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Comparing Face Recognition and Visual Scanning Skills in Children With and Without Autism Using Eye-Tracking*

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Abstract

This study aimed to compare the visual scanning skills of children diagnosed with autism spectrum disorder (ASD) and typically developing children using eye tracking systems. The study group consisted of 37 children with ASD and 41 typically developing children aged between 3 and 10 years, who met the basic selection criteria of the study. The research applications were carried out at the Human-Computer Interaction Laboratory of the Middle East Technical University. A set of visual materials on visual scanning and recall features were prepared to compare the visual scanning skills of children with ASD and typically developing children. As a result of the statistical analysis of the data obtained from the participant children through the eye-tracking device, it was determined that children with ASD exhibited unusual visual scanning and recall characteristics that were different from those of children with typical development. Children with ASD focus their visual attention on familiar faces and objects, whereas children with typical development focus their visual attention on novel (unfamiliar) faces and objects. Based on this result, it was suggested that in educational materials to be prepared for children with ASD, human faces and stimuli with which they have developed familiarity should be preferred, taking into account the visual focus of attention. Another striking result of this study was that children with ASD tended to focus more on the stimuli (objects) when the human face and the stimuli were presented together.

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INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by marked social-communicative deficits, repetitive behaviors, and limited interest (American Psychiatric Association, 2013; Mundy & Burnette, 2005). Children with ASD exhibit intense problems in social skills such as making eye contact, initiating and maintaining verbal and non-verbal social interaction, understanding others' intentions and feelings, and adapting to changes (Charman, 2004). Children with ASD are known to exhibit an intense focus on specific sensory stimuli—such as bright lights, repetitive sounds, or moving visual patterns—that align with their individual perceptual preferences and sensitivities in daily life and natural environments (Ceyhun, 2015; Ceyhun, 2023). However, some studies have identified atypical characteristics of children with ASD. Some studies suggest that children with ASD exhibit limited performance in face scanning and recognition and differ from children with normal development in face processing skills (Boucher & Lewis, 1992; Ceyhun & Özdemir, 2014; Chawarska et al., 2007; Chawarska & Volkmar, 2007; Joseph & Tanaka, 2003; Klin et al., 1999; Özdemir et al., 2017). In particular, the different patterns exhibited by individuals with ASD in looking at their faces and eyes are quite remarkable and have been the subject of research in recent years. Face processing skills are known as face scanning and face identification skills for moving, talking people or object images, static people or object images and require visual attention and visual perception skills (Chawarska et al., 2007; Chawarska et al., 2012). In typically developing (TD) infants, the process of face recognition begins at birth (Bedford et al., 2012) and continues with the development of joint attention skills, which become evident at the end of the first year and develop in the 6th and 9th months. After the age of two, TD children can recognize the faces of many people (Pascalis, de Haan, & Nelson, 2002). It has been suggested that children with ASD have limitations in scanning key features of the face during face processing and simple face recognition performance, and that these limitations can be recognized in the first years of life (Chawarska & Shic, 2009; Chawarska & Volkmar, 2007). In fact, when family videos of children who were later diagnosed with autism (regressive autism) were examined retrospectively, atypical social behaviors such as lack of eye contact and lack or absence of mutual gaze were observed in children with ASD (Golarai, Grill-Spector, & Reiss, 2006).

There are different perspectives on the origin of face processing disorders in individuals with ASD: Specific to ASD, the face is not a focal point to which attention is directed and sustained; problems encoding information from the eyes, lack of perception of cues to recognize and process the face; There are opinions that the act of speaking on the face and establishing eye contact does not attract sufficient attention in children with ASD; that these individuals may avoid face-to-face interaction even when an appropriate social environment and interaction partners are present—possibly due to reduced social motivation or atypical processing of social stimuli, rather than merely a lack of experience (Bradshaw et al., 2011; Dawson et al., 2002; Klin et al., 2003; Noris et al., 2012; Schultz, 2005). Delays in face processing skills during the early stages of development can negatively affect other areas of development, particularly social and cognitive development (Pascalis et al., 2002). Visual attention to people, situations and stimuli and eye tracking skills are important components in the development of social and cognitive skills, and limitations in these skills can lead to serious problems in other developmental areas (Shic et al., 2011). Children with ASD spend more time looking at, focusing on, and following facial expressions than typically developing children do (Chawarska et al., 2011; Chawarska & Shic, 2007; Chawarska & Shic, 2009; Chawarska & Volkmar, 2007). In addition, facial processing problems negatively affect the perception of facial expressions (Gross, 2004; Pelphrey et al. 2002). In ASD, limitations in recognizing and understanding information related to social interactions from human faces begin to be observed at an early age (Chawarska et al., 2010). Individuals with ASD have problems in preferring human faces over other stimuli, limitations in receiving emotion-related cues from faces in non-obvious situations, problems in forming joint attention by watching people's gaze, using unusual face scanning strategies, and face processing disorders leading to problems in social interaction (Chawarska et al., 2010). Understanding the source of these social interaction problems that individuals with ASD exhibit in understanding social and emotional cues from human faces and determining the differences in the strategies used are the subject of studies aimed at better understanding the mechanism underlying social inadequacy and research on early intervention practices (Jones et al., 2008; Rutherford & Towns, 2008). A review of the literature reveals that the concepts of 'visual scanning, ’ 'face processing, and 'ye-tracking skills are used interchangeably. While face processing skills focus on the face and facial regions, visual scanning skills focus on the entire stimuli presented, including the facial region. Eye tracking skills refer to the ability to follow presented stimuli with eye movements. Determining the face processing, eye tracking, and visual scanning skills of individuals with ASD and identifying their differences from individuals with typical development is important for studies in many developmental areas, such as social interaction, language, and cognitive development. It is also stated that these studies can shed light on understanding the core characteristics of ASD—such as difficulties in social communication and restricted, repetitive behaviors—as well as how these characteristics emerge and evolve over time during early childhood development (Ceyhun, 2015; Ceyhun, 2023). Thus, it provides important clues for recognizing and following individuals with ASD risk in the earliest period (Ceyhun, 2015; Ceyhun, 2023). Thus, it provides important clues for recognizing and following individuals with ASD risk in the earliest period (Ceyhun, 2015; Ceyhun, 2023).

