Responses to Sad Emotion in Autistic and Normal Developing Children: Is There a Difference?

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***Abstract*—This paper describes how the gazing pattern differ between the responses of Normal Developing (ND) and Autistic (AP) children to sad emotion. We employed an eye tracking technology to collect and track the participants' eye movements by showing a dynamic stimulus (video) that showed a gradual transition from pale emotions to melancholy facial expressions in both female and male faces. The location of the child's gaze in the stimulus was the focus of our data analysis. We deduced that there was a distinction between the two groups based on this. ND children predominantly concentrated on the eyes and mouth region of both male and female sad faces, but AP children showed no interest in these areas by glancing away from the stimuli faces. Based on the findings, an ideal eye tracking model for early ASD diagnosis can be constructed. This will aid in the early treatment of Autism children as well as the development of socio-cognitive skills.**

***Keywords*—autism, eye tracking, human face recognition**

I. INTRODUCTION

ASD is a complex neurodevelopmental disease that causes repetitive/restricted activities, considerable difficulties in verbal and nonverbal communication, and substantial difficulties in interpersonal communication [1]. Pediatricians or parents/caregivers can spot the first symptoms of this disease before a child turns a year old. By the time a child is 2 or 3 years old, symptoms, however, usually start to emerge more frequently. When a child first enters school, the functional impairment associated with autism may be minor and not noticeable. However, once in a peer group, the deficiencies may become more obvious [2−4]. It is possible to improve the social and behavioral abilities of children with autism by diagnosing it early. For these goals, modern technology such as eye tracking is utilized. The eye tracking software can capture the children's gaze patterns in response to various visual stimuli. The use of different analytic metrics to analyze this gaze pattern can aid in the research of their interests and preferences [1]. When viewing these verbal and nonverbal inputs, ASD youngsters have a particular gaze pattern. Normal developing persons tend to make direct eye contact with the opponent's face [2]. Direct eye contact is a natural behavior that improves an individual's socio-cognitive abilities. However, the autism children don't exhibit this behavior traits.

Researchers analyzed at how attentional biases in social settings – as assessed by eye movements – varied between children with ASD and children who are normally developing. They used eye tracking software to observe the visual patterns of young children while performing various fundamental motor tasks such as button pressing. The most appealing feature of eye tracking is its non-invasive nature, which motivates medical professionals to use it for early detection. It does not require advanced motor skills or language [5−7]. The ocular and social perception mechanisms in autism have been investigated using this paradigm, with inconsistent results. The use of diverse populations and a range of stimuli may cause variability in the results [8]. Based on the movement of visual images, the visual stimuli utilized to generate gazing patterns can be classified as static or dynamic [9]. Visual images with no motion are called static stimuli, while moving visual images are called dynamic stimuli. Our study employs dynamic stimuli, which include a variety of human emotions and expressions, with the resulting visual pattern being examined using static measures. The participants in this study are selected individuals from Dubai Autism Centre and other private autism facilities. Our research is first initiative for early ASD diagnosis in the region, and the main goal is to model an efficient eye tracking system for early ASD detection in United Arab Emirates and beyond.

The literature overview and latest developments in eye tracking are discussed in Section II. The third section discusses the research goals. The case study and methods are explained in Section IV. Section V summarizes the findings of the study. Section VI concludes this investigation by summarizing the findings and conclusions.

II. LITERATURE REVIEW

ASD should be diagnosed in its early stages since it deeply impacts the lives of individuals and their families [10]. It affects around 78 million people globally. USA

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witnessed a significant surge of 23 percent in ASD count based on research done by US Centers for Disease Control and Prevention in 2009 [11]. Another study conducted by Cambridge University claimed that number of ASD individuals has risen twelve times in the last thirty years. While discussing with Head of community services of Dubai Autism Centre, she revealed that proportion of ASD in UAE is also increasing steadily these years. According to her viewpoint, there are problems in early detection of ASD since there a lot of people in the evaluation waiting list. This is due to the disorder's intricacy, which has made tracking its onset difficult. The limitation of the biological indicators for early ASD detection, consistently changing diagnosis methods and various autism types are the main challenges. Therefore, the evaluation should be conducted by an experienced team of medical practitioners from different streams such as occupation therapist, cognitive specialist, psychologist, speech and language therapist and pediatrician. By detecting ASD in early age can facilitate efficient treatment procedures for individuals, hence medical researchers have concentrated on its early signs in recent years [12, 13]. On the contrary, most of the medical research isn't ideal and doesn't use computational data analysis. Autism can be diagnosed early, which can aid ASD youngsters to enhance their mode of socio-cognitive interactions. As a result, technology can assist psychologists in obtaining accurate autism diagnosis, allowing autistic youngsters to get proper medical help [14].

