Eye-tracking Dataset to Support the Research on Autism Spectrum Disorder

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Abstract: The availability of data is a key enabler for researchers across different disciplines. However, domains, such as healthcare, are still fundamentally challenged by the paucity and imbalance of datasets. Health data could be inaccessible due to a variety of hurdles such as privacy concerns, or lack of sharing incentives. In this regard, this study aims to publish an eye-tracking dataset developed for the purpose of autism diagnosis. Eye-tracking methods are used intensively in that context, whereas abnormalities of the eye gaze are largely recognised as the hallmark of autism. As such, it is believed that the dataset can allow for developing useful applications or discovering interesting insights. As well, Machine Learning is a potential application for developing diagnostic models that can help detect autism at an early stage of development.

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a neuro-developmental disorder, which is characterized by various impairments, mainly social communication and interaction issues, and repetitive behaviour (American Psychiatric Association, 2013). ASD-diagnosed individuals usually suffer from troubles in interaction and communication in multiple forms. The most remarkable symptom is the poor development of non-verbal skills such as the lack or absence of eye contact. With such troubling deficits, a considerable strain can unfortunately be placed on the well-being of autistic individuals and their families as well. From an economic standpoint, it was estimated that autism costs the UK, for example, more than heart disease, cancer, and stroke combined (Buescher et al., 2014).

The detection of autism at an early stage of development is highly favourable to realise common benefits for children and their families. Multiple studies (e.g., Smith et al., 2000; Dawson et al., 2010) reported improved outcomes of treatment such as intellectual capacity, communication, adaptive behaviour, and educational support. However, the diagnosis of autism has been considered as a challenging task. The diagnosis process includes a variety of cognitive tests that typically require hours of intensive clinical examinations. Furthermore, standardised tests require a considerable amount of time and effort to be conducted, and the diversity of symptoms increase the complexity of identifying an accurate classification.

In this regard, a large body of the psychological research endeavoured to develop assistive instruments based on observational measures or diagnostic interviews. Examples include Childhood Autism Rating Scale (Schopler et al., 1980), Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 1989), and Autism Diagnostic Interview (ADI-R) (Lord, Rutter, and Le Couteur, 1994). More recently, a range of technologies have been embraced for aiding the process of screening and diagnosis. In particular, the eye-tracking technology has received an extensive research interest in the ASD context. Abnormalities of the eye gaze have been largely recognised as the hallmark of autism (Guillon et al., 2014), which makes eye-tracking methods suitable for a variety of diagnostic tasks.

This study seeks to contribute to the research community of ASD by providing an eye-tracking dataset. On the one hand, part of our earlier work (Carette et al., 2018) has published an image dataset, which represented the visual patterns of eye-tracking

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scanpaths. On the other hand, the present work aims to publish the raw eye-tracking output, which should allow for extended opportunities for studying and analysing the gaze behaviour of ASD. This study has been generally initiated in the frame of an interdisciplinary research of Psychology and AI. The collaboration has brought together psychologists from the CRP-CPO lab along with AI researchers from the MIS lab, based at the University of Picardie Jules Verne in France.

2 BACKGROUND AND RELATED WORK

This section aims to provide a review of the literature as follows. Initially, a brief history is given on the origins of eye-tracking. Further, we review selective studies that employed eye-tracking to analyse the gaze behaviour among ASD-diagnosed individuals.

2.1 Brief History of Eye-tracking

Eye-tracking refers to the process of capturing and measuring eye movements and the absolute point of gaze (POG) (Majaranta, and Bulling, 2014). The POG represents the focal point of the eye gaze in the visual scene. Modern eye-trackers largely fall into three categories including screen-based eye-trackers, eye-tracking glasses, and Virtual Reality (VR) headsets as well.

However, the use of eye-tracking interestingly has a long history that dates back to the 19th century. The early development of eye-tracking is credited to the French ophthalmologist Louis Javal from the Sorbonne University. In seminal research that commenced in 1878, Javal had produced the novel observations of fixations and saccades based on the gaze behaviour during the reading process (Javal 1878; Javal 1879). A fixation describes the brief moments while the eye gaze is paused on a particular object, which allow the brain to perform the perception process. The average duration of fixation was estimated to be around 330ms (Henderson, 2003). While saccades include a constant scanning with very rapid and short eye movements. Saccades consist of quick ballistic jumps of 2^{o} or longer, which continue for about 30–120ms (Jacob, 1995).