Recent literature shows that one of the prominent research topics in the field of autism spectrum disorder is the investigation of how individuals with ASD process faces, establish eye contact, and visually scan their environment. In addition to ongoing genetic finding-based or neurological research in individuals with ASD, the measurement of social behaviors of individuals with ASD, which are among the behavioral symptoms of autism, has been a research area that has been emphasized in recent years. In the literature, it has been observed that there is a tendency towards research to determine the level and predisposition of individuals at risk of ASD to perceive social cues, such as eye contact, following other people's gaze, joint attention, and communicative and emotional gestures (Bradshaw et al., 2011; Chawarska & Shic, 2009; Chawarska & Volkmar, 2007; Dawson et al., 2004; Jones, Carr, & Klin, 2008; Rutherford & Towns, 2008; Webb et al., 2010).

The use of eye-tracking technologies, which is a preferred method in many visibility activities such as psychology, market research, media, and advertising, to identify the areas and regions where the target audience concentrates its attention, and to understand the nature of the developmental course of individuals with ASD has attracted the attention of experts in the field in recent years. Research shows that eye-tracking technologies are an effective method for identifying and measuring where individuals focus their attention in complex social situations (Klin et al., 2002). Understanding the attentional patterns of children with ASD through such technologies is especially important, as it provides insights into their social attention deficits, helps differentiate them from typically developing peers, and informs the development of early intervention strategies targeting social and communication skills. The fact that eye-tracking technologies can directly measure visual and social attention (Klin et al., 2002) and the widespread use of this technological application and the ease of access to eye-tracking systems (Sasson & Elison, 2012) have increased the number of eye-tracking studies. Despite the growing literature on face processing, there is limited research examining how familiarity with stimuli influences the visual scanning of children with ASD using eye-tracking in naturalistic contexts. From this perspective, this research is based on the understanding and measurement of visual scanning and face recognition features of children with ASD using eye-tracking technologies. This study aimed to compare the visual scanning skills of children diagnosed with ASD and typically developing (TD) children between the ages of 3-10 years using eye tracking systems. For this purpose, we sought to answer the following question: Do eye-tracking findings differ in the visual scanning skills of children with ASD and typically developing children in terms of visual scanning and recall characteristics?

METHOD

RESEARCH DESIGN

Quantitative research methods were used in this study. This study is a correlational survey model since it examines the visual scanning skills of children diagnosed with ASD and typically developing children through eye-tracking systems. Survey models aim to describe past or present situations as they exist. According to Karasar (2012), the relational survey model aims to determine the existing change between two or more variables and/or the degree of this change, which are interpreted in the context of predicting the other if the situation in one variable is known, rather than a cause-and-effect relationship. There are two types of relational survey model: correlation and comparison. In the comparison type of correlational survey, we examined whether there was differentiation between at least two variables (Karasar, 2012).

STUDY GROUP

Descriptive characteristics of the study groups are presented in Table 1**.**

Table 1. *Descriptive Characteristics of the Study Group*

TD (Age)	*TD*	*TD Total Age (%)*	*TD Min-Max looking at screen (%)*	*TD looking at the screen (%)*	*ASD (Age)*	*ASD*	*ASD Total. Age (%)*	*ASD Min-Max looking at screen (%)*	*ASD looking at screen (%)*
3	7	17.0%	50-71	63.2%	3	6	16.2%	10-19	13.3%
4	5	12.2%	67-77	73.4%	4	6	16.2%	22-31	25.0%
5	4	9,7%	61-84	78,0%	5	5	13.5%	27-38	33.6%
6	3	7.3%	75-82	78,6%	6	3	8,1%	41-43	41.6%
7	4	9,7%	76-90	83.0%	7	6	16.2%	40-46	43.6%
8	6	14.6%	75-91	82.6%	8	4	10,8%	46-57	50,7%
9	7	17.0%	87-95	90,8%	9	3	8,1%	48-56	51.6%
10	5	12.2%	90-97	94.2%	10	4	10,8%	46-72	56.2%
Total	41		50-97	80,3%		37		10-72	36.9%

The study group consisted of 78 children residing in Ankara, 37 children between the ages of 3 and 10 years who were diagnosed with ASD and 41 children with typical development (TD). The main selection criteria for children with ASD included in the study group were that they were diagnosed with ASD according to the DSM-V diagnostic criteria, had no additional disability or visual defect, participated in any activity for at least 10 min, and had no problem behaviors or sensory sensitivity that would affect the research process. In children with TD, the inclusion criterion was the absence of any suspicion of disability or visual defects, in accordance with the parental report. Parents of the children in both groups consented to participate in the study.

When the descriptive characteristics of the study group are analyzed in Table 1, it is seen that there were a total of 29 girls in the study group, including 6 girls diagnosed with ASD and 23 girls with typical development, while there were a total of 49 boys in the study group, including 31 boys diagnosed with ASD and 18 boys with typical development. In addition, the percentages of looking at the screen on the eye-tracking device of the children participating in the study were 80.3% in TD children and 36.9% in children with ASD. While the minimum and maximum percentages of looking at the screen were between 10-72% in children diagnosed with ASD, the percentages were between 50-97% in TD children.

DATA COLLECTION TOOLS

*Participant Information Form***:** This contains information about the participating children (chronological age, developmental history, regressive autism, gender, birth order, birth order, health status, etc.) developed by the researcher to record personal information about the research participants and to determine the basic selection criteria for forming the study group.

*Gilliam Autistic Disorder Rating Scale-2-Turkish Version (GOBDÖ-2-TV)***:** It is a rating scale that aims to assess individuals between the ages of 3-23 who exhibit behaviors characteristic of autism spectrum disorder.GOBDÖ-2-TV; 1) identifying and diagnosing individuals with ASD; 2) assessing severe behavioral problems; 3) determining/evaluating behavioral progress; 4) determining goals for Individualized Education Plan (IEP), and 5) it can be used to collect data for scientific research GOBDÖ-2-TV (Gilliam Autism Rating Scale-2 - Turkish Version) is a standardized scale adapted to Turkish by Diken, Ardıç and Diken (2012). It is designed to help identify individuals with autism spectrum disorder by evaluating behavioral characteristics in areas such as communication, social interaction, and stereotyped behaviors. The scale has been reported to have high reliability and validity in Turkish samples. In this study, as a result of the application of the GOBDÖ-2-TV scale, the mean subscale standard scores (X = 13.4), range values (Xmin-Xmax = 10-17; ss = 1.9), autistic disorder index value (X = 118.7; ss = 9.7), and range values (Xmin-Xmax = 103-138) achieved in children with ASD. According to the data on the subscale standard scores and ASD index values of the scale, it was determined that the probability of ASD was quite high in all children with ASD in the study group, in line with the decision guide of the scale.