Certain facial expressions have allegedly been widely interpreted as emotions for a very long time (for instance, rage, disgust, fear, joy, sadness, and surprise) [15]. Significant cognitive deficits in social and nonsocial information processing are present in people with ASD [16−18]. One of the most prevalent cognitive deficits seen in ASD research involves identifying and classifying emotional expressions on faces [19]. Though, the current research on these subject yields wildly divergent conclusions: While some research indicates that autism clearly impairs the ability to recognize emotion through facial recognition [20−22], others contradict [23, 24]. This disparity can be partially attributed to the recognized variability of ASD, along with differences in the activities and stimuli employed in the studies, some of which may be a result of the particular components of face emotion recognition that were examined in the experiments.

The inability to maintain eye contact is the most visible sign of ASD. Regardless of their origin or cultural differences, most six-month-old newborns have this symptom [25]. Researchers can easily comprehend people's cognitive thought processes by evaluating what they usually focus on using eye tracking devices. Various study disciplines, such as Human Computer Interface (HCI), psycholinguistics, cognitive therapy, and psychology, investigate the pattern of eye movements. Emotional facial expressions are effective in describing unique information to viewers [26]. In social interactions, comprehending such emotions is critical since it allows you to detect others' intentions. It also elicits a suitable response, which aids in the generation of various levels of emotion in interactions [27]. This tracking software can also be used to determine where a person is glancing at something and for how long. The relationship between the user's socio-cognitive behavior and his gaze pattern is also taken into account. Fixations, saccades, pupil dilation, and scan routes are all ocular behavioral reactions that are used to characterize eye movements [28, 29]. A spatially fixed gaze lasting between 200 and 300 milliseconds is defined as eye fixation [1, 30] and is thought to be the most effective methodology for assessing and analyzing data from eye movements [31].

The results of eye tracking systems in current studies vary because of the diverse types of stimuli employed. Images, movies, human faces, fruits, plants, and animations are all examples. ASD patients can exhibit attention patterns such as conventional or deviant to the ocular region of faces based on these cues [32]. Dynamic stimuli tend to be considerably superior to static images for examining a social reaction, and highly ecological paradigms representing genuine interacting settings have been demonstrated to be the best stimuli [33]. The physiologically focused peripheral region of the right fusiform gyrus, including the fusiform face area, shows substantial differences between ASD and normal development individuals in response to dynamic rather than static social cues, according to functional neuroimaging data [34].

III. Research Objectives

The ASD based emotion recognition research generates inconsistent results since one of the main signs of ASD is decreased social interaction and behaviors. Most of the researchers ascertain the lack of convincing factors for poor emotion recognition [35−38], while others asserted that there is variation in emotions during eye tracking experiments [39, 40]. This may occur due to a few reasons. One of the reasons is the difference in mode of experiments conducted; a particular example is the emotion [36, 40] or paradigm [37] classification by participants. The variation in results is also possible by the variation of stimuli used from study to study, with most employing static facial expressions [35, 36, 38, 40] and only a few using moving photographs of dynamic facial motions [37, 41]. Also, photographs of facial emotions are not ideal [42, 43] because non-verbal interactions present in real life scenarios may be missed.

Several studies in early detection of autism have employed eye tracking as the tool for analyzing visual pattern of individuals [28, 29, 43, 44]. Most of them focused on static image cues. Abnormal gazing patterns in ASD individuals have been obtained from some experiments [28, 29, 43, 44], while no variation in gazing pattern of normal and autism individuals has been reported in others [40, 44−46]. As mentioned earlier, the most optimal cue is dynamic stimuli which relates to real life social interactions. Therefore, the proposed experiment should be executed by a face investigation that involves various dynamic emotions such as Happy, Sad, Surprised, Angry, Scared and Disgusted. Due to word constraints, we've focused on sad behavior in this study. However, in future, we will consider other five emotions and their corresponding visual pattern.

