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RESEARCH ARTICLE

A Dual Eye Tracking Study of Joint Attention in Adults with Autism Spectrum Disorder

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ABSTRACT

Introduction: Joint attention (JA) is a fundamental aspect of social interaction and a cornerstone of social communication. This study explores factors influencing JA in adults with Autism Spectrum Disorder (ASD) using an interactive, dual eye-tracking paradigm during a tangram puzzle computer gameplay. The JA performance of adults with ASD and a typically developing non-clinical control group (TD-NCC) was assessed alongside partner familiarity (familiar / stranger), partner roles (presenter / operator) and gaze cue (present / absent). Two main objectives were: 1) to evaluate JA through gaze recurrence (GR) in adults with ASD, and 2) to examine the effect of partner familiarity on JA by comparing the performance in the task conducted with either a familiar or an unfamiliar partner (stranger).

Methods: The sample consisted of 42 participants (21 adults with ASD; ages 18–50, 9 females and 12 males and 21 TD-NCC; ages 21–50, 11 females and 10 males). Two non-intrusive desktop eye trackers simultaneously recorded gaze during the JA tangram task. Gaze recurrence was used as an indicator of JA. The gaze cue (present/absent) was a semi-transparent indicator showing where to look. Additionally, to control for potential eye pathophysiology in JA, saccade and anti-saccade tasks were applied to the eye movements of each participant.

Results: The Linear Mixed Effect Model revealed that GR was significantly lower in the ASD group compared to controls. However, the presence of a gaze cue significantly improved the ASD group's GR, especially when interacting with a familiar partner under gaze-cue on conditions.

Conclusion: Understanding factors influencing JA in autism may foster further exploratory studies and significantly impact future research. Eye movements may serve as objective, quantitative, and non-invasive biomarkers for ASD, particularly in interactive gaming contexts.

Keywords: Autism spectrum disorder, dual tracking, eye movements, gaze recurrence, joint attention

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INTRODUCTION

Autism Spectrum Disorder (ASD) is marked by distinct social interaction and communication challenges, characterized by variations in eye contact, facial expressions, speech patterns, repetitive behaviors, and restricted interest (1,2). Previous research indicates significant variability in social skills among individuals with ASD, particularly in Joint Attention (JA), a critical component for language development and social learning from early childhood (3).

Joint attention involves the coordinated focus between individuals on an object or activity for social purposes. Traditional JA assessments focus on responding to JA (RJA) and initiating JA (IJA). While individuals with ASD can respond to joint cues similarly to non-autistic peers, they often struggle to initiate these interactions (4).

Individuals with high-functioning autism are often capable of understanding and processing social information while facing difficulties in spontaneous social interactions, being less structured and predictable than in experimental settings (5). This discrepancy highlights the need for research that explores real-life social dynamics and the effectiveness of interventions that stimulate these interactions, like gaming.

Highlights

- **Joint attention was significantly lower in the ASD group compared to controls.**
- **ASD group performed better when using gaze cues with familiar individuals.**
- **Game-based joint attention studies reveal variables in the social interaction.**

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Contrary to traditional views of gaming as mere entertainment, recent studies demonstrate its efficacy in enhancing social and cognitive skills through structured interaction and engagement (6). Specifically, digital game environments offer a controlled yet engaging setting providing a more comfortable space for individuals with ASD to engage in engagement in social interactions compared to traditional settings (7).

The study of eye movements in ASD provides insights into how individuals with ASD perceive and engage in social interactions. Eye-tracking studies revealed that people with ASD exhibit unique fixation patterns and saccade behaviors, suggesting potential interventions for improving their social engagement (8,9). Divergent results have been reported in studies that investigated oculomotor anomalies in ASD. Studies show that individuals with autism display different fixation patterns during complex social conditions (9) and their saccade frequency increases in the absence of a visual stimulus (8).

Eye movements provide indicators of how individuals process social information, especially in scenarios where visual attention plays a significant role, across a wide range of ASD groups (10). In this study, the analysis of eye movements serves as a critical approach to understanding the underlying mechanisms of JA impairments. Social attention deficits disrupt fundamental social interaction processes, such as maintaining eye contact and focusing on shared objects. Through eye movement analysis, this study provides deeper insights into the social aspects of autism (11).

