Visual face scanning and emotion perception analysis between Autistic and Typically Developing children

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Abstract

Autism is a neuro-developmental condition that is characterized by a number of unconventional behaviors such as restricted and repetitive activities. It is often largely attributed to deficiency in communication and social interaction. Therefore, it is difficult to make autistic individuals, especially children, to comply with researches that aim at comprehending this condition. However, with the availability of non-invasive eye-tracking technology, this problem has become easier to deal with. The following research probes into the visual face scanning patterns and emotion recognition between 21 autistic and 21 control or TD (typically developing) children when displayed pictures of 6 basic emotions (happy, sad, angry, disgusted, fearful and surprised). Tobii EyeX Controller was used to attain the gaze data and the data was processed and analyzed in MATLAB. The results revealed that children with autism look less at the core features of the face (eyes, nose and mouth) while scanning faces and have more difficulty in perceiving the correct emotion compared to the typically developing children. This atypical face scanning and lack of preference to the core features of the face can be the reason why autistic individuals have trouble understanding others' emotions and an overall incompetency in communication and social interaction. To delve more into this, further eye-tracking,

neuroimaging and behavioral studies should be done in integration.

Author Keywords
Autism; eye-tracking; face scanning; emotion perception; typically developing; Tobii EyeX Controller.

ACM Classification Keywords
I.4 Image Processing and Computer Vision;

H.5.m. Information interfaces and presentation (e.g., HCI): User-centered design; Miscellaneous;

I.2.9 Robotics: Sensors

I.4.8Scene Analysis

Introduction
Autism is a developmental disorder that includes a range of abnormal behaviors. The main trait of this disorder consists of social and communication incompetency, repeated activity, sensory problems and delay in learning. Autism is often attributed to abnormal visual behavior such as avoiding eye contact [1]. With the prevalence of eye-tracking devices in the market, visual behavior studies of autistic individuals have become a research field with great potential.

The ability of perceiving facial expressions and deducing other important social cues from looking at the faces of others is a vital prerequisite for normal social interactions and communication. To perceive and to judge facial expressions means to understand the emotional state of another by looking at the major features of their faces. Typically developing children usually perceive emotions and process facial expressions by looking at the core features of the face, which includes the eyes, nose and the mouth [2]. The understanding of emotions by correctly scanning the major features of the face plays a vital role in the efficiency of one's social and communication abilities. The face offers notable stimuli whose social significance is exhibited at a very young age in humans. Infants are able to orient their gaze at faces from birth [3]. This visual behavior allows the early communicative ability which is essential in the establishment and development of social and emotional relationships. The understanding of facial expressions mainly stems from looking at the eye region of the face and can influence the ability to understand the mental state of others [4]. Due to their informative nature, the eyes and the mouth are the favorable visual targets in the observation or inspection of the face and typically developing individuals spend more time looking at these features [5]. Neurobiological studies show that face perception is atypical in individuals with autism and this is thought as one of the likely reasons for their social incompetency [6]. In many behavioral studies, children showed flawed perception of faces and a lack of interest to look especially at the eye area [7], [8]. However, very few studies have been conducted in this regard using eye-trackers.

The purpose of this research is to carry out visual face scanning pattern and emotion perception analysis between typically developing children and children with autism. This is done by studying visual data provided by these two groups when they are shown the pictures of 6 basic emotions (happy, sad, angry, surprised, disgusted and fearful). The atypical visual behaviour of children with autism is likely to spring from their inability to effectively process information that they

see. An understanding of the difficulties that these children experience by those around them can make a big difference in their ability to integrate effectively in the society. The novel contribution of this paper is that, in perspective of Bangladesh, this is a complete new contribution. In global perspective, the methodology and approach is different from previous related works. A moderate amount of samples has been used. Most importantly, the device used for the research is very inexpensive, user-friendly and readily available in the market.

Related Works

Face processing and recognition shortcomings are usual among individuals with autism [9]. Aversion to making eye contact could lead to poor face and emotion processing [10]. A study found reduced fixation on the eye area of the face in people with Autism Spectrum Disorder (ASD) as compared to age-matched typical controls in a face recognition task [11]. The two groups showed a similar trend for fixation on the mouth region and the face region in general [11]. Reduced fixation to the eye region was also found in other researches on face recognition in autism [12], [13]. There are also findings that contradicted these results [14], [15], [16]. A study indicates that deficits in face processing might be present in individuals with autism as early as the first year of life [17].

There are discrepancies in findings with regards to longer fixation on the mouth compared to eye for children with autism [11], [18]. One possible explanation for this might be the difference in stimuli as one study used dynamic scenes as stimuli [18] and the other used static face photographs [11]. There are studies using adults and adolescents with ASD, which concluded that they have diminished fixation towards the eye region [19], [20].