*Eye Tracking Device and Software***:** Eye tracking is a method that provides data on where, how long, and how often a person looks at visual stimuli, offering insights into attention, perception, and cognitive processes. It is implemented using an eye-tracking device that detects the pupil via infrared technology and tracks gaze direction and duration. This allows for the creation of heat maps, gaze paths, and statistical reports on visual attention. In this study, eye movements of children with ASD and typically developing peers were recorded using a Tobii T120 eye tracker (17-inch screen, 60 Hz) and analyzed with the Tobii Studio 3.3 software. This program converts infrared reflections into visual and numerical data and enables detailed analysis of variables such as fixation frequency and duration. The system uses pupil/corneal reflection techniques, and gaze direction is calculated based on the relative position of these reflections. Tobii Studio also allows synchronized recording of screen images, participant views, and gaze patterns during the task.

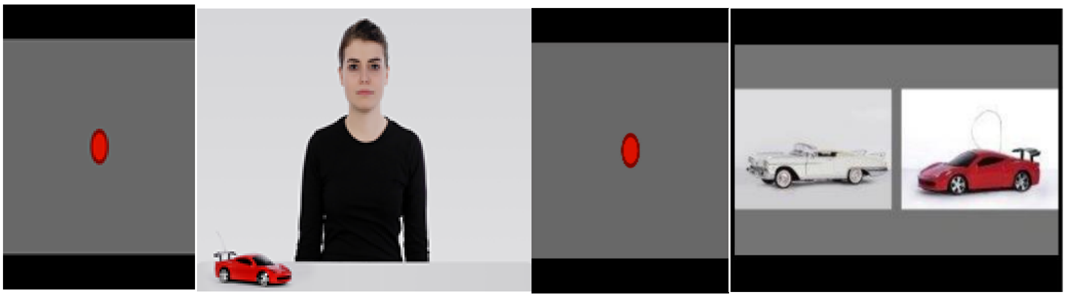
RESEARCH ENVIRONMENT

The pilot and main implementation process of this research was conducted at the Middle East Technical University Human and Computer Interaction Research and Application Laboratory. The laboratory has two rooms, an outer room and an inner room, separated by an observation mirror. The outer room was organized for the researcher to follow the implementation process and for parents to watch their children, while the other room, the inner room, was the practice environment. In this room, there is a Tobii eye-tracking device for collecting eye-tracking data, as well as a table and chair. The windows were covered with dark blinds and the walls were covered with black Styrofoam, which prevented light reflection and sound permeability. The room was illuminated to ensure precise measurements during the eye-tracking process, and there were no stimuli that could distract the participants. The laboratory has one eye-tracking device (Tobii T120) that provides information about where, how long, and how many times the user looks at the screen during the test and records eye movements. The computer to which the user will perform the test, to which this device is connected, was also connected to another computer in the observer room that recorded the user's screen image. There is a control unit that controls the 360° rotating cameras connected to a monitor that shows the screen images of the user and observer computers, together with the images taken by the two cameras. There are two moving cameras in the test room, one showing the user's face and the other showing the keyboard usage.

MATERIALS

In addition to the Tobii T120 eye-tracking device and software program, a visual material set was used to determine the differential effects of visual scanning skills of children with ASD and typically developing children in terms of visual scanning performance. This set of materials was prepared by the researcher to determine visual scanning features, such as focusing on familiar and unfamiliar human faces, familiar and unfamiliar stimuli, stimulus and face recognition, and recall/novelty preference. The Face Scanning and Recognition Set was presented with a flow fiction consisting of nine photographs and three sets. First, a picture with a model (face) and an object (target face-target object) is presented on the screen. After a 10-second examination (familiarity development) phase, a blank gray screen was presented on the screen for 5 s, and a red dot image was presented on the blank gray screen for 1 s, which is called the re-centering stimulus. In the next stage of editing, the face in the first picture (target face) and another similar model (face) were displayed on the screen for 5 s. Likewise, the object in the first picture (target object) and a pair of pictures with another similar object appeared on the screen for 5 s for recognition and examination. In this set of materials, four different models and four different object pictures are used to prevent the development of familiarity. The objects in each set had similar characteristics (e.g., red and white cars). Likewise, the appearance characteristics of the models for each set, such as hair color, eye color, facial expression, and clothing, were similar to each other. In addition, in the presentation of each set, we tried to ensure internal validity by changing the position (right-left) of the pictures and objects of the old and new faces. In addition, the order in which the models and objects appeared on the screen was also changed in each set to affect the recall. This set of materials remained on the screen for 108 seconds in total. An example of the static picture recognition setup is shown in Figure 1.

Figure 1. *Example of Static Pictures Recognition Material Set Setup (Set I)*



Two expert panels consisting of experts (special education specialists, visual communication specialists, psychologists, and graphic designers) were organized to evaluate the suitability of this visual material for research purposes. During the expert panel, the suitability of the visual material prepared for the purpose of the research was evaluated using an expert opinion evaluation form based on a 3-point Likert scale. Some pictures were modified in line with the opinions of the expert panelists. Suitable photographs were rearranged by a graphic designer, taking into account the elements of color, light, distance proximity, and brightness. To prevent the queue effect in the examination of the visual materials used in the study, they were randomly uploaded to the Tobii Studio program in a mixed order. In accordance with the purpose of the research, nine photographs were used in three sets.

Data Collection Period: In the process of collecting eye-tracking data, each participant child was tested individually in an inner room at the Middle East Technical University Human and Computer Interaction Research and Application Laboratory. The researcher managed the implementation process for each child in the study group. The child was seated in a comfortable chair 50-80 cm away from the computer screen at a 25° angle to the screen. Before the visual materials were shown, to ensure that the children focused on the screen, verification trials called calibration, which requires tracking five consecutive dots on the screen with eye movements, were performed by the software to ensure that the focus on the screen was achieved with a high level of accuracy. To perform the calibration process, children were asked to look at the computer and follow the dots appearing in five different regions of the computer screen with their eyes. After the children looked at the five points appropriately and reliable calibration data were obtained, the application was initiated. Before the application, it was explained to the children that they would watch a short (20 s) animated cartoon that they would have fun. At the beginning of the intervention, all children in the study group were given the instruction "You are watching the screen with all your attention without taking your eyes off the screen.” When the children were distracted or took their eyes away from the screen, the instruction was repeated, and the instruction to look at the screen was given to ensure that all the children directed their attention to the screen. For children aged 3-4 years of age, the researcher modeled the appropriate way to look at the screen to ensure that they fulfilled the verbal instructions correctly. The experimental process was completed by placing the child in the room where the application was performed, sitting in the appropriate position, explaining the application, performing the calibration process, and showing the visual materials.