An additional factor that may potentially affect interpersonal interactions is the level of familiarity with the partner. In the literature, the familiarity of the interacting partner has been shown to elicit significant differences in neural responses within sample groups during interactive paradigms, including both individuals with ASD and control groups (12).

Individuals with ASD engage in social interactions in digital game environments as it provides a more comfortable space for engagement than in traditional social settings. In this study, we aimed to investigate the eye movement patterns of adults with ASD in a dual-eye tracking setup within the context of game-playing. Instead of the widely used gaze following experiments, gaze monitoring of the participants was assessed by gaze recurrence (GR) through dual eye tracking. Gaze recurrence is a measurement that intends to quantify the degree of gaze coordination among pairs while engaged in a joint task. In this study, GR was proposed to be an indicator of JA (13). While responding to JA (RJA) was assessed with an *operator role*, Initiating JA was evaluated with a *presenter role* in the JA paradigm. By simulating a realistic social environment through gaming, we studied natural behaviors and eye-movement coordination, offering a comprehensive understanding of social interaction in ASD.

This study has two main objectives. The first is to compare JA performance of adults with ASD to that of a control group in responding and initiating JA as independent variables within a gaming context. The second is to investigate the influence of partner familiarity on JA performance byhaving participants perform the same task with a familiar person and a previously unknown person, *the experimenter*, (as independent variables). Our innovative approach combined traditional JA assessment with dual eye-tracking in a game-mediated environment, offering novel insights into the social cognitive processes of adults with ASD. Unlike most JA studies, which focus on infants and children in face-to-face settings, this study explored adults with ASD in a game-mediated communication environment. Based on the previous studies, we hypothesize that GR would be observed in a lower degree in individuals with ASD compared to controls, and that partner familiarity would affect the groups differently.

METHOD

Participants

Forty-seven participants were recruited for the study, including 23 adults diagnosed with ASD according to DSM 5th edition (14) criteria and 24 typically developed non-clinical controls (TD-NCC). The patient group was composed of adults who had been monitored for a long time in the same private psychiatry clinic by a psychiatrist. TD-NCC were recruited through community referrals.

Individuals with comorbid conditions such as intellectual disability, schizophrenia, any psychotic disorder, any neurological disorder, or a history of clinically significant head trauma were not included in the study. Due to technical issues in data collection, the analysis included data from 21 ASD participants (age range 18–50, M=34.10, SD=10.40, 9 females and 12 males) and 21 TD-NCC (age range 21–50, M=32.38, SD=8.60, 11 females and 10 males). All participants provided written informed consent in accordance with the Declaration of Helsinki (1964), with approval from the Ethics Committee of Ankara University (09-389-14/2014).

The JA paradigm was adapted from the task developed by Spanger et al. (2012) (15) for studying referring expressions in various languages, such as English, Japanese, and Turkish (16). The game was adapted to display eight tangram puzzles; the first four were paired by a familiar partner. The experimental session involving participation of a familiar partner (a relative or peer) was completed by 11 participants from each group (22 pairs in total).

The study started with an eye movement experiment session (Saccade Task and Anti-Saccade Task) where each participant participated in individually. The participants then completed JA task (Tangram Task) with the partner (accompanied by the peer and the researcher or accompanied by the researcher only).

Materials

Apparatus

Two non-intrusive desktop eye trackers (Eyetribe Inc., 60 Hz) simultaneously recorded the eye movements of pairs (participant and partner and / or participant and researcher) during the JA paradigm (17). Custom software, developed by the lab team, was used to display stimuli for saccade and anti-saccade tasks.

For the JA task, a remote monitoring tool, Teamviewer Inc. v10 was used for sharing the tangram puzzle environment between partners and transferring mouse control. A custom software tool was developed in Java, utilizing Eye Tribe SDK libraries, visualized partners' gaze cues on screens as semi-transparent circles and streamed eye movement data to a server computer in real-time.