Afterwards, Edmund Huey built a primitive eye-tracking tool for analysing eye movements while reading (Huey, 1908). More advanced implementations of eye-tracking instruments were developed by (Buswell 1922; Buswell 1935). Photographic films were utilised to record the eye movements while looking at a collection of paintings. The eye-tracking records included both of the direction and duration of movements. Eye trackers are currently utilised in a plethora of applications. To name a few, applications of marketing (Boerman, and Müller, 2022), psychology (Åsberg Johnels et al., 2022), product design (Jeon, Cho, and Oh, 2021), and many others.

2.2 Eye-tracking Research in Autism

Making an accurate diagnosis of autism has been considered as a challenging task, which usually requires an intensive clinical assessment and experience. With contemporary advances in technology, new approaches have come into prominence to assist the procedures of diagnosis and assessment. Examples includes a variety of technologies such as Electroencephalography (EEG) (Abdulhay et al., 2020), Magnetic Resonance Imaging (MRI) (Dekhil et al., 2019), and eye-tracking (Cilia et al., 2021) in particular.

In this context, the literature contains abundant contributions that endeavoured to apply eye-tracking methods for analysing and understanding the characteristics of autism. Various interesting physiological elements were reported based on findings output from eye-tracking experiments. For instance, eye movements in face-to-face interactions were observed to be different for individuals who had different levels of the autism severity (Vabalas, and Freeth, 2016). Specifically, highly autistic individuals were noticed to experience saccades of shorter duration and less frequency as well. In another application of eye-tracking, ASD toddlers could be identified based on the frequency of saccades and fixations (Pierce et al., 2011). The results showed that the ASD-diagnosed group spent significant longer periods of fixations on dynamic geometric images.

Other studies sought to integrate eye-tracking with contemporary AI approaches to advance the diagnostic applications of autism. For example, a Deep Learning model was implemented to detect autism using eye-tracking tasks of free-image viewing (Jiang, and Zhao, 2017). Deep Learning was utilised to extract features automatically from a collection of discriminative images. Likewise, CNN-based architecture was applied for the detection of eye contact during social interactions (Chong et al., 2017). Their results reported a precision and recall of 76% and 80%, respectively. Another Deep Learning-based framework was developed for ASD screening using photo-taking tasks (Chen, and Zhao, 2019).

They applied LSTM models for encoding the temporal information of eye movements.

The present study endeavours to contribute with an eye-tracking dataset to the research community of autism. The dataset is based on a set of eye-tracking experiments. Our earlier work (Carette et al., 2018) published an image dataset of the eye-tracking output. The images illustrated the dynamics of eye movements in visualisations of the eye-tracking scanpaths. The dataset was used in numerous publications such as (Ahmed, and Jadhav, 2020), (Akter et al., 2021), (Gaspar et al., 2022), and (Elbattah et al., 2022). It is hoped that the present dataset will also deem useful to develop further applications for the ASD diagnosis.

3 DATA DESCRIPTION

3.1 Brief History of Eye-tracking

The participants included a set of 59 children recruited from a few schools in the region of Hauts-de-France. The age of participants ranged from 3 to 12 years old. It was highly desirable for the participants to be at an early stage of development. A parental permission was obtained for every child before taking part in our experiments. Further, the parents were acquainted with the study objectives through orientation sessions.

Initially, the participants were organised based on a basic binary grouping as: i) Typically developing (TD), and ii) ASD-diagnosed. In addition, the CARS score (Schopler et al., 1980) was employed to classify the severity of autism more precisely. The CARS method has been widely applied in the Psychology practice for describing the severity of ASD symptoms (Jones, and Klin, 2013). The scale includes various ratings on different behavioural aspects (e.g., verbal communication, activity level). Table 1 gives a summary of the characteristics of participants.

3.2 Experimental Protocol

The eye-tracking experiments included a set of photos and video scenarios, which were particularly designed to stimulate the eye gaze across different parts of the screen. The participants were seated at approximately 60cm distance away from the monitor. A quiet room at the university campus was used for running our experiments. In addition, physical barriers were applied around the screen to avoid visual distractions.

Table 1: Summary of participants.