The project's long-term objective is to develop and refine a framework for eye-tracking experiments which facilitates the ASD early diagnosis. Following are the study's research questions:

- What are the differences between Autistic Participant (AP) and Normal Developing (ND) visual patterns?
- Do ND youngsters gaze the sad emotion faster than AP?
- Do participants from the ND and AP groups look at the dynamic human face at different times?
- Is there any change in visual patterns of AP and ND children while viewing male and female sad face as stimuli?

IV. Study Design and Methodology Participants

In this study, 65 Emirati and expatriate children participated (34 AP and 31 NP). The participants' age range is from eight to sixteen years old. The oldest is sixteen, while the youngest is four. Three-quarters of the participants (73%) are ladies, while the rest are men (27 percent). Sixty percent of the participants are expatriates, with the balance being Emirati natives (40 percent). Seventy-two percent of kids attend inclusive educational institutions, while 28 percent attend special education schools. Eighty percent of the participants were from nuclear households. Moreover, half of the individuals' parents (70 percent) were between the ages of 30 and 50. They came from various socioeconomic backgrounds. The kids were arriving from all around the UAE.

A. Material and Procedure

Tobii Studio eye tracking software is utilized to analyze the eye movements of subjects. To guarantee that emotional expressions were exhibited consistently, the Dynamic Affect Recognition Evaluation (DARE) [36]. This DARE dynamic stimuli are constructed by Cohn–Kanade Action Unit–Coded Facial Expression Database. A range of 2000 images are collected from above two hundred peoples. The visual stimuli in this eye tracking experiment are a dynamic video sequence for triggering sad expressions. The total length of this video is almost twenty seconds that starts with a neutral expression then slowly changes to a sad face. Fig. 1 shows five frames taken at the following intervals: 0 seconds, 5 seconds, 10 seconds, 15 seconds, and 20 seconds for female face. Fig. 2 shows five frames taken at the following intervals: 0 seconds, 5 seconds, 10 seconds, 15 seconds, and 20 seconds for male face.

The moderator initiates the experiment by giving a brief introduction about the research objective and main steps involved in this investigation. Data on eye movement was collected using eye-tracking equipment (Tobii X2 model). The moderator configured the eye tracker before each subject sat down in front of the computer to watch the movie. Since participants oversaw selecting and proceeding on to the following stimulus throughout the research, the experiment was conducted in a controlled atmosphere.

V. Research Result

Heat maps are powerful tools that can visually represent the gaze pattern of subjects as hot spots and analyze the viewing behavior. We can see visual attention of participants are scattered across the dynamic stimuli from these heat maps. In this study, three Areas of Interest (AOI) were considered for sad face. AOI_1 covers the eyes, AOI_2 covers the mouth and AOI_3 covers off the face. The eye tracking data was acquired while participants were fixated on the sad female and male faces. The sad female and male face images were altered, with the finished film beginning with a pale face expression and gradually transitioning to an emotional sad face. At 10 seconds into the stimulation, the mouth begins to form a sad face, which progresses to a full sad expression at 20 seconds. A heat map is constructed by data analysis of movement of a subject's focus at a particular element along with fixation time. They give insights about the visual attention distribution associated with stimuli. Gaze plot generally shows the gaze order, location, and the length of fixation on different corners of visual stimuli and the elapsed time. It identifies the most and least area of interests for participants. The various gaze plot and heat map analysis for the selected three area of interests will be explained in the following sections.

B. Heat Map Analysis

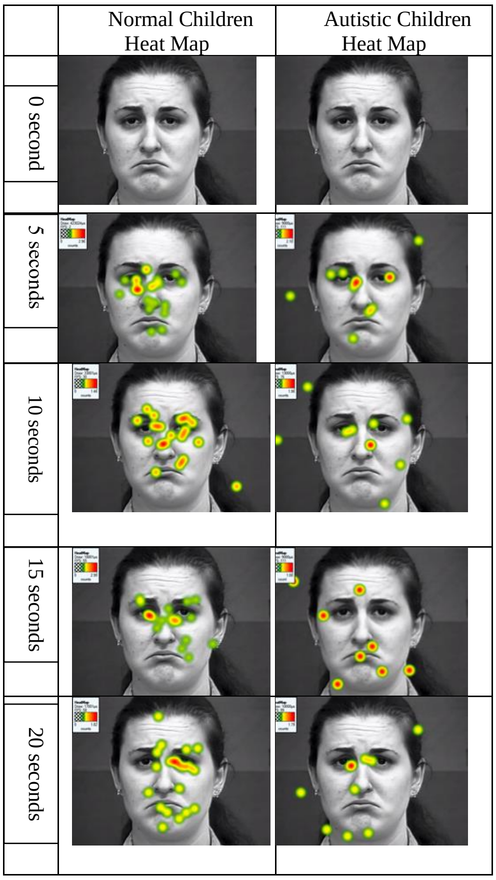

Figure 1. Heat maps for normal and autistic children at 4 different intervals for female sad face.

