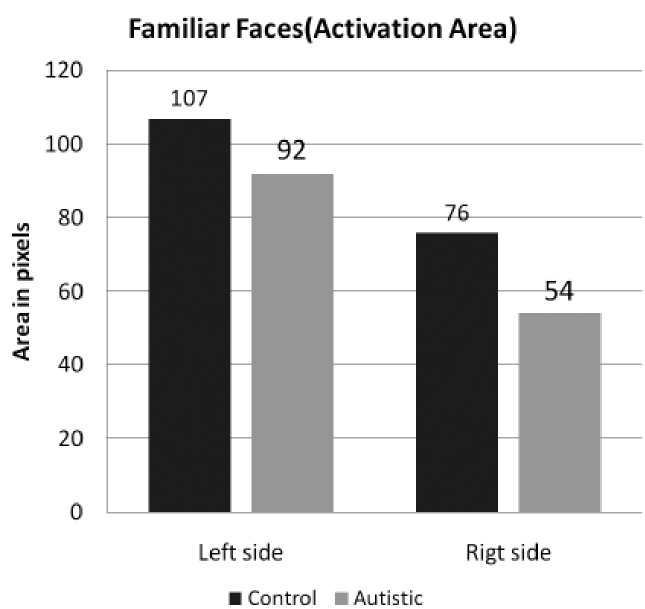


Figure 13: Graphical representation of both control and autistic for familiar faces.

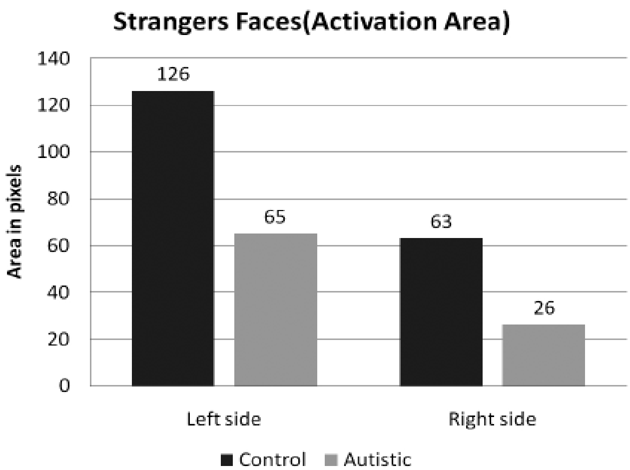


Figure 14: Graphical representation of both control and autistic for stranger faces.

V. Conclusions

By using New operator the edge detection of fusiform gyrus of brain is very clear from different operators (Sobel, Roberts and Prewitt operators). Then applying threshoding, segmentation and binarization operation on fMRI scan images of control and autistic individuals, it is clearly visualized that there are differences in calculated values of activation area of the fusiform gyrus for three types faces (all faces, familiar faces and stranger faces). From these differences, it has been observed that the activation areas in fusiform gyrus are hypoactive in patient with autism than in control. As the activation area extracted from the fusiform gyrus and its segments is significant, the results of this study could be used to assess the detection human neurological disorders such as autism. It is a simulation model to understand the risk of autistic individuals. To understand more about autism, functional studies of fusiform gyrus and its surroundings are of key interest and molecular level investigations are needed for further detailed study.

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