Eye Gaze Differences in School Scenes Between Preschool Children and Adolescents With High-Functioning Autism Spectrum Disorder and Those With Typical Development

Yuko Ishizaki (ishizaki@nisiq.net)
Kansai Ika Daigaku Fuzoku Takii Byoin
https://orcid.org/0000-0002-3695-0644

Takahiro Higuchi
Kansai Ika Daigaku

Yoshitoki Yanagimoto
Kansai Ika Daigaku

Hodaka Kobayashi
Kansai Ika Daigaku

Atsushi Noritake
national institute of natural science

Kae Nakamura
Kansai Ika Daigaku

Kazunari Kaneko
Kansai Ika Daigaku

Research

Keywords: Eye gaze behavior, High-functioning autism spectrum disorder, Classroom, Typical development, Preschool children, Adolescents

DOI: https://doi.org/10.21203/rs.3.rs-41707/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

Children with autism spectrum disorder (ASD) sometimes find it difficult to adapt to the daily life in a nursery or at school. For a better understanding on the difficulties that preschool children and adolescents with ASD face in their daily lives, this study aimed to identify the differences in eye gaze behavior in the classroom environment between children with ASD and those with typical development (TD). A total of 30 children with ASD and 49 children with TD were included. We presented images of a human face and a classroom setting and used eye tracking with an iView X system in evaluating and comparing how long the two groups gazed at specific regions of the visual stimuli. Compared to children with TD, children with ASD spent less time gazing at the eyes of the human face and the object pointed by the teacher in the school classroom scene. Preschool children with no classroom experience and adolescents with TD spent the same amount of time looking at the eyes and the object pointed by the teacher in the school classroom scene. Children with ASD did not look at the eyes in the facial image or the object pointed at in the classroom image, which might indicate their inability to analyze situations, understand instruction in a classroom, or act appropriately in a group. An educational program that focuses on joint attention in a classroom is desirable for the improvement of school life for children with ASD.

Introduction

Autism spectrum disorder (ASD) is a behavioral disorder characterized by impairments in social interaction and communication, as well as repetitive and restricted behaviors; although, intellectual development is not always delayed (American Psychiatric Association 2013). Increasing evidence suggests that patients with ASD, in contrast to persons with typical development (TD), exhibit characteristic eye gaze behavior (Kliemann et al. 2010; Klin et al. 2002; Noris et al. 2012; Nakano et al. 2010; Pierce et al. 2011; Shaffer et al. 2017; Shi et al. 2015; Shic et al. 2011), including paying attention to a person's mouth rather than his or her eyes (Klin et al. 2002; Kliemann et al. 2010), less attention to children playing (Shaffer et al. 2017) and social activities of others and more on background objects (Shic et al. 2011), and downward-looking of the fields of view (Noris et al. 2012).

In addition to faces, classroom scenes are among the most important social and visual images for children because they spend most of their time in classrooms. The classroom scene is also characterized by situations where a teacher points to objects, such as a whiteboard, and displays, requiring “joint attention” (McArthur and Adamson 2011; Jones and Carr 2004) rather than direct communication with each child. Thus, we hypothesized that the characterization of eye gaze behavior of ASD children using classroom scenes would uncover the reasons behind their difficulties at school (Higuchi et al. 2017). Therefore, we first analyzed eye gaze behavior in a school classroom scene as well as on a widely studied human face. Second, we hypothesized that the pattern of eye gaze in a classroom setting may emerge as the subjects’ nature of scene analysis rather than the experience of attending the class. If so, preschool children with ASD and those with TD who never had classroom experiences should respond differently. We, thus, compared the eye gaze behavior of children with ASD to that of children with TD in
discontinuous age groups of preschool children (age, 3–6 years) and adolescents (age, 11–15 years), but not in intermediate children aged 7–10 years (first to fourth graders).

Methods

Participants

Thirty high-functioning ASD and 49 TD Japanese subjects were tested. Participants from two discontinuous age groups were included – preschool children ages 3 to 6 years who never had any previous classroom experience and adolescents aged 11 to 15 years who had attended elementary school or junior high school. Thus, we compared the eye gaze behavior of four groups: preschool children with TD (n = 25; 7 males), preschool children with ASD (n = 12; 9 males), adolescents with TD (n = 24; 11 males), and adolescents with ASD (n = 18; 11 males). Participants with any past or present psychiatric illness and problems in eyeball movement or visual function and those who could not accomplish a ten-minute experiment were excluded. Written informed consents of all participants were obtained from their parents.