Conducting the Pilot Application: After determining the participant group and finalizing the materials in line with expert opinions, a pilot study was conducted to test the applicability of the research. In this context, a total of 12 children, 6 children with typical development, and 6 children diagnosed with autism participated in the pilot study. In line with the pilot study, distracting stimuli were controlled in a laboratory environment. For example, it was observed that children were distracted when they saw their own reflections in the observation mirror, which divided the laboratory into two separate sections. To prevent this, the observation mirror was covered with a black curtain and distracting stimuli, such as an air conditioner button. It was observed that the children were hesitant to enter the laboratory environment because the walls and windows were blacked out for sensitive eye tracking in the laboratory environment. When the actual implementation of the research was carried out, the corridor where the laboratory was located and the outer door of the laboratory were decorated with balloons to eliminate this situation and to encourage the children. In addition, it was observed that some of the young children did not want to be separated from their mothers during the pilot implementation; therefore, in the main implementation, the environment was organized to ensure that their mothers were close to their children during the laboratory practices so that the children felt safe. During the implementation, reinforcers were given to the children to help them fulfill the instructions given. Conducting the Main Implementation: In the main intervention, typically developing children and children with ASD in the study group participated on separate days. Each child in the study group participated individually in the study. The families of the children selected for the study were given detailed information about the implementation process of the study. During the implementation process of the study, families were told that they could accompany their children if they wished to do so, and it was ensured that the child felt comfortable and safe, especially with the participation of the parents of young children. Eye tracking calibration of the children was performed at the beginning of the research. After it was determined that all children's eye calibrations were at the appropriate level for eye tracking, they were shown images in line with the research objectives. During the implementation process of the study, the research applications could not be conducted with two children who had physiological problems with eye calibration. During the implementation process, children who moved their eyes away from the screen to avoid losing their eye movements were warned and their attention was directed to the screen. Therefore, an experimental environment was created in which the researcher could supervise the experimental process during the implementation.

VALIDITY AND RELIABILITY

To control for factors that might threaten the validity and reliability of the study, the experimental process was carried out in a standardized manner with each child in the study group. To prevent the order effect when each of the visual materials used in the study was examined by the children in the study group, the visual materials were shown randomly in a mixed order. Thus, we tried to control for the effect of the order in which the visual materials used in the study appeared on the screen on the duration of focusing on the visual material. Additionally, expert panels were organized to ensure the reliability of the visual material sets used in the study, and expert opinions were obtained. The material sets were scored to ensure interobserver reliability. Inter-observer reliability data were obtained using the formula "Agreement / (Agreement + Disagreement) X 100" (Kırcaali-İftar & Tekin, 1997). The photo sets with a consensus above 80% were re-examined by two coders. At this stage, the visual material sets with the highest score among the photo sets were determined with an 86% consensus among the observers.

DATA ANALYSIS

To obtain eye-tracking data of the children in the study group regarding the visual materials, the visual materials of the study were categorized into areas of interest. Areas of interest were determined in accordance with the characteristics to be measured in the study and the regions in which visual attention was distributed. While determining the areas of interest in each visual field, care was taken to ensure that the areas did not overlap. Thus, each gaze of the children was measured in only one region, and there were no intersection points between the regions. The Tobii Studio 3.3. computer program used in the study was used to analyze the eye-tracking variables of all stimuli in the visual material set after data entry according to the codes specified in the user manual. In the analysis of quantitative data in the study, the Mann-Whitney U rank difference test was used to compare the looking/focusing tendencies of typically developing children and children with ASD in different regions. This statistical test is used to test the significance of the difference between groups in terms of the characteristics intended to be measured when the data are not normally distributed; therefore, parametric statistics cannot be used. Since the data collected within the scope of the research did not show a normal distribution, and the percentage of missing data was high, this analysis was used for inter-group comparison.

Dependent Variables of the Study: Areas of interest are the visual materials used in the eye-tracking data analysis process. Areas of interest (AOI), which were determined in accordance with the characteristics to be measured in each sub-objective of the study and the regions where visual attention was distributed, were also included in the eye-tracking data in the study, time to first fixation, total fixation duration, and total visit duration. To explain these data, a) time to first fixation: this value indicates the time elapsed before the participants' first gaze fixation within the Area of Interest (AOI) or AOI group. b) Total fixation duration refers to the total duration of each gaze fixation within an Area of Interest (AOI) or the AOI group. c) Total visit duration (total visit duration); indicates the total duration of navigation to each area of interest (AOI /Area of interest) in the gaze focusing performed by the participants within the AOI or AOI group.

RESULTS

For the purpose of this study, time-to-first fixation, total fixation duration, and total visit duration values were analyzed in the Face Scanning and Recognition visual material sets presented to typically developing children and children with ASD. The Mann-Whitney U rank difference test was used to compare the looking/focusing tendencies of typically developing children (TD) and children with ASD in different regions.

TIME TO FIRST FIXATION FINDINGS IN A STATIC FACE SCANNING AND RECOGNITION SET

The results of the Mann–Whitney U analysis examining the time to first fixation measurements in the eye-tracking data reflecting the visual scanning and recall features of the photographs in the static picture recognition sets of the children participating in the study are given in Table 2.