Another research reported discrepancies in face scanning patterns between ASD and TD children [14]. The study compared the visual scanning patterns in a group of 3- to 6 year-old children with ASD (n=11) and a 5-year-old control group during exploration of faces showing positive and negative emotions. Areas of interest (AOI) included the eyes, nose and mouth. The ASD group looked less at the AOIs compared to non-AOI areas on the screen, and spent less time scanning the mouth [14]. It is a notion that directing gaze to the eyes of other people is crucial for extracting emotional information [21]. Furthermore, brain-imaging techniques such as fMRI (functional magnetic resonance imaging) have offered insight into the face perception and processing deficit in ASD.

Method

A. Participants

A total of 42 children participated in the research experiment. 21 children with autism were taken (14 male and 7 female). The participants were aged between 5 to 17 years. They were recruited from an Autism habilitation school. All of them were previously diagnosed with autism by doctors. The participants were all able to speak and understand instructions.

For the control group, a total of 21 typically developing (TD) children were selected from the local community. The participants were gender and age matched with the autistic group i.e., 14 male and 7 female between the ages 5 to 17. These children had no previous records of neurological or mental illness.

The research was conducted with utmost regards to all ethical issues since it involved dealing with clinical subjects who have been diagnosed with autism previously. Ethical clearance was received from the Director and the Head of the Pediatrics Department of Dhaka Medical College Hospital. Individual parental permission was also received for each participant. It was made sure that all the guardians and the participants understood the aim and procedure of the research. Participants and guardians were also assured that they can withdraw from the study anytime if they wished to, without any penalty.

B. Stimuli

The participants were required to look at 6 images displaying different basic emotions (happy, sad, angry, disgusted, fearful and surprised) and correctly identify the emotion. For their convenience, they were verbally given two options for each image. This was done in order not to unsettle the children (especially, the ones with autism), as more than two options were highly likely to confuse them or make it hard for them to follow and respond within only 7 seconds. The images were collected from a database that is comprehensive and established [22], [23]. Each image had a resolution of 640x490 pixels and had duration of 7seconds. The images were in grayscale so as to make them less distracting and more accurate for the study.

C. Experimental Setup and Procedure

The research experiment was carried out in a room with lights that were not too bright. This was done to make sure that the children do not get distracted and concentrated mostly on the display screen. The Tobii EyeX Controller was mounted on the laptop screen and was kept an approximate of 60 cm away from the chair where the participants sat. Guardians/ teachers were allowed to accompany the children throughout the experiment. The researcher explained the procedure of the study to the guardian and the participant. Once it was clear that they completely understood the procedure and were willing to continue, the experiment began. At the beginning, a 9-point calibration took place where if 6 points were correctly looked at, it was considered as a successful calibration. After each successful calibration, the images started to appear, each for 7 seconds. The participants were instructed to look at the image and answer the question of the experimenter (or their guardian if necessary). For each image, the experimenter or the guardian gave the participant two options verbally and they had to pick the one that correctly matched the emotion on the screen.

Data Analysis

The Tobii EyeX Controller was used to record the gaze data of the participants. This eye-tracking device can operate at a maximum range of 90cm and has a data rate of ~60 Hertz. However, it does not support internal memory and cannot store raw data. Hence, an open source MATLAB toolkit was used to interface and store the data acquired from the Tobii EyeX Controller [24]. A code was written in MATLAB to display the images and to simultaneously acquire and save the gaze data received. After the data was acquired, it was processed and analyzed using MATLAB.

Region of interest (ROI) and scanning pattern analysis was used to process the data received. In ROI method,

a region of interest is determined beforehand and the numbers of data that fall in that particular defined area are calculated. The data analysis of face scanning mainly involved the parameter of duration of fixation at different regions of the face. The core features of the face as mentioned are the eyes, nose and the mouth. These 3 areas of the face were considered as the ROI for the data analysis. Firstly, the total duration that a particular participant looked at the screen was calculated for each image. This divided by the total duration of the image gave the percentage of time the participant was engaged in looking at the image. These calculations were made for all 6 images for each participant.

The next step was to separately calculate the duration a participant looked at the eyes, nose, and the mouth respectively. These duration data were then converted to fixation percentage with respect to the total fixation duration of that particular participant, i.e., fixation percentage for the eyes, mouth and nose separately. In addition to these, the data for looking at the non-feature areas was calculated and designated as 'rest'.