Red and green circles differentiated each participant's gaze. The red circle represented the participants' gaze cue, while the green circle was used to signify the gaze cue of the relative / peer or the researcher. To smooth the gaze visualization, a moving average of the last three coordinates was computed.

The server's screen captured both partners' utterances and gaze cues, and it recorded synchronized gaze locations. The procedure is detailed in the following experiment presentation.

Procedure

Saccade Task and Anti-Saccade Task

Participants were seated with chin and forehead supported, undergoing a nine-point calibration before each eye-tracking session. They completed three to four practice trials of the Saccade and Anti-Saccade tasks, followed by 20 experimental trials. In these tasks, participants fixated on a central cross that disappeared [a zero millisecond difference, (18)], triggering a peripheral stimulus on the left or right, randomly (the zero-gap paradigm). A total of 20 trials were presented to the participants [2 directions (right/left) × 2 amplitude (5° and 10°) × 5 trials] for both the saccade and the anti-saccade task, as described below.

The Saccade Task

Each trial began with a central target, a white cross displayed for 1 or 2 seconds on a black background, covering 0.5 degrees of visual angle. Following the disappearance of this target, a peripheral white circle target appeared 5 or 10 degrees left or right for 1 second. Participants were instructed to focus on the cross, which served as a fixed point after the circle vanished. The latency of each saccade was measured as the dependent variable.

The Anti-Saccade Task

In the anti-saccade task, with the same experimental set-up, participants were asked to gaze in the opposite direction from the peripheral white circle target, measuring correct and incorrect saccades, their latencies, amplitudes, correction times, error latency and error amplitude.

Joint Attention Tasks (Tangram Game)

The study involved two phases of collaborative puzzle-solving using tangram games, first with a familiar partner and then with an unfamiliar researcher (Figure 1). Participants completed eight puzzles, half with their familiar partner and the other half with the researcher. Participants who preferred to come to the experiment alone performed the tangram task (the last 4 tangrams) with only the researcher. They were separated by an opaque barrier, relying on verbal communication, and used dual eye-tracking systems without chin-rests to allow speech communication. The tasks used a dual-monitor setup where participants alternated roles as 'presenter' and 'operator' . The presenter, who could see the puzzle, guided the operator in placing and rotating pieces based on semi-transparent gaze cues displayed on the screen, indicating where to look. Gaze cue was alternatingly turned on and off before each trial such that half of the trials were attempted with gaze cue on and off, respectively. The experiment took about 20–25 minutes.

Neuropsychological Tests

Autism Spectrum Quotient [AQ– (19,20)]; Empathy Quotient [EQ– (21,22)]; Reading the Mind in the Eyes [RMET– (23,24)]; Attention Deficit Hyperactivity Self Rating Scale [ASRS– (25,26)]; Wender Utah Rating Scale for the Attention Deficit Hyperactivity Disorder [WURS– (27,28)], Liebowitz Social Anxiety Scale [LSAS– (29,30)] and Hand Usage Questionnaire [HUQ– (31,32)] were administered to all participants.

Data Analysis

Eye-tracking data were analyzed by measuring GR across synchronized data streams from paired participants, following established methods (13). An operational assumption identified concurrent gaze samples if they coincided within the same Area of Interest (AOI) by less than 17 milliseconds (corresponding to the sampling frequency of the 60 Hz eye tracker). A spatiotemporal filter then quantified the percentage of GR for each trial. Gaze overlaps were determined by the proximity of gaze coordinates –defined as within 102 pixels on a screen covering a 20-degree visual angle from 60–65 cm away– analyzing the synchronization and overlap within a 2-second window. This method aimed to measure the extent of coordinated attention in joint tasks, providing insights into the spatial and temporal dynamics of gaze interactions. According to this, gaze data were labeled overlap or non-overlap, based on whether the other participants' gaze coordinates fell within 102 pixels in a time window of ±2 seconds.

RESULTS

The data of 42 participants (21 individuals with ASD and 21 TD-NCC) were included in the analysis. The first four tangrams, which required the participation of a familiar partner, were completed by a subgroup of 11 participants from each group (22 pairs in total).