Table 2. *Time To First Fixation Measurements in Static Image Recognition Sets*

		TD						ASD						p
	Area	n	$\bar{X}$	Med	SS	Max	Min	n	$\bar{X}$	Med	SS	Max	Min	
I.SET	Old Object	14	18.11	17.96	0.68	19.49	17.42	9	18.11	17.72	0.73	19.58	17.42	.95
	Old Face	13	22.85	22.82	0.44	23.59	22.36	8	22.99	22.49	1.35	26.29	22.36	.47
	Target Face	13	1.46	1.42	0.1	1.75	1.42	8	3.43	1.49	3.24	8.66	1.42	.06
	Target Object	12	1.85	1.62	0.64	3.52	1.27	9	2.84	1.63	1.58	7.39	1.28	**.04***
	New Face	14	17.57	17.42	0.37	18.82	17.42	8	17.93	17.54	1.01	20.37	17.42	.23
	New Object	12	22.5	22.3	0.25	23.03	22.36	9	23.05	22.54	1.45	26.87	22.36	.23
II.SET	Old Face	13	17.8	17.7	0.47	18.9	17.2	8	18.0	17.6	1.24	20.9	17.2	.59
	Old Object	14	22.5	22.5	0.6	24.3	22.0	7	23.0	22.7	1.08	25.2	22.0	.33
	Target Face	13	1.16	1.14	0.04	1.29	1.14	8	2.35	1.14	2.58	8.44	1.14	.17
	Target Object	12	1.72	1.63	0.28	2.15	1.3	7	2.06	1.64	0.9	3.52	1.23	.80
	New Face	12	17.5	17.3	0.37	18.2	17.2	7	18.0	17.4	1.55	21.5	17.2	.50
	New Object	13	22.2	22.0	0.28	22.7	22.0	8	22.3	22.4	0.33	23.0	22.0	.59
III.SET	Old Face	13	22.4	22.0	0.46	23.2	22.0	6	22.6	22.0	1.23	25.1	22.0	.70
	Old Object	14	17.7	17.3	1.23	21.9	17.0	8	17.8	17.3	1.13	20.6	17.2	.89
	Target Face	14	1.73	1.05	2.37	9.96	1.05	8	1.06	1.05	0.04	1.15	1.05	**.03***
	Target Object	9	2.75	1.97	1.76	6.09	1.33	9	2.58	1.49	1.7	6.09	1.43	.83
	New Face	13	22.2	22.4	0.34	23.1	22.0	8	22.7	22.6	0.47	23.6	22.0	.07
	New Object	13	17.6	17.3	0.61	19.1	17.0	8	18.2	17.7	1.36	21.4	17.2	.19

*$p < .05$

When the time to first fixation findings of Set I were analyzed (Table 2), there was a significant difference between children with typical development (n = 12, X < B-> = 1.85, SD = .64) and children with ASD (n = 9, X < B-> = 2.84, SD = 1.58) for the Target Object region (p = .04). In children with ASD, the mean focus on eye tracking in this region was higher.

When the time to the first fixation findings of Set II in Table 2 were analyzed, there was no significant difference between children with typical development and children with ASD.

When the time to first fixation findings of Set III were analyzed (Table 2), there was a significant difference between children with typical development (n = 14, X < B-> = 1.73, SD = 2.37) and children with ASD (n = 8, X < B-> = 1.06, SD = 0.04) for the Target Face region (p = .03). In children with typical development, the mean focus on eye-tracking in this region was higher.

TOTAL FIXATION DURATION FINDINGS IN THE STATIC FACE SCANNING AND RECOGNITION SET

The results of the Mann–Whitney U analysis examining the total fixation duration measurements in the eye-tracking data reflecting the visual scanning and recall features of the photographs in the static picture recognition sets of the children participating in the study are given in Table 3. The source of significant differences in the analysis results is explained.

Table 3. *Total Fixation Duration Measurements in Static Image Recognition Sets*

		TD						*ASD*						*p*
	Area	*n*	$\bar{X}$	*Med*	*SS*	*Max*	*Min*	*n*	$\bar{X}$	*Med*	*SS*	*Max*	*Min*	
I.SET	Old Object	14	1.57	1.63	0.59	2.66	0.25	9	1.32	1.45	0.93	2.7	0.1	.80
	Old Face	13	1.61	1.51	0.75	3.4	0.3	8	1.36	1.32	0.58	2.05	0.27	.32
	Target Face	13	5.1	5.34	2.56	9.18	1.1	8	3.17	2.9	1.92	5.83	0.98	**.04***
	Target Object	12	2.09	1.58	1.5	5.15	0.07	9	2.67	1.83	2.19	7.35	0.43	.64
	New Face	14	2.24	2.33	0.91	3.9	0.54	8	2	2.08	1.1	3.76	0.43	.50
	New Object	12	1.84	1.98	0.73	2.54	0.48	9	1.74	1.93	1.01	2.97	0.06	.94
II.SET	Old Face	13	1.67	1.63	0.66	3.1	0.63	8	1.95	0.8	0.64	2.3	0.12	**.01***
	Old Object	14	1.66	1.64	0.94	3.71	0.18	7	1.27	1.08	0.71	2.51	0.5	.39
	Target Face	13	5.21	6.14	2.62	8.19	0.94	8	2.88	2.62	2.46	7.51	0.09	.09
	Target Object	12	1.83	1.79	1.02	4.31	0.73	7	2.58	2.7	0.73	3.5	1.7	.11
	New Face	12	1.67	1.71	0.91	2.95	0.06	7	1.47	1.07	1.09	3	0.1	.67
	New Object	13	2.44	2.32	0.92	4.22	1.07	8	2.28	2.43	0.97	3.62	0.63	.47
III.SET	Old Face	13	1.03	0.98	0.52	2.1	0.3	6	1.32	0.96	0.99	2.67	0.18	.87
	Old Object	14	2.08	2.25	0.83	3.05	0.09	8	2.16	2.56	1.18	3.1	0.13	**.02***
	Target Face	14	5.59	5.99	3.17	9.67	0.23	8	3.11	2.61	2.74	8.48	0.41	.25
	Target Object	9	1.95	1.91	1.03	3.4	0.38	9	2.42	1.58	1.93	6.51	0.37	.70
	New Face	13	2.64	2.42	0.77	3.98	1.67	8	1.33	1.09	1.27	3.98	0.18	**.03***
	New Object	13	1.87	1.76	0.68	3.33	1.03	8	1.4	1.4	0.69	2.31	0.17	.18

*$p < .05$

When the total fixation duration findings of Set I in Table 3 are analyzed, there is a significant difference between children with typical development (n = 13, $\bar{X}$ = 5.1, SD = 2.56) and children with ASD (n = 8, $\bar{X}$ = 3.17, SD = 1.92) for the Target Face region (p = .04). Typically, developing children have a higher mean eye-tracking focus in this region.