High-functioning ASD was diagnosed by specialists in the field of pediatric neurology and/or developmental pediatrics according to the following criteria: (i) autistic disorder or pervasive developmental disorder based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (American Psychiatric Association 2000); (ii) a full scale intelligence quotient (FSIQ) score of ≥70 in the Wechsler Intelligence Scale for Children, Fourth Edition, (Wechsler 2003) for children >5 years old and a developmental quotient (DQ) of ≥70 in the Kyoto Scale of Psychological Development (Koyama et al. 2009) for children less than 5 years old; and (iii) a score of ≥25.5 in the Childhood Autism Rating Scale (CARS) (Schopler et al. 1980) or a score above the cutoff value for the relevant age group in the Parent-Interview ASD Rating Scale, Text Revision (PARS-TR) (Kamio et al. 2006).

The CARS score indicates the severity of autism. Originally, scores < 30 indicated no autism and scores > 30 indicated mild-to-moderate or severe autism (Schopler et al. 1980). However, Tachimori et al. (18) recently reported that children diagnosed with Asperger’s syndrome could be distinguished from those without ASD using cutoff values of 25.5/26.0. We also used this criterion in differentiating children with ASD from children with TD. The Japanese version of the PARS-TR (Kamio et al. 2006) was administered in a semi-structured interview together with a parent or family member of the child. It evaluates both the current symptoms and the most pronounced symptoms during infancy (the peak symptoms scale). There was a significant correlation between PARS-TR scores and Autism Diagnostic Interview-Revised (ADI-R) scores, particularly between qualitative abnormalities in reciprocal social interaction in the ADI-R score and social communication in the PARS-TR score (Ito et al. 2012).

Ethical approval

The research was approved by the Ethics Committee of Kansai Medical University (No. 1100).
Experimental procedure

Experiments were conducted in a quiet, well-lit room at Kansai Medical University Medical Center. Participants were seated in front of a 48 × 30 cm monitor for the presentation of visual stimuli, and their chins were placed on a chin rest to minimize head movement. The distance between the monitor and the chin rest was 60 cm. Partitions were placed to ensure that only the monitor was within the participant’s field of vision. On the monitor, two social images—a smiling human face and a classroom scene in a high school setting (Figure 1)—were presented sequentially, once for each, with no sound. Each stimulus was shown for nine seconds followed by an intertrial interval of one second. The duration of the whole experiment was approximately ten minutes (Figure 1, row 1). The participants were instructed to freely watch the static visual images on the monitor. The eye gaze position was measured at 250 Hz using an infrared camera attached to the bottom of the monitor (iView X RED, SensoMotoric Instruments, Teltow, Germany). Eye tracking data were analyzed using a custom software written in MATLAB (Mathworks, Natick, MA, USA).

Four of 79 participants for a human face and one participant for a classroom scene could not accomplish a ten-minute experiment, hence were excluded from the following analyses.

Statistical analysis

To compare the eye gaze behavior between children with TD and children with ASD and between preschool children and adolescents, we first identified the visual areas that were regions of interest (ROIs) (Figure 1, second row). The ROIs were set as eyes and mouths for the human face and the face, finger, pointed-at object, and wall for the high school classroom. We compared the eye gaze time for each ROI using a two-way analysis of variance (ANOVA) with two factors: age (preschool children vs. adolescents) and development (ASD vs. TD). Within the nine seconds of each stimulus presentation, we measured the duration of the gaze in each ROI. Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA).

Results

Patient characteristics

The mean ± standard deviation of the developmental assessment of patients with ASD were as follows: DQ, 87.3 ± 14.5, for preschool and FSIQ, 96.0 ± 13.7, for adolescents. The mean CARS score of participants with ASD was 28.1 ± 3.6. The mean PARS-TR peak symptom score was 30.4 ± 5.4, and the mean current symptom score was 21.0 ± 9.8. These scores were higher than the cutoff values (25.5 for CARS, 9 for preschool, 13 for elementary school, and 20 for junior high school and adults for PARS) which means autism symptoms were obvious in patients with ASD.

Characteristics of eye gaze behavior
Figure 1 illustrates the representative eye gaze patterns of children with TD and ASD. For the human face stimulus (Figure 1, left column), TD children held their gaze longer on the eyes and mouth (third row), whereas, ASD children gazed longer on the points between eyes and mouth or the wall, and two participants never looked at the face (fourth row). For the classroom scene (right column), TD children gazed longer at the areas near the teacher’s face and the object pointed by the teacher. Conversely, ASD children tended to gaze longer at the location irrelevant to the class, such as the center of the screen, the pencil case on the desk, or the wall. These ASD children almost never looked at the teacher’s face or the pointed object.

