Original Research

Introduction of a New Video-Based Eye Tracking Paradigm for Early Detection of ASD

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Recently, there is growing interest inapplying eye tracking technology to study infants and young children with Autism Spectrum Disorder (ASD). As a non-invasive and convenient measurement, it uses relatively objective parameters, which will greatly avoid the possibility of bias in traditional subjective evaluations caused by asymmetric information between patients (or parents) and examiners. As a result, it has been considered as having the greatest direct clinical potential for early screening for ASD. This study aims to introduce a new video-based eye tracking paradigm. The paradigm consists of 10 video scenarios, with each scenario targeting a different aspect of ASD in infants and children. The total paradigm lasts about 2 minutes. We believe this eye tracking paradigm may be a useful tool for early screening for ASD.

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INTRODUCTION

Autism spectrum disorder (ASD) is a group of complex neurodevelopmental disorders with a rapidly rising rate of incidence. The etiology and pathophysiology of ASD are not well understood, and there is currently no effective treatment or cure. More than 70% of individuals with ASD need lifetime care, and the Centers for Disease Control and Prevention (CDC) has called it a national healthcare crisis.

A growing body of evidence suggests early diagnosis and intervention can significantly impact the prognosis of individuals with ASD. The earlier the detection and diagnosis, the better the prognosis and functional status later in life. The current average age for diagnosis is around 4 years of age, but ASD individuals show signs as early as infancy. Development of an easily-applied early detection tool and screening test is crucial and has drawn the attention of investigators in recent years.[1]

The fourth and fifth editions of the Diagnostic and Statistical Manual of Mental Disorders and the tenth edition of the International Classification of Diseases emphasize that an early onset of symptoms is essential for core autism and other forms of ASD.[2] Nevertheless, the majority of ASD studies have been carried out on subjects past mid-childhood,[2] which have significantly impeded the development of early diagnosis and intervention methods.

Currently, the Autism Diagnostic Observation Schedule (ADOS) and the Autism Diagnostic Interview - Revised (ADI-R) are considered the 'gold standard' in diagnostic evaluations for autism, but both methods can only be performed by trained professionals, usually require a considerable waiting time for both the test and the report, are not applied on children younger than one year old, and may be subjective and variable. Overall, there is a shortage of resources for early evaluation. As a result, most children with ASD are diagnosed in later childhood. To improve this situation, easier and faster alternative methods, especially for younger children, are urgently needed.[2-3]

Generally speaking, the tools currently applied to explore ASD can be classified into two categories: subjective tools such as questionnaires, observation scales, interviews and developmental tests and objective measurements such as eye tracking and brain imaging tools, including electroencephalography (EEG), event-related potentials (ERPs), magnetoencephalography (MEG), functional and structural magnetic resonance imaging (MRI), diffusion tensor imaging (DTI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), and

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near infrared spectroscopy (NIRS). Each of these tools have pros and cons. Subjective tools are widely used in clinics and are still the predominant method for diagnosing and evaluating autism, but they are hampered by subjective bias. Although objective tools can provide objective measurements and hold great potential, their connection with clinical symptoms remains undetermined.[2-3] Also, though accumulating evidence has demonstrated that ASD is associated with brain morphometry and functional changes as compared with typically developing (TD) controls,[3-4] the high expense and complexity of data analysis and interpretation have significantly limited the application of brain imaging tools such as MRI, PET, DTI and MEG.

One objective tool that is promising and is being increasingly applied in ASD clinics is eye tracking (ET).[5] As a non-invasive and convenient measurement, it uses relatively objective parameters, which will greatly avoid the possibility of bias in traditional subjective evaluations caused by asymmetric information between patients (or parents) and examiners.

Eye tracking can measure the point of gaze (where one is looking) and the motion of the eyes relative to the head. Eye movements and pupillary motility are tightly regulated by brain circuits and indirectly reflect functional and structural changes in the brain. Thus, exploring how children use their eyes in various contexts may reflect their learning and development processes in the brain.[5] As a result, there is substantial growing interest in eye-tracking, particularly when studying infants and young children. It is considered to have the highest direct clinical potential for early screening for Autistic Spectrum Disorder.[2]

Currently, various stimulus paradigms have been developed in eye tracking studies. These paradigms have predominantly used dynamic social scenes.[3,5-9] Although these visual paradigms can distinguish ASD children from typically developing controls, they tend to be too complicated for young infants and thus are of limited use.

This manuscript aims to develop a short and simple paradigm that can be applied for infants, toddlers and children to catch early signs of ASD in eye gaze, eye following, joint attention, and emotion response. This paradigm can be used to detect early, subtle and unique cues for infants at risk to ASD. In addition, although this paradigm is designed for an Asian population (by using a Asian actress), it can be easily optimized to other populations due to its simplicity. The paradigm consists of 10 scenarios, and the total test lasts around two minutes.

Rationales for an eye tracking paradigm

Eye contact plays an important role in social interaction. Facial movements, gestures, and direction of one's gaze provide critical information about a person's intentions and emotions. Gaze direction and duration provide information about what the other person is interested in.[5,8] Thus, this paradigm includes several scenarios, including a woman talking (without sound), a woman talking presented alongside a white dot moving in a circle, a sad face next to a neutral face, a happy face next to a neutral face, and a face with the eyes looking side-to-side. In addition, we also have a photograph of an infant's face presented next to a picture of a fan.

Preferential attention to biological motion represents a basic mechanism in humans and monkeys facilitating adaptive interaction with other living beings.[10] Investigators have found that two-year-old infants with ASD fail to orient towards point light displays of biological motion, and their viewing behavior when watching these point light displays can be explained as a response to non-social, physical contingencies - physical contingencies that are different from control children.[10] Specifically, ASD children attended less to upright biological motion than did TD toddlers. The findings were further replicated by other studies.[9,11] Thus, in this paradigm, we include video of a point light display of a human walking next to an inverted version of the figure (i.e., upside-down biological motion). In addition, we also show a clipart duck moving horizontally from the left side of the screen to the right side followed by a clipart helicopter moving vertically from the top of the screen to the bottom, to further explore how children watch non-human motion.

Circumscribed interest refers to a type of repetitive behavior frequently observed in children with ASD. It is characterized by intense interest in a narrow range of subjects and by rigid organization of activities exclusively around this interest.[12] We thus also present an array of multiple items including both high-autism-interest (HAI) objects such as vehicles and computers, as well as low-autism-interest (LAI) objects such as furniture or clothing to investigate the circumscribed interest of children.

Each video will contain one or more Areas of Interest (AoI) covering the parts of the screen that may potentially be used to distinguish between ASD and TD children. We will measure the duration of the point of gaze in each AoI, as well as the duration of gaze outside any AoI. For example, in the video of the speaking woman, the woman's eyes would constitute one AoI and her mouth would constitute another, to see if the child favors looking at the eyes, the mouth, or neither. In the point light display video, we can use AoIs covering each figure to see which figure is viewed longer or more often.

Detailed description of the eye tracking paradigm

Scenario 1a (5 seconds): The video will show a woman sitting still and looking directly at the camera. One AoI will cover the eyes, and the other AoI will cover the mouth.

Scenario 1b (5 seconds): The video will be similar to Scenario 1a, but the woman will be mouthing the alphabet. One AoI will cover the eyes, and the other AoI will cover the mouth.

Scenario 2a (5 seconds): A point light display figure of a person walking upright will be shown on one side of the screen. On the other side, the same figure will be shown rotated 180 degrees, with the person appearing to walk upside down. Each figure will be an AoI.

Scenario 2b (5 seconds): This is identical to Scenario 2a, but with the positions of the figures switched (left vs. right side of the screen).

Scenario 3a (5 seconds): A video of a dot moving along a circular path will be displayed on one side of the screen, while a video of a woman mouthing the alphabet will be shown on the other side. Each video will be an AoI.

Scenario 3b (5 seconds): This will be identical to Scenario 3a, but with the positions of the videos switched.

Scenario 4 (10 seconds): A clipart duck will be shown moving horizontally from the left side of the screen to the right side. This will be followed by a clipart helicopter moving vertically from the top of the screen to the bottom. The two images will be the AoIs.

Scenario 5a (5 seconds): An image of a fan will be presented next an image of an infant's face. Each image will be an AoI.

Scenario 5b (5 seconds): This will be identical to Scenario 5a, but with the positions of the images switched.

Scenario 6 (10 seconds): An array of objects will be presented on the screen. Roughly half of the objects will be high-autism-interest (trains, planes, electronics, etc.), and the remaining objects will be low-autism-interest (clothes, furniture, food, etc.). Each object will be an AoI.

Scenario 7 (25 seconds): A woman holding a tablet will be shown on the screen. She will look directly at the viewer for a few seconds, then turn on the tablet. On the tablet, various moving, colorful shapes will be displayed. After a few seconds, she will turn off the tablet and look back at the viewer. The AoIs will cover the woman's face and the tablet.

Scenario 8a (10 seconds): An isolated face of a woman will be displayed in the center of the screen. After a few seconds of looking directly at the viewer, the woman will look to one side. The AoI will be the woman's eyes.

Scenario 8b (10 seconds): This will be similar to Scenario 8a, except that the woman will look to the other side.

Scenario 9a (5 seconds): Two videos of a woman, one with a sad face and one with a neutral face, will be presented side by side. Each face will be an AoI.

Scenario 9b (5 seconds): This will be identical to Scenario 9a, but the positions of the videos will be switched.

Scenario 10a (5 seconds): This will be identical to Scenario 9, but with a happy face and a neutral face.

Scenario 10b (5 seconds): This will be identical to Scenario 10a, but the positions of the videos will be switched.

We believe this paradigm will provide crucial information on different aspects of ASD in children, making it a useful tool for early screening. The next step would be to collect real data to test how well the paradigm can distinguish ASD children from TD children.

CONFLICT OF INTEREST

JK has a disclosure to report (holding equity in a startup company (MNT)), but declares no conflict of interest.

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AUTHOR CONTRIBUTIONS

Xuejun Kong and Jian Kong have equal contributions for conceiving the ideas, developing the protocol/paradigm and organizing the project.
Bryan K. Wang, helped to write the first draft, participated the project, searched and organized references, finished English proof reading.
Joseph Park helped the video production, technical support, editing and proof reading.

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