When the total fixation duration findings of Set II are analyzed in Table 3, there was a significant difference between children with typical development (n = 13, $\bar{X}$ = 1.67, SD = 0.66) and children with ASD (n = 8, $\bar{X}$ = 1.95, SD = 0.64) for the Old Face region (p = .01). In children with ASD, the mean focusing in eye tracking in this region was higher.

When the total fixation duration findings of Set III are analyzed in Table 3, there is a significant difference between children with typical development (n = 13, $\bar{X}$ = 2.64, SD = 0.77) and children with ASD (n = 8, $\bar{X}$ = 1.33, SD = 1.27) for the New Face region (p = .03). Children with typical development had higher averages of focusing in eye tracking in this region. For the Old Object region, there was a significant difference between children with typical development (n = 14, $\bar{X}$ = 2.08, SD = 0.83) and children with ASD (n = 8, $\bar{X}$ = 2.16, SD = 1.18, p = .02). In children with ASD, the mean focusing in eye tracking in this region was higher.

TOTAL VISIT DURATION FINDINGS IN THE STATIC FACE SCANNING AND RECOGNITION SET

The results of the Mann–Whitney U analysis examining the measurements of the total visit duration findings in the eye-tracking data reflecting the visual scanning and recall features of the photographs in the static picture recognition sets of the children participating in the study are given in Table 4. The source of the significant differences is explained in the analysis results.

Table 4. *Total Visit Duration Measured in Static Image Recognition Set*

		TD						*ASD*						*p*
	Area	*n*	$\bar{X}$	*Med.*	*SS*	*Max.*	*Min.*	*n*	$\bar{X}$	*Med.*	*SS*	*Max.*	*Min.*	
I.SET	Old Object	14	1.61	1.63	0.62	2.66	0.25	9	1.43	1.54	1.17	3	0.1	.49
	Old Face	13	1.64	1.51	0.77	3.53	0.3	9	1.29	1.31	0.66	2.05	0.27	.49
	Target Face	13	5.37	5.69	2.64	9.49	1.1	7	3.58	3.28	2.45	6.81	0.98	.10
	Target Object	12	2.14	1.8	1.48	5.15	0.07	9	2.66	1.92	2.25	7.35	0.43	**.02***
	New Face	14	2.3	2.36	0.93	3.9	0.54	7	2.03	1.78	1.24	3.76	0.43	.49
	New Object	12	1.92	2.06	0.71	2.85	0.48	9	1.75	1.73	1.1	2.97	0.06	**.04***
II.SET	Old Face	13	1.71	1.74	0.65	3.1	0.75	8	1.86	0.74	0.69	2.3	0.12	**.02***
	Old Object	14	1.66	1.64	0.94	3.71	0.18	6	1.45	1.49	0.66	2.51	0.52	.22
	Target Face	13	5.61	6.98	2.79	9.04	0.94	7	3.38	3.75	2.49	7.71	0.09	.07
	Target Object	12	1.92	1.79	1.13	4.31	0.73	6	2.82	2.84	0.88	3.69	1.93	.08
	New Face	12	1.67	1.71	0.91	2.95	0.06	7	1.47	1.07	1.09	3	0.1	.67
	New Object	13	2.71	2.69	1.06	4.49	1.07	8	2.24	2.5	1.3	4.27	0.3	**.04***
III.SET	Old Face	12	1.06	0.87	0.56	2.1	0.3	5	1.08	0.93	0.9	2.59	0.18	.76
	Old Object	13	2.19	2.37	0.99	3.54	0.09	7	2.24	2.68	1.34	3.54	0.13	**.03***
	Target Face	13	5.83	6.75	3.37	10.07	0.23	7	3.73	3.72	3.14	8.88	0.41	**.04***
	Target Object	8	1.96	1.68	1.07	3.4	0.63	9	1.78	1.4	1.23	3.63	0.37	.83
	New Face	12	2.79	2.9	0.72	3.98	1.71	7	2.12	1.87	1.43	3.98	0.46	**.01***
	New Object	12	1.94	1.81	0.83	3.61	1.03	7	1.27	1.37	0.63	2.07	0.17	.31

$^*p < .05$

When the total visit duration findings of Set I are analyzed in Table 4, there was a significant difference between children with typical development (n = 12, $\bar{X}$ = 2.14, SD = 1.48) and children with ASD (n = 9, $\bar{X}$ = 2.66, SD = 2.25) for the Target Object region (p = .02). Children with ASD had a higher average focus on eye tracking in this region. There was a significant difference between children with typical development (n = 12, $\bar{X}$ = 1.92, SD = 0.71) and children with ASD (n = 9, $\bar{X}$ = 1.75, SD = 1.1) for the New Face region (p = .04). In children with typical development, the mean focusing in eye tracking in this region was higher.

When the total visit duration findings of Set II are analyzed in Table 4, there is a significant difference between children with typical development (n = 13, $\bar{X}$ = 1.71, SD = 0.65) and children with ASD (n = 8, $\bar{X}$ = 1.86, SD = 0.69) for the Old Face region (p = .02). The mean focusing in eye tracking in this region was higher in children with ASD. For the New Object region, there was a significant difference between children with typical development (n = 13, $\bar{X}$ = 2.71, SD = 1.06) and children with ASD (n = 8, $\bar{X}$ = 2.24, SD = 1.3, p = .04). In children with typical development, the mean focusing in eye tracking in this region was higher.

When the total visit duration findings of Set III are analyzed in Table 4, there was a significant difference between children with typical development (n = 13, $\bar{X}$ = 5.83, SD = 3.37) and children with ASD (n = 7, $\bar{X}$ = 3.73, SD = 3.14) for the Target Face region (p = .04). In children with typical development, the mean focusing in eye tracking in this region was higher. There was a significant difference between children with typical development (n = 12, $\bar{X}$ = 2.79, SD = 0.72) and children with ASD (n = 7, $\bar{X}$ = 2.12, SD = 1.43) for the New Face region (p = .01). In children with typical development, the mean focusing in eye tracking in this region was higher. There was a significant difference between children with typical development (n = 13, $\bar{X}$ = 2.19, SD = 0.99) and children with ASD (n = 7, $\bar{X}$ = 2.24, SD = 1.34) for the Old Object region (p = .03). In children with ASD, the mean focusing in eye tracking in this region was higher.

DISCUSSION

When the first focusing time of the regions in Set I is analyzed, it is seen that "target object" is the region where the first focus of attention of children with ASD is directed. However, in Set III, in the "target face" region, the mean initial focusing time of children with typical development was significantly higher than that of children with ASD. In the same sets, no significant difference was found between children with typical development and children with ASD in terms of the first focusing time variable in the other regions and in the regions belonging to set II. This result shows that children with ASD focus their visual attention on objects rather than people, unlike children with typical development.