For a particular image, the number of autistic participants that correctly recognized the emotion was referred to as 'successful identifiers'. Then the fixation percentages for all the core features and 'rest' for these participants were averaged to observe where exactly they looked to correctly identify the emotion. For the 'unsuccessful identifiers' too, the same process was carried out to look for differences in the gaze pattern from the ones who correctly recognized the emotion. For the TD group, a total average of the fixation for each area was found.

Scanning pattern analysis, on the other hand, means analyzing the data to find the areas of the stimuli on which the participant fixated and studying his/ her visual pathways. For the scanning pattern analysis, a code was written in MATLAB to find the gaze points numbered with respect to time. For instance, the first gaze point becomes number 1; the second gaze point becomes number 2 and so on. This information can be a valuable measure of the saccade made by the participants and is expected to be more irregular and higher in participants with autism. The images showing the results are not in grayscale in order to understand the right and left eye gazes clearly.

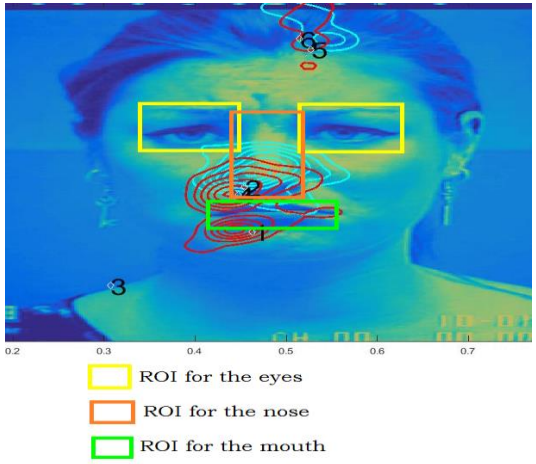

Figure 1: The red and blue patterns indicate the right and left eye gaze respectively, and the numbers represent the order of fixation.

Result

The two datasets for autistic and TD group were found to have significant dissimilarities. The duration values