Count of Participants (TD, ASD)	59 (30, 29)
Gender (Female, Male)	21 (≈ 36%), 38 (≈ 64%)
Age (Mean, Median)	7.88, 8.1 years
CARS Score (Mean, Median)	32.97, 34.50

Figure 1: A screenshot from one of the videos used in the eye-tracking experiments.

We used a SMI Red-M eye tracker with 60 Hz sampling rate, which is a screen-based eye-tracker. The eye-tracker was operated along with a 17-inch monitor in our experiments. The screen resolution was 1280x1024.

The content and length of videos varied to allow for analysing the ocular activity from different aspects and levels. The content of photos and videos was generally aimed to include visual items (e.g., colourful balloons, cartoons), which could be attractive to children in particular. The position of items can change over the experiment timeline. In addition, other videos included human presenters. The presenter usually attempted to turn the participant's attention to elements, which could be visible or invisible around the display area. The French language was the working language in all videos and conversations, as the mother tongue of participants. Figure 1 presents a sample screenshot captured from one of the videos.

We used other stimuli provided by the SMI Experiment Center Software. The Stimuli included a variety of types, which are used in the eye-tracking research. For instance, static and dynamic naturalistic scenes with and without receptive language, static face or objects and cartoons stimuli, and other joint attention stimuli. Eye-tracking experiments usually took about 5 minutes. The participants were inspected with respect to the quality of eye contact with the presenter, and the level of focus on other elements. A five-point scheme of calibration was applied. A set of verification procedures followed the calibration scheme.

Table 2: Summary of participants.

Timestamp [ms]	Eye Movement Category	Point-Regard X [px]	Point-Regard Y [px]	Pupil Diameter-Right [mm]	Pupil Diameter-Left [mm]
8005654.069	Fixation	1033.9115	834.0902	4.3785	4.5431
8005673.953	Fixation	1030.3754	826.0894	4.4050	4.5283
8005693.85	Saccade	1027.337	826.3127	4.4273	4.6036
8005713.7	Saccade	1015.0085	849.2188	4.3514	4.5827
8005733.589	Saccade	613.7673	418.1735	4.3538	4.5399

The eye-tracking device captured three categories of eye movements including fixations, saccades, and blinks. Additionally, the POG coordinates were captured by the eye tracker. Table 2 gives a simplified view of the eye-tracking records. As an example, the table lists five eye-tracking records that represent a sequence of two fixations and three saccades. The records also give the POG coordinates for the right and left eye over time. Due to limited space, many variables had to be excluded from the table below (e.g. pupil position, pupil diameter, pupil size).

3.3 Dataset

The dataset is distributed over 25 CSV-formatted files. Each file represents the output of an eye-tracking experiment. However, a single experiment usually included multiple participants. The participant ID is clearly provided at each record at the 'Participant' column, which can be used to identify the class of participant (i.e., TD or ASD).

Furthermore, a set of metadata files is included. The main metadata file, Participants.csv, is used to describe the key characteristics of participants (e.g. gender, age, CARS). Every participant was also assigned a unique ID. Table 2 presents a couple of metadata examples. Table 3 provides some examples in this regard.

Table 3: Summary of participants.

ID	Gender	Age	CARS	Class
27	F	5.6	40	ASD
51	F	10.7	NA	TD

3.4 Ethical Approval

The study received the ethical approval by the ethics committee of Rouen University (Reference: 2016-02-B). The CNIL (Commission nationale de l'informatique et des libertés) declaration number of research conformity is 2208663v0.

The study fulfils the principles and terms of the 1964 Helsinki declaration. Before starting the study, the approval was obtained from the heads of the regional and district education authorities, as well as the head and teachers of the participating schools. The parents of participants had also given their written informed consent.

3.5 Usage Notes

The dataset is shared publicly on the Figsahre repository. The files along with metadata can be downloaded directly from the URL below.

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4 LIMITATIONS AND CONCLUSIONS

There are some limitations that should be considered as follows. First, the relatively small number of participants is one limitation of the dataset. Second, the duration of eye-tracking experiments was also relatively short (≈ 5 min). Longer scenarios could have allowed for a more exhaustive representation of the gaze behaviour.

Despite limitations, it is conceived that the dataset can be effectively utilised in the ASD research in many ways. We believe that further studies can avail of the dataset by applying data analysis or Machine Learning. For instance, predictive models could be developed to assist the diagnosis process.

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