A preliminary data analysis was conducted to check for normality, homogeneity of variance, and linearity to determine if the data met parametric assumptions. Group differences were investigated through analysis of variance (ANOVA), while non-parametric tests were employed when the assumptions were not satisfied. Multilevel modeling analysis was applied to evaluate GR in terms of the main independent variables, namely role, partner familiarity, and gaze cue. All analyses were conducted with IBM Statistical Package for Social Sciences (SPSS) program version v.26. The analysis pipeline is presented in Figure 2.

Demographic and Clinical Assessment

The ASD and TD-NCC groups were similar in terms of age, gender, duration of education, duration of mother's education, and duration of education of the father (Table 1).

According to clinical assessment results, individuals with ASD had higher scores in all subtests of AQ-50 than controls, except for the imagination sub-test. They also showed lower empathy, as evidenced by higher scores from the EQ. Their anxiety levels were higher, and avoidance behaviors were more prominent in social settings according to the LSAS. In contrast, there was no significant difference between the groups in terms of RMET, ASRS and HUO scores (ASD: right-handed=18, left-handed=3; non-clinical control: right-handed=19, left-handed=2 persons) [χ^2 (1)=0.227, p=0.634]. According to the WURS, individuals with ASD reported more symptoms of attention deficit than the TD-NCC (Table 2).

Assessment of Eye Movements

Saccade Task and Anti-Saccade Task

A one-way ANOVA analysis showed no significant difference in both saccade and anti-saccade task between the groups. (p>0.05, see Supplementary Table 1 and Table 2.)

Assessment of Joint Attention Performance

This section assesses JA performance, testing two hypotheses: the control group would outperform the ASD group, and partner availability would affect JA performance differences between groups. We analyzed GR through variables:

Group (ASD vs. control),

Role (presenter vs. operator),

Partner (familiar vs. researcher), and

Gaze Cue (on vs. off) using a Multilevel Model /Linear Mixed Effect Model.

In our design, *the presenter initiates JA*, and *the operator responds*. We also measured the number of words uttered as an indicator of engagement (verbal analysis), assuming equal task difficulty across all trials. The presenter guides the operator to position pieces correctly, using verbal instructions as a participation measure**.**

Tangram Analysis: Part I

In the first four-level hierarchical model, the effects of Group, Role, Partner, and Gaze-cue on GR were evaluated (ASD group n=11, TD-NCC group n=11). The main effect of Group was significant, F (1,22.16)=6.06, p<0.05, η^2=0.22, where the TD-NCC group's GR values (M=0.42, SE=0.03) were significantly higher than the ASD group (M=0.30, SE=0.03; MD=0.12,

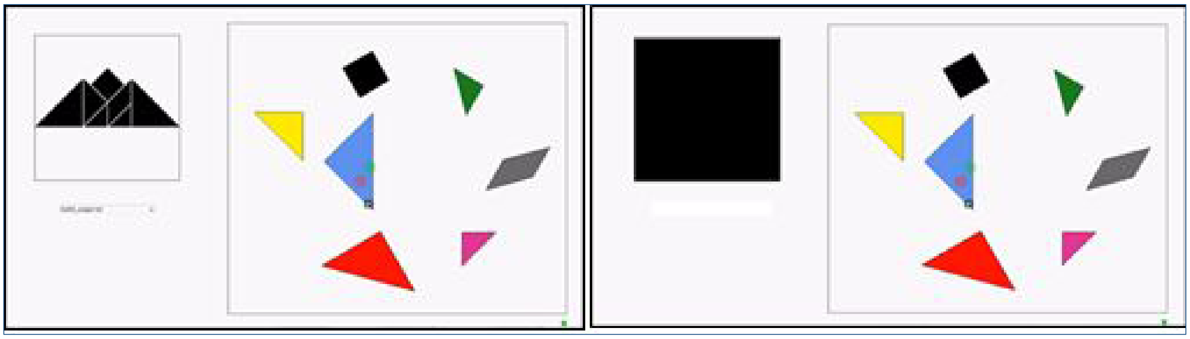

Figure 1. Screenshots for the presenter (left) and the operator (right) interfaces for the tangram game.