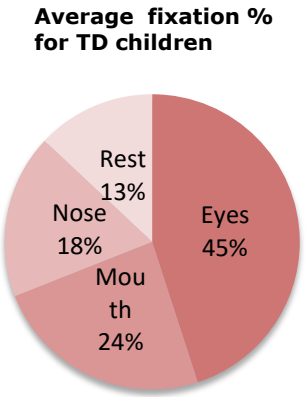

Figure 3: Average fixation percentage for the Typically Developing group

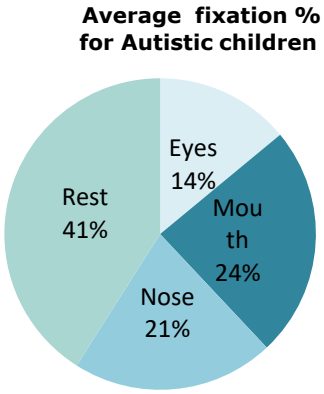

Figure 4: Average fixation percentage for the Autistic group

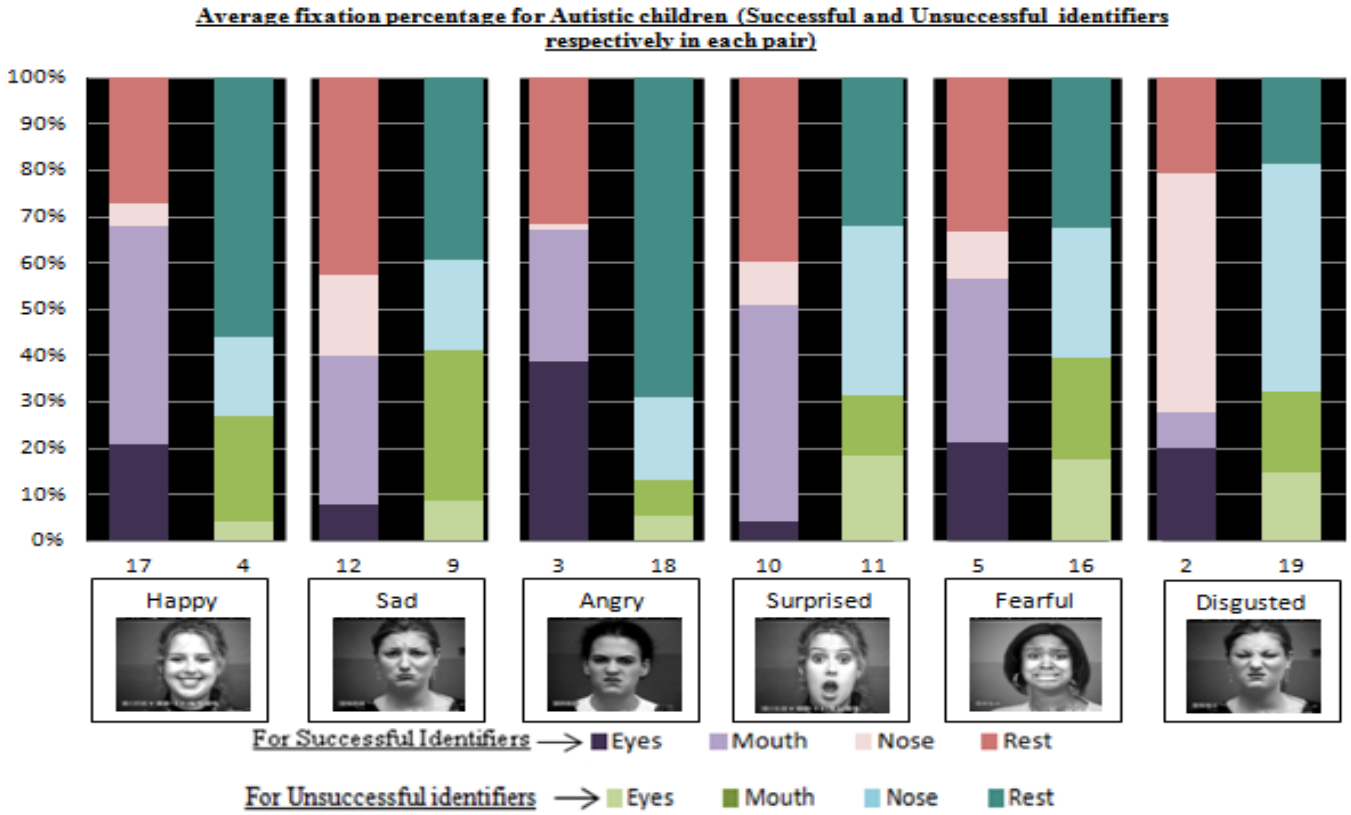

Figure 2: Average fixation percentage for the Autistic group (Successful and unsuccessful identifiers are indicated by the first and second bar respectively for each emotion. The gaze percentage for eyes, mouth, nose and rest are given for each case).

differed largely from each other. The autistic group showed less concentration level than the TD group and had lower affinity towards the key features.

The average looking duration of autistic children was 68.29% of the total test time. This was substantially lower than the 87.33% that was determined for TD children. The comparison of the two datasets also showed that the key features (eyes, nose and mouth) got much less importance from autistic children compared to the control children and this is in agreement with previous literature. Figure 2 shows the average fixation percentages for the TD children. It can be seen that they tend to focus more on the core features of the face in order to perceive emotions. On the other hand, the average fixation percentages for

the autistic group in Figure 3 indicate that they do not show any preference towards the key features of the face. Their value for the fixation towards the eyes is particularly low, which is very likely to indicate that they have an aversion towards looking at the eyes. It is seen that they tend to spend more time looking at the non-feature parts of the face (hair, ears, neck, etc.) or at the background of the images.

In Fig. 4, the average fixation percentages for the autistic group are shown. For each emotion, two bars are shown; the first one represents the individual fixation percentages for the ones who correctly identified the emotion and the second bar represents the fixation percentages for those who failed to identify the emotion. The fixation or gaze percentages for the eye region, mouth, nose and rest are shown in each bar. It can be seen at a glance that the values for the fixation towards the non-feature areas of the face is significantly high in almost all the bars.

On the other hand, the value for looking at the eye region is very low in all the bars, indicating that children with autism is most likely to have an aversion towards looking at the eyes. The values for fixation at the mouth are higher for those who successfully identified the correct emotions than those who could not. For the nose area, the values are very high for the 'disgusted' emotion image, but in other cases it is pretty low and shows no pattern. The number of autistic children who could correctly perceive the emotions is also not very high. For the 'happy' emotion, they performed pretty well and except four, all of them could understand that happiness was being expressed in the image. Here, it is seen that they looked mostly towards the mouth to understand the 'happy' emotion.

Performance was satisfactory for both 'sad' and 'surprised' emotions where almost half of them could recognize the emotion correctly. Here too, it is evident that they looked mostly at the mouth region. However, for the other three emotions, the children performed very poorly and only a few could name the emotions accurately. Overall, this is a significantly poorer performance in comparison to the TD group. All the TD participants identified the emotions correctly except for only 2 and 4 participants who failed to identify the 'surprised' and 'disgusted' emotions respectively.