When the findings of total fixation duration in eye-tracking data reflecting visual scanning and recall features in the photographs included in the static picture recognition sets in the study were analyzed, Children with ASD and typically developing children had different visual scanning characteristics. When the focusing duration findings of Set I were analyzed, it was observed that children with typical development focused on the "target face" region more than their peers with ASD in the Target Face-Target Object photograph pair. Accordingly, it is possible to say that children with ASD look at the "target face" region for less time by directing their visual attention less; in other words, they perform visual scanning by focusing less on the human face. In this set, no significant difference was found between children with ASD and typically developing children in the average total focusing time for the "target object" region. In this regard, children with ASD prefer non-social areas. When the total fixation duration findings of Set II data are analyzed In the image with the Old Face-New Face photo pair, it is possible to say that children with ASD, unlike children with typical development, direct their visual attention more to the "old face" region and look at this region for more time; in other words, they perform visual scanning by focusing more on the familiar face.

This result is consistent with other studies (e.g., Chawarska & Shic, 2009). Accordingly, research has shown that individuals with ASD tend to focus more on familiar faces than their typically developing peers. When the total fixation duration findings of Set III were analyzed, it was observed that children with ASD directed their visual attention more to the "old object" region and looked at this region for a longer period of time in the image with the Old Object-New Object photograph pair, unlike children with typical development; In other words, it is possible to say that they performed visual scanning by focusing more on the familiar object. This result is consistent with those of other studies (Dawson, 2002; Klin et al., 2002). This result shows that individuals with ASD tend to focus more on familiar objects than their typically developing peers do. On the other hand, in the Old Face-New Face photograph pair in the same set, typically developing children directed their visual attention more to the "new face" and spent more time looking at this region; in other words, it is possible to say that they performed visual scanning by focusing more on the new face, which is consistent with the research. This finding shows that typically developing children direct their visual attention to and focus more on new faces.

When the total visit duration findings were examined in the eye-tracking data of the photographs included in the static picture recognition sets reflecting the visual scanning and recall features in the study, Children with ASD and typically developing children exhibited different visual scanning characteristics. In the Target Face-Target Object photograph pair in Set I, it is seen that children with ASD exhibit more time focusing in the "target object" region. Accordingly, it is possible to say that children with ASD direct their visual attention to the "target object" region more, glance more and look at the "target object" region for a longer period of time. This finding suggests that children with ASD, unlike typically developing children, focus on objects rather than people for longer periods. On the other hand, in the image of the old face–new face photograph pair in the same set, it is possible to say that children with typical development directed their visual attention more to the "new face" region, glanced more and looked at the "new face" for more time. This finding suggests that typically developing children focus on novel faces for longer periods and examine them more. When the dependent variable of total visit duration for Set II was analyzed, it was observed that the mean of the "old face" region of children with ASD is high in the image with the Old Face-New Face photo pair, whereas the mean of the "new object" region of children with typical development was high in the image with the Old Object-New Object photo pair in the same set. Accordingly, it is possible to say that children with ASD tend to examine familiar faces more, whereas typically developing children spend more time looking at novel stimuli. This pattern is consistent with findings in the literature, which indicate that individuals with ASD show a preference for familiar visual stimuli and often display reduced interest in novel social cues (Pierce et al., 2011; Klin et al., 2002; Chevallier et al., 2012).

When the averages of the total visit duration for Set III are analyzed, it is seen that children with typical development tend towards the "target face" in the image with the Target Face-Target Object photo pair, unlike children with ASD. Likewise, it is possible to say that children with typical development directed more attention to the "new face" region in the image of the Old Face-New Face photograph pair, glanced more and looked at the "new face" region for more time. It is possible to say that children with ASD, on the other hand, directed more attention to the "old object" in the image with the Old Object-New Object photo pair, glanced more, and spent more time examining the familiar object. These findings suggest that typically developing children focus on human faces more than objects, whereas children with ASD focus on familiar objects for longer periods.

When the results of the study are evaluated, it is quite striking that children with ASD and typically developing children exhibit different visual attention and focusing characteristics in terms of human face and object preferences in static picture recognition sets. In the literature, it has been stated that children with ASD differ from typically developing children in facial processing features that are expected to develop from infancy, distinguish facial expressions of emotion, and respond appropriately to facial expressions (Bradshaw et al., 2011; Chawarska et al., 2007; Chawarska & Shic, 2009; Chawarska & Volkmar, 2007; Dawson et al., 2004). In a similar study, Chawarska and Shic (2009) examined face recognition and visual scanning features using eye tracking in 30 typically developing children aged 2-4 years and 44 children with ASD. In this study, children were divided into two age groups, and the research was conducted in two dimensions: face familiarity and face recognition. The fact that all older children who participated in the study spent less time examining the face suggests that there is a face processing process that regresses with age. In this context, it may be recommended to examine the age variable in the construct in future research.

It was observed that children with ASD looked at and focused more on familiar objects and human faces in the pictures included in the study. Chawarska and Shic (2009) found that children diagnosed with ASD have different face processing skills than typically developing children, and that they show an atypical face examination pattern when presented with unfamiliar faces. Similarly, Boucher and Lewis (1992) and Klin et al. (1999) reported that individuals with ASD made significantly more errors in recalling photographs of faces—a socially meaningful stimulus—while there was no significant difference in recalling images of objects. According to earlier studies on eye-tracking patterns, children with ASD require more time to perceive the facial features necessary for face recognition (Bradshaw et al., 2011; Chawarska, Macari, & Shic, 2012; Chawarska & Volkmar, 2007; Webb et al., 2010). Recent studies continue to support and extend these findings. For instance, studies by Wagner et al. (2019) and Black et al. (2021) emphasize that children with ASD show delayed and limited fixation on socially relevant areas such as the eyes and mouth, which are essential for facial identity recognition. These atypical patterns are thought to reflect differences in cognitive processes related to attention, recognition, and memory encoding. Furthermore, research by Keehn et al. (2022) highlights that attention to familiar faces may be a compensatory strategy to reduce social complexity and cognitive load. Therefore, the tendency of children with ASD to focus more on familiar objects and faces may stem not only from recognition-based memory processes but also from a reduced motivation to engage with novel social stimuli.