Normal developing youngsters mostly focused on the eyes and mouth region of a female sad face stimuli at the beginning of the 5th second (Fig. 1, columns 1), whereas visual attention pattern of autistic subjects was scattered (Fig. 1, columns 2). Throughout the remainder of the stimulus presentation period, the ND group's visual intensity was substantially greater and much more concentrated (10 till 20 seconds). The visual intensity rose more quickly when the stimulus presentation progressed from the pale face emotion expression to the sad face emotion expression. Autistic youngsters, on the other hand, maintained the same low visual intensity for the remainder of the stimulus exposure duration (10 till 20 seconds). However, when the stimulus presentation changed from the pale face emotion expression to the sad face emotion expression as conveyed by the visual intensity, the autistic children showed little interest (Fig. 1, column 2). The heat analysis described above is the same for male sad faces (see Fig. 2). Throughout the rest of the stimuli presentation, the ND group's visual intensity was significantly greater and concentrated (10 till 20 seconds).

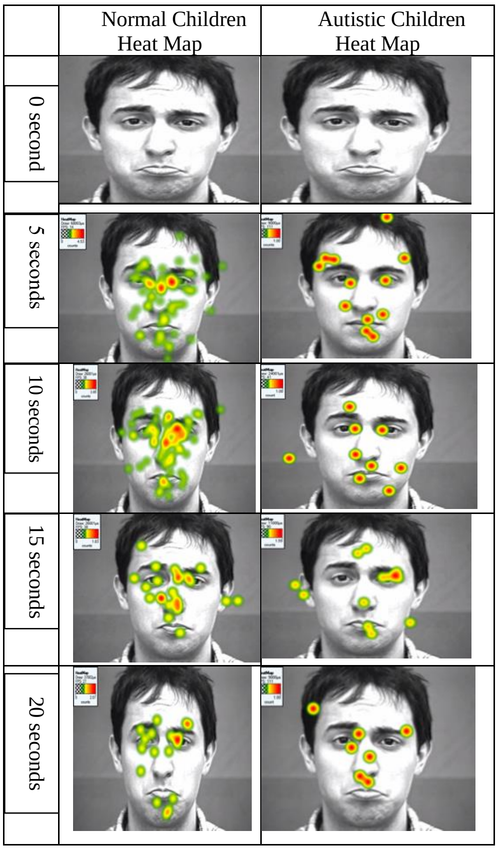

Figure 2. Heat maps for normal and autistic children at 4 different intervals for male sad face.

C. *Descriptive Statistical Data*

The attention pattern of subjects is analyzed using data collected from eye movements. Eye, mouth, and off face region are the three similar Area of Interests (AOI) studied in this experiment. Three metrics are selected to compare the gazing pattern of the participant groups. We picked three measures to compare the visual behavior of the two groups for this article. The following sub sections provide a description of each statistic as well as the analysis result.

1) *Time to first fixation*

The time it takes for a participant to fixate on an AOI or object for the first time is measured in time to first fixations. We observed a substantial difference in the time taken by the Normal Developing (ND) and Autistic (AP) children to have their first fixation for female sad face on the three AOIs. However, for male sad face, the time to first fixation at the eyes and off-face areas is the same, whereas the time for the mouth region differs

First, we discuss the time for first fixation for female sad face. For the AP children, the average period for the first fixation mean gazing at the eyes (AOI_1) was 13.23 seconds, while for the ND children it was 10.55 seconds. Furthermore, the AP children's average period for the first fixation mean gazing at the mouth (AOI_2) was 14.31 seconds, whereas the ND children's was 12.59 seconds.

The disparity between the two groups is about two seconds. Surprisingly, the AP group's mean time for the initial fixation mean staring at the off-face area (AOI_3) was 12.04 seconds, whereas the ND group's was 14.00 seconds. From this, it is clear that the AP group's first fixation was on the off face, implying that the members of the AP group are uninterested in the human eye and mouth, and later the sad face emotion expression.