Figure 2 presents the box and whisker plot of eye gaze duration on ROIs on the human face and classroom scenes between children with ASD and those with TD (Figure 2). There was a statistically significant developmental effect on the duration of the gaze (two-way ANOVA, ASD vs. TD effect) (Table 1). The duration of the gaze on the eyes of the human face image was significantly shorter among children with ASD in comparison to participants with TD (p = .005). For the classroom scene, the duration of the gaze on the object pointed by the teacher was significantly shorter in children with ASD than in those with TD (p = .010), and a similar tendency was noted for the teacher’s pointing finger (p = .091). The interaction between age and ASD versus TD effect was not significant in this result. Welch’s t-test revealed that a significant difference between TD and ASD was noted in preschool children when they saw the pointed object [t(21) = 4.83, p = .039], whereas, adolescents with TD tended to look at the pointed object longer than those with ASD [t(39) = 3.22, p = .080].

Unlike the developmental effect, there was no significant effect on age on any part of the images (two-way ANOVA, preschool children vs. adolescent effect) (Table 1). The effect of interaction between age and ASD versus TD effect was insignificant. It was noteworthy that despite the lack of classroom experience for preschool children with TD, they looked at the teacher’s face and the pointed object for the same length of time as did adolescent TD children. Moreover, it was also noteworthy that although the shortened gaze duration in ASD was evident in a smiling human face, the difference was not significant for the same face but in the classroom. Preschool children with TD gazed significantly longer at the eyes of the human face image than did preschool ASD children [t(31) = 11.70, p = .002]. No significant difference was observed between TD and ASD adolescents for the human face image [t(39) = 1.41, p = .242].

**Discussion**

Preschool children with TD looked at the eyes of the human face and the pointed object in the classroom scene longer than did adolescents with ASD. The most beneficial result of this study was that preschool children with TD, even those with no previous classroom experience, looked at the object pointed at in the classroom, which indicated that they might understand others’ intentions. This is in strong contrast to the eye gaze behavior of adolescents with ASD who had experience attending school. It is suggested that the ability of joint attention in the classroom is equipped in preschool children with TD and had no classroom experience. However, it is not acquired in adolescents with ASD.
Joint attention is an early-developing social communicative skill where two people use gestures and gaze to share attention with respect to interesting objects or events. It plays a vital role in social and language development (Jones and Carr 2004; Adamson et al. 2019). Children with ASD spent less time gazing at the eyes of the human face and at the pointed object by the teacher and spent more time gazing at irrelevant areas, such as a pencil case on a desk in the school classroom scene. This behavior is consistent with a previous report by Noris et al. (2012) where children with ASD did not understand others' intentions if the intentions were implied by eye gaze rather than language; this is because ASD children did not look toward objects that were pointed at. Therefore, it is likely that children with ASD have difficulty in understanding interpersonal communication and acting appropriately in specific situations in groups, resulting in social maladjustment.

We propose that these characteristics also apply in classroom environments, resulting in difficulty in school performance for students with ASD. If a lower school performance of children with ASD, despite high IQ, may be linked to impairment of joint attention in the classroom, then educational program focused on joint attention could improve the school life of children with ASD. In the field of education, the result of this study is useful for tuition of lecture and classroom arrangements for children with ASD. Even adolescents with ASD spent less time looking at the pointed object, which suggests that instructing them to look at the teacher's face or at what the teacher is pointing so that they can understand what others require and how they are expected to act would be beneficial and could improve their social adjustment.

This study comes with a limitation. We only described the difference in the duration of the gaze on facial features or specific objects between children with TD and those with ASD. To determine how well students understand a pointing behavior, we plan to analyze joint attention abilities in the future.

The differences in eye gaze behavior between children with ASD and those with TD suggest that eye gaze behavior analysis could be used as an objective assessment for the early diagnosis of ASD in preschoolers. Thus, this study highlights the future applicability of using eye gaze behavior as both a screening tool and educational approach for children with ASD.

Declarations

Funding: This work was supported by Japan Society for the Promotion of Science (JSPS KAKENHI 25461566) and Kansai Medical University (KMU) Research Consortium.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics approval: The research was approved by the Ethics Committee of Kansai Medical University (No. 1100).