Note: Red and green circles indicate the current gaze location of both participants

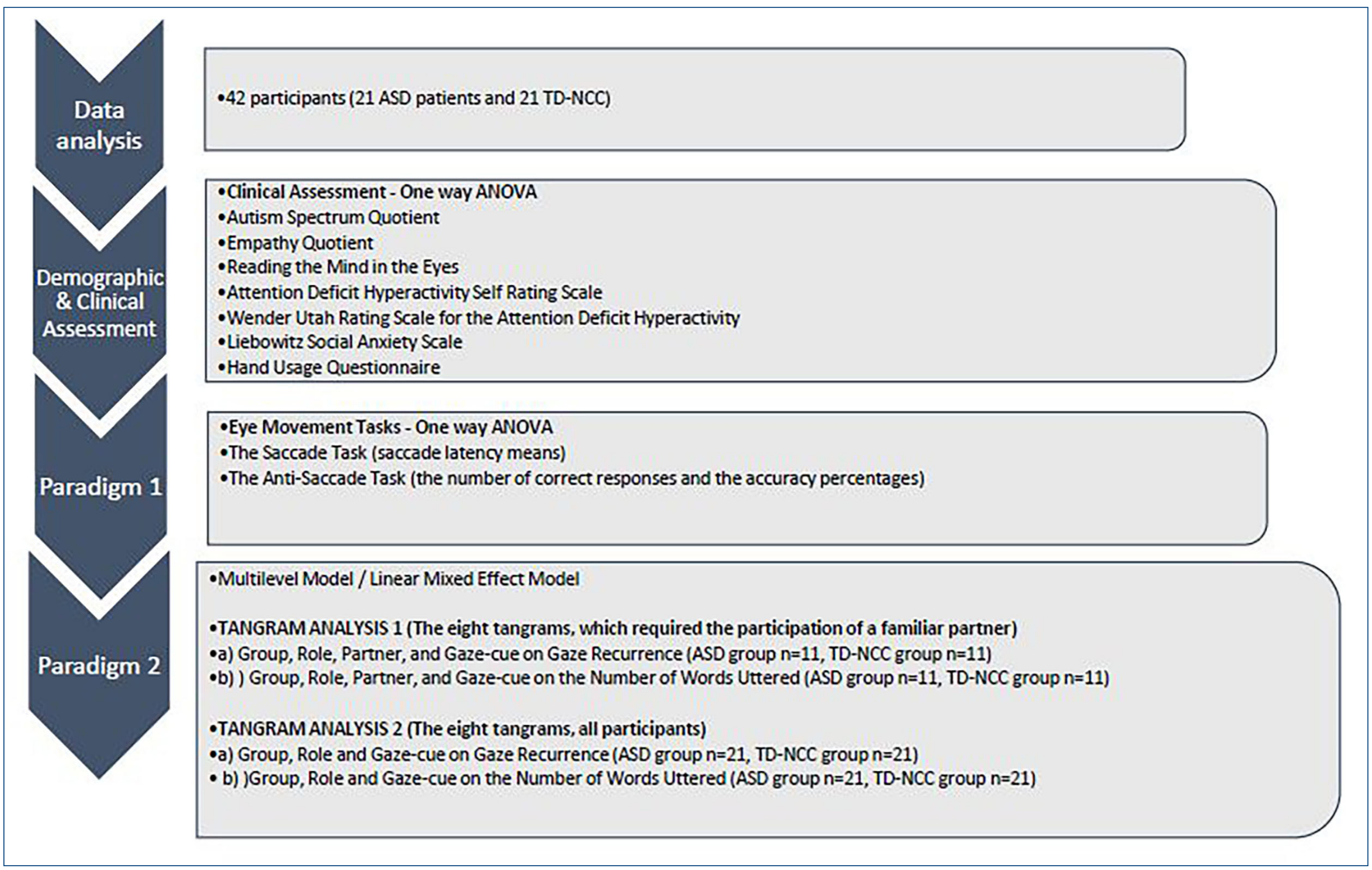

Figure 2. Data analysis pipeline.

Table 1. Demographic assessment results

	ASD group (n=21)			TD-NCC group (n=21)			Analysis
Gender (Male/Female)	12/9			10/11			X^2 (1)=0.382, p=0.537
	mean	**Sd**	**range**	**mean**	**Sd**	**range**	
Age	34.10	10.40	18-50	32.38	8.60	21-50	F (1.40)=0.34, p=0.564
Duration of education (year)	15.48	3.67	8-21 median: 17	16.05	3.26	11-21 median: 17	U=208.00, p=0.744
Duration of mother's education (year)	12.59	5.00	0-21 median: 15	10.65	4.27	5-21 median: 11	U=125.50, p=0.110
Duration of father's education (year)	14.65	4.14	5-21 median: 15	12.81	4.32	5-21 median: 13	U=122.50, p=0.078

ASD: Autism Spectrum Disorder; Sd: Standart deviation; TD-NCC: Typically developed non-clinical controls.

Table 2. Clinical assessment results

	ASD group (n=21)			TD-NCC group (n=21)			Analysis
	mean	Sd	Range	mean	Sd	Range	
Autism Spectrum Quotient (AQ-50)	26.94	5.34	14–35	16.00	4.62	9–26	F (1,35)=44.578, p<0.001*
Autism Spectrum Quotient Social skills	6.44	2.10	2–10	3.29	1.77	0–6	F (1,35)=24.624, p<0.001*
Autism Spectrum Quotient Attention switching	5.88	2.13	2–10	4.10	1.64	1–7	F (1,35)=8.282, p=0.007*
Autism Spectrum Quotient Atttention to Detail	6.69	2.06	2–10	4.57	1.89	0–8	F (1,35)=10.575, p=0.003*
Autism Spectrum Quotient Communication Skills	4.31	2.21	0–8	1.57	1.21	0–4	F (1,35)=23.280, p<0.001*
Autism Spectrum Quotient Imagination	3.94	2.35	1–8	2.81	1.44	0–5	F (1,35)=3.257, p=0.080
Empathy Quotient	54.07	10.58	35–71	61.81	6.50	49–72	F (1,34)=7.394, p<0.010*
Reading the Mind in the Eyes	25.22	2.29	21–30	26.19	2.60	21–32	F (1,37)=1.499, p=0.229
Liebowitz social anxiety scale Anxiety	54.12	15.33	33–85	44.55	10.16	33–68	F (1,35)=5.148, p=0.030**
Liebowitz social anxiety scale Avoidance	47.94	12.74	30–81	39.85	7.76	32–62	F (1,35)=5.628, p=0.023**
Wender Utah Rating Scale for the ADHD	40.65	17.66	13–74	24.37	13.56	9–59	F (1,34)=9.737, p=0.004*
Adult ADHD Self-Report Scale	35.00	11.20	18–54	30.55	9.42	11–46	F (1,35)=1.725, p=0.198

*p<0.01, **p<0.05
ADHD: Attention Deficit Hyperactivity Disorder; ASD: Autism Spectrum Disorder; Sd: Standard deviation; TD-NCC: Typically developed non-clinical controls.

p=0.022, Cohen's d=0.72). This finding is consistent with the first hypothesis.

The main effect of Role was also significant, *F* (1,151.27)=20.04, *p* <0.001, η^2=0.12, where the GR of all participants significantly increased when they were in the operator role (*M*=0.41, *SE*=0.03) as compared to the presenter role (*M*=0.31, *SE*=0.03; MD=0.10, p <0.01, Cohen's d=0.65).

Finally, we observed a marginally significant three-way interaction between Group, Gaze-cue, and Partner, *F* (1,152.09)=2.57, p=0.056 (one-tailed), η^2=0.02. Bonferroni corrected follow-up tests showed that the ASD group had a significantly lower GR than the TD-NCC group when they were interacting with a familiar partner (*MD*=0.18, *p* <0.01, Cohen's *d*=0.38) and with the researcher (*MD*=0.12, *p*=0.053, Cohen's *d*=0.26) when the gaze-cue was turned off. However, when the gaze-cue was on