In the Target Face-Target Object image, which was first presented in the setup in the study, and which participant groups were given more time to examine and remember than the time to examine the other pairs of photographs in the set, it was observed that children with ASD preferred objects as the focus of visual attention more than faces and looked at objects for longer periods of time. Similarly, studies have found that children with ASD can perform better in visual processing of non-social stimuli despite their inability to process social stimuli such as faces (Mottron et al., 2006). In support of this finding, Dawson et al. (2002) compared object and face recognition skills and found that, in face recognition activities, children with ASD concentrated their attention on the face to a lesser extent and within a shorter response time. When the research findings are analyzed, it is observed that children with typical development prefer human faces as the center of attention rather than objects. At the same time, typically developing children tend to look at new objects or human faces in presented visuals. In the literature, this is referred to as the 'novelty preference' (Chawarska & Shic, 2009). This finding shows that individuals with typical development direct their visual attention to novel stimuli and gaze more toward novel areas.

Eye movements provide important information about areas that people pay attention to and ignore, and by observing and interpreting eye movements, it is possible to learn about cognitive processes in the brain (Russell, 2005). For example, it has been stated that the long fixation time of the eye, which is one of the eye movement parameters, expresses an intense mental process, and values such as the number of fixations, average fixation time, and total review time of the gaze are closely related to the learning process (Rayner, 1998). In this context, the fact that the focusing variables of children with typical development towards novel regions in this study were higher than those of children with ASD suggests that children with typical development perform cognitive processing to recognize, understand, or learn novel stimuli by directing their eyes to the novel region.

The results of this study showed that children with ASD had unusual facial examination and visual scanning features compared with typically developing children. According to researchers, children with ASD have limitations in scanning key facial features during face processing and simple face recognition performance (Chawarska & Shic, 2009; Chawarska & Volkmar, 2007). In a study of adults with ASD (Klin et al., 2002), it was found that, when shown images of objects or people in a social setting, individuals with ASD spent more time watching objects and focused on faces for the limited time they spent looking at them. In relation to this research result, it has been suggested that human faces do not attract the attention of individuals with ASD and that individuals with ASD may spend less time on face processing because they do not prioritize human faces and do not find human faces stimulating enough (Chawarska et al., 2003; Chawarska et al., 2010; Volkmar et al., 2004).

As a result of the study, it was strikingly determined that while individuals with ASD focused their visual attention on familiar faces and objects, the visual attention focus preferences of children with typical development were for novel (unfamiliar) faces and objects. Based on this result, it can be suggested that in the educational materials to be prepared for individuals with ASD, human faces and stimuli that they constantly encounter in their environment, in other words, with which they develop familiarity, should be preferred to provide an opportunity to develop visual attention focus. For example, considering the tendency of individuals with ASD to focus on familiar faces, it can be suggested to actively include people familiar with children with ASD in their daily lives in the education process in teaching social interaction skills. In future research, it is believed that the use of familiar faces in visual materials within the scope of technologically based applications (for example, the preference of familiar faces in the preparation of virtual reality applications and avatars) will be effective in educational applications. In addition, while organizing educational environments to teach academic and social skills to individuals with ASD, planning a teaching process from known to unknown stimulus preferences may be recommended.

Another striking finding of this study was that children with ASD tended to focus more on stimuli (objects) when a human face and stimuli were presented together. This research result may have a two-way reflection on educational practices; firstly, considering that objects may affect the visual attention focus in teaching social interaction skills, it may be recommended to organize structured teaching environments where stimuli are limited. Second, it can be suggested to use visual stimuli that attract interest as visual support to use the visual perceptual skills of individuals with ASD. In future studies, it may be recommended to conduct eye-tracking studies using stimuli with different characteristics to determine which related or unrelated characteristics of the stimuli affect the visual attention focus of individuals with ASD.

The social interaction limitations of individuals with ASD include problems in preferring human faces among other stimuli, limitations in receiving emotion-related cues from faces, problems in forming joint attention by watching people's gaze, using unusual face scanning strategies, and face processing disorders (Chawarska et al., 2010). On the other hand, understanding the source of these social interaction problems that individuals with ASD exhibit in understanding social and emotional cues from human faces and determining the differences in the strategies used provides an opportunity to better understand the mechanisms underlying social inadequacy (Jones et al., 2008; Rutherford & Towns, 2008). Research has shown that eye-tracking technologies are an effective way to see and measure where people focus on complex social situations (Klin et al., 2002).

LIMITATIONS AND RECOMONDATIONS

The fact that the number of children diagnosed with ASD in the study group in this study was limited to 37, the age range of the children varied between 3 and 10 years, and the degree of ASD varied may be a limitation in generalizing the findings of the study in children with ASD. In this context, the limitations of the study group should be evaluated by considering the distribution of children with ASD in the population and the limitations specific to the diagnosis of ASD. The number of typically developing children who participated in the study was 41, and they were selected by chronological age-matching with children with ASD. In comparative studies conducted on children with ASD, the selection of the study group by chronological age matching is also accepted in the literature (Charman, 2004).

Second, the eye-tracking analyses conducted in this study were limited by the selection criteria of the study group. The effects of gender, developmental level, and percentage of children looking at the screen in the study group were not considered. Considering these limitations, future studies should include children with ASD who have a homogeneous distribution in terms of ASD grades, age groups, gender, developmental level, and developmental level. It is important to examine visual scanning skills in sample groups, including children with a similar percentage of looking at the screen, by comparing them to generalize the findings obtained in the study.

Third, the measurement of the visual scanning features that were determined in this research was limited to the visual materials prepared within the scope of the research. This may be a limitation in generalizing the research findings. Therefore, these limitations can be eliminated by adding qualitatively different stimuli and quantitatively enriching the visual material sets used in this study.

Despite the limitations of the research, with the advancement of technology, trying to understand the characteristics of children with ASD through computer and eye-tracking technologies other than traditional methods may guide future studies in many developmental areas, such as social interaction, language, and cognitive development. In addition, it is thought that these studies will shed light on the nature and development of ASD and will play a key role in recognizing and following up individuals at risk of ASD at the earliest stage.

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AUTHOR CONTRIBUTION

Ayşe Tuba Ceyhun: Conceptualization, Methodology, Data Collection, Analysis, Writing – Original Draft. Selda Özdemir: Supervision, Writing – Review & Editing.

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