Consent to participate: Written informed consents of all participants were obtained from the parents.
Consent for publication: Written informed consents of all participants were obtained from the parents.

Availability of data and material: The parents of the participants gave written consent.

Code availability: Not applicable.

Authors’ contribution: All authors contributed to the study conception and design. Data collection were performed by Yuko Ishizaki, Takahiro Higuchi, Yoshitoki Yanagimoto, Hodaka Kobayashi, and Atsushi Noritake. Analysis were performed by Kae Nakamura, and Kazunari Kaneko. The first draft of the manuscript was written by Yuko Ishizaki and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements: We thank Dr. Yasuko Nagao, Dr. Yuri Fuji, and Ms. Azusa Oshima for their assessment of the subjects’ development.

References

1. Adamson, L.B., Bakeman, B., Suma, K., & Robins, D.L. (2017). An Expanded View of Joint Attention: Skill, Engagement, and Language in Typical Development and Autism. *Child Development*, 90, e1-18. https://doi.org/10.1111/cdev.12973

2. American Psychiatric Association. (2000). Task Force on DSM-IV. Diagnostic and Statistical Manual of Mental Disorders: DSM-IV-TR. 4th ed. Washington, DC: American Psychiatric Association.

3. American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, DSM-5. Washington, D.C.: American Psychiatric Association.

4. Higuchi, T., Ishizaki, Y., Noritake, A., Yanagimoto, Y., Kobayashi, H., Nakamura, K., et al. (2017). Spatiotemporal characteristics of gaze of children with autism spectrum disorders while looking at classroom scenes. *PLoS One*, 12, e0175912. https://doi: 10.1371/journal.pone.0175912

5. Ito, H., Tani, I., Yukihiro, R., Adachi, J., Hara, K., Ogasawara, M., et al. (2012). Validation of an interview-based rating scale developed in Japan for pervasive developmental disorders. *Research in Autism Spectrum Disorders*, 6(4), 1265-1272. https://doi.org/10.1016/j.rasd.2012.04.002

6. Jones E.A., & Carr, E.G. (2004). Joint attention in children with autism theory and intervention. *Focus on Autism and Other Developmental Disabilities*, 19(1), 13-26. https://doi.org/10.1177/10883576040190010301

7. Kamio, Y., Yukihiro, R., Adachi, J., Ichikawa, H., Inoue, M., & Uchiyama, T. (2006). Reliability and validity of the pervasive developmental disorder (PDD)—Autism Society Japan Rating Scale (PARS): a behavior checklist for adolescents and adults with PDDs. *Seishin-Igaku*, 48(5), 495-505.

8. Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59 (9), 809-816. https://doi:10.1001/archpsyc.59.9.809
9. Kliemann, D., Dziobek, I., Hatri, A., Steimke, R., & Heekeren, H.R. (2010). Atypical reflexive gaze patterns on emotional faces in autism spectrum disorders. *The Journal of Neuroscience*, 30 (37), 12281-12287. https://doi: 10.1523/JNEUROSCI.0688-10.2010

10. Koyama, T., Osada, H., Tsujii, H., & Kurita, H. (2009). Utility of the Kyoto Scale of Psychological Development in cognitive assessment of children with pervasive developmental disorders. *Psychiatry and Clinical Neuroscience*, 63(2), 241-243. https://doi:10.1111/j.1440-1819.2009.01931.x

11. McArthur, D., & Adamson, L.B. (1996). Joint attention in preverbal children: Autism and developmental language disorder. *Journal of Autism and Developmental Disorders*, 26 (5), 481-496. https://doi.org/10.1007/BF02172271

12. Nakano, T., Tanaka, K., Endo, Y., Yamane, Y., Yamamoto, T., Nakano, Y., et al. (2010). Atypical gaze patterns in children and adults with autism spectrum disorders dissociated from developmental changes in gaze behaviour. *Proceedings of the Royal Society B: Biological Sciences*, 277 (1696), 2935-2943. https://doi: 10.1098/rspb.2010.0587

13. Noris, B., Nadel, J., Barker, M., Hadjikhani, N., & Billard, A. (2012). Investigating gaze of children with ASD in naturalistic settings. *PLoS One*, 7(9): e44144. https://doi: 10.1371/journal.pone.0044144.

14. Pierce, K., Conant, D., Hazin, R., Stoner, R., & Desmond, J. (2011). Preference for geometric patterns early in life as a risk factor for autism. *Archives of General Psychiatry*, 68 (1), 101-109. https://doi: 10.1001/archgenpsychiatry.2010.113.