The findings for male sad face's time of first fixation are as follows. For both the AP and ND youngsters, the average period for the first fixation mean gazing at the eyes (AOI_1) was 0.38 sec. Surprisingly, the AP children's average period for the first fixation mean gazing at the mouth (AOI_2) was 0.85 seconds, while the ND children's was 0.47 seconds. For both groups, the average period for the first fixation mean looking at the off-face area (AOI_3) was 0.34sec. This demonstrates that the AP and ND groups do not differ much. The AP group took slightly double the time to fixate on the mouth area while both groups had equivalent time and behavior when looking at the eyes and off face area.

2) *Visits count mean*

A visit is measured as the time from the initial fixation on the active area of interest and the completion of the final fixation inside the same active AOI with no fixations outside the AOI. We found a substantial discrepancy in the visit count taken by the ND and AP participants across the three AOIs for both male and female sad faces.

First, we can discuss the visit count mean for female sad face stimuli. The AP group had a mean visit count of 2.37 seconds on the eyes (AOI_1), while the ND group had a mean visit count of 3.60 seconds. The AP group's total visit count mean to mouth region (AOI_2) was 1.75 seconds, whereas the ND group's was 2.25 seconds. Surprisingly, the AP group's mean time spent gazing at the off face (AOI_3) was 2.12 seconds, whereas the ND group's was 1.58 seconds. This metric revealed that the AP group had the maximum time interval between initial and last fixation on the off face, instead of the eyes or mouth.

The findings for male sad face's visit count mean are as follows. The results demonstrate that the AP group's visit counts mean on the eyes (AOI_1) was 5.17 seconds, whereas the ND group's was 8.86 seconds. The AP group's total visit counts mean gazing at the mouth (AOI_2) was 4.36 seconds, while the ND group's was 4.64 seconds. The AP group's visit count mean gazing at the off face (AOI_3) was 3.26 seconds, while the ND group's was 2.20 seconds. As this statistic shows, the AP group had the largest time period between first and last fixation on the off face instead of the eyes. Both groups maintain the same behavior when looking at female and male sad face. The AP group are more interested in off face instead of the eyes and the mouth.

3) Total visits duration mean

Total visits duration mean can be defined as the average sum of visit durations of an active area of interest (AOI).

First, we can discuss the total visits duration mean for female sad face. In comparison to the NP group's total visit duration mean of eyes (AOI_1) (4.66 visits), the AP group's visit duration mean was shorter (2.13 visits). Similarly, the average number of visits to the mouth in the AP group ($AOI_{2)}$ (0.98 visits) was lower than the ND group (1.50 visits). As predicted, the AP group's total visit duration mean of off-face (AOI_3) (1.2 visits) was greater than the ND group's (0.74 visits). From these findings, it is confirmed that autism children preferred to look at the off face of a female sad face rather than the eyes or lips.

The following are the results for the total visit length mean of male sad face. The AP group had a lower total visit duration mean of the eye (AOI_1) (4.63 visits) than the ND group (9.04 visits). The AP group (3.26 visits) had a greater total visit duration mean to the mouth region (AOI_2) than the ND group (2.55 visits). The AP group (2.57 visits) had a greater average number of off-face visits compared to ND group (1.31visits).

This research also demonstrates and validates that the AP group preferred to gaze at off faces rather than sad female and male features' eyes or lips. Overall, the autism children exhibited somewhat higher interest in the off faces when it came to the sad female and male faces.

VI. Conclusion

To summarize, we employed eye tracking technology to distinguish between Normal Developing (ND) and Autistic (AP) children's responses to sad face. First, we presented a dynamic stimulus (video) that involves female and male face showing a gradual transition from pale emotions to sorrowful facial expressions. By analyzing heat maps and gaze plot, the results suggested that ND children mostly focused on eyes and mouth region of both male and female sad faces, whereas the AP children didn't show any interest in these areas by staring away from the given stimuli faces. An optimal eye tracking model for early ASD diagnosis can be developed based on the obtained results. This will help for providing the early treatment and development of socio-cognitive skills for autistic children.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The entire research experiment was designed and set up by all the authors. Dr. Almourad and Dr. Bataineh were in charge of the experiment's execution and data collection. Dr. Almourad and Ms. Wattar were in charge of data analysis and interpretation. All authors had approved the final version.

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