Figure 5 shows the scan pattern analysis samples for both the autistic and the TD group. Here it can be again seen that the children with autism tend to look less at the core features of the face and concentrate more on the other aspects of the picture. In particular, they are very keen to avoid looking at the eye region of the image in most cases. A lot of gaze patterns are seen at the background of the images which are pretty plain. However, for the control or the TD group, it can be seen that they mostly concentrate on the key features of the face, i.e., towards the eyes, nose and mouth and their gaze pattern is quite clustered in these regions. It can also be seen that the number of fixation points for the TD children is much more than that for the autistic children. This can be because of the fact that autistic children's overall screen looking time is much less than that of the TD children. The gaze pattern within the autistic group was rather random and had no specific pattern or preference towards any special point. But the gaze pattern for TD children did not exhibit much variation and focused mainly on the core features.

In summary, whether the children with autism perceived the emotions correctly or not, no particular

preference towards the core features of the face was evident from their gaze behavior. This was in contrast with the TD participants, who showed clear preference towards looking at the core features of the face in order to perceive its emotion.

compared to their peers. Their total screen time was much less than the controls and they preferred to look at the non-feature areas of the face (ears, neck, hair, background, etc.) rather than the core features (eyes, nose and mouth).

Typically developing group

Autistic group

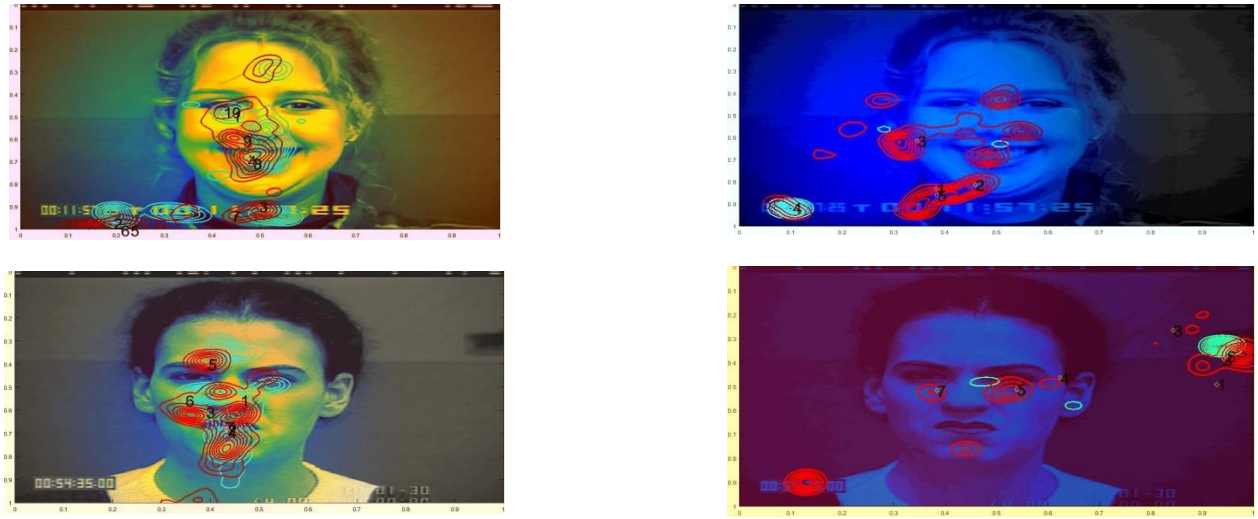

Figure 5: Scan pattern analysis samples for the TD and the Autistic group. Here the red and blue patterns indicate the right and the left eye gaze respectively. The numbers represent the gaze order, for example, number 1 is the first fixation point, number 2 the second, etc. (Note that, the images were obtained from the MATLAB display and their contrasts were adjusted for better understandability.)

Conclusion

The face scanning and emotion perception analyses between children with autism and typically developing children exhibited results that are open to interpretations and are parallel with previous findings. Participants with autism were found to have an aversion towards looking at the faces in general

In many neuro-imaging, behavioral and few eye-tracking studies, the results found were similar. This type of aversion towards faces and the lack of understanding of other people's emotions can be a result of the abnormal face processing mechanism of the individuals with autism. One of the main markers of autism is the incompetency in social interaction which is

often linked to the inability to properly process facial emotions and perceive them [25]. This means that they scan the essential parts of the face (eyes, mouth and nose) less than that which is typical to normal human beings. The results found in our research also showed a general aversion to the core features of the face which is keys to understanding the emotion of a person. It can also be the reason why autism is greatly associated with deficiency in social interaction and communication [6]. Further studies by collaborating eye-tracking and neuroimaging should be carried out to delve deeper into this.

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