15. Schopler, E., Reichler, R.J., DeVellis, R.F., & Daly, K. (1980). Toward objective classification of childhood autism: Childhood Autism Rating Scale (CARS). *Journal of Autism and Developmental Disorders*, 10 (1), 91-103. https://doi.org/10.1007/BF02408436

16. Shaffer, R.C., Pedapati, E.V., Shic, F., Gaietto, K., Bowers, K., Wink, L.K., et al. (2017). Brief Report: Diminished Gaze Preference for Dynamic Social Interaction Scenes in Youth with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 47 (2), 506-513. https://doi: 10.1007/s10803-016-2975-2.

17. Shi, L., Zhou, Y., Ou, J., Gong, J., Wang, S., Cui, X., et al. (2015). Different visual preference patterns in response to simple and complex dynamic social stimuli in preschool-aged children with autism spectrum disorders. *PLoS One*, 10: e0122280. https://doi: 10.1371/journal.pone.0122280.

18. Shic, F., Bradshaw, J., Klin, A., Scassellati, B., & Chawarska, K. (2011). Limited activity monitoring in toddlers with autism spectrum disorders. *Brain Research*, 1380, 246-254. https://doi: 10.1016/j.brainres.2010.11.074.

19. Wechsler, D. Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV). (2003). San Antonio, TX: The Psychological Corporation. https://doi.org/10.1007/978-0-387-79061-9_3066

20. Tachimori, H., Osada, H., & Kurita, H. (2003). Childhood Autism Rating Scale-Tokyo Version for screening pervasive developmental disorders. *Psychiatry and Clinical Neuroscience*, 57 (1), 113-118. https://doi: 10.1046/j.1440-1819.2003.01087.x

Tables
Table 1. Comparison of gaze duration on facial features and objects between children with ASD and those with TD

|                      | A smiling human face | A classroom scene in a high school |
|----------------------|-----------------------|-----------------------------------|
|                      | Eyes                  | Mouth                             | Face                  | Finger               | Pointed-at object |
| Preschool Children   |                       |                                   |                      |                      |                     |
| TD (n = 24)          | 1.18 ± 0.14           | 0.53 ± 0.10                       | 1.06 ± 0.19           | 0.16 ± 0.05          | 1.00 ± 0.13        |
| ASD (n = 10)         | 0.44 ± 0.21           | 0.31 ± 0.16                       | 0.78 ± 0.29           | 0.11 ± 0.06          | 0.55 ± 0.20        |
| Adolescents          |                       |                                   |                      |                      |                     |
| TD (n = 23)          | 0.92 ± 0.14           | 0.39 ± 0.10                       | 0.70 ± 0.20           | 0.21 ± 0.04          | 0.97 ± 0.14        |
| ASD (n = 18)         | 0.71 ± 0.16           | 0.31 ± 0.12                       | 1.01 ± 0.23           | 0.10 ± 0.05          | 0.58 ± 0.16        |

Two-way ANOVA

|                      | F (1, 71) = 8.43      | F (1, 71) = 1.54                  | F (1, 74) = .004       | F (1, 74) = 2.93      | F (1, 74) = 7.07   |
|                      | p = .005              | p = .218                          | p = .952               | p = .091              | p = .010           |

Welch’s t test

|                      | t (31) = 11.7         | t (21) = 4.83                     |
|                      | p = .002              | p = .039                          |

|                      | t (39) = 1.41         | t (39) = 3.22                     |
|                      | p = .242              | p = .080                          |

|                      | F (1, 71) = .002      | F (1, 71) = .275                  | F (1, 74) = .080       | F (1, 74) = .139      | F (1, 74) = .000   |
|                      | p = .961              | p = .602                          | p = .777               | p = .710              | p = .988           |

Data are presented as mean ± standard deviation of the number of seconds

TD denotes typical development
ASD denotes autistic spectrum disorder

Figures
Figure 1

Visual stimuli and ROIs. Row 1, original stimuli; row 2, original stimuli with visual areas as ROIs; row 3 and 4, representative gaze patterns of children with TD (row 3) and ASD (row 4) shown as heat maps.
Figure 2

Visual stimuli and box-and-whisker plot of gaze duration on ROIs on the human face and classroom scenes between children with ASD and those with TD. ASD-Y, preschool children with ASD (n = 10); TD-Y, preschool children with TD (n = 24); ASD-O, adolescents with ASD (n = 18); TD-O, adolescents with ASD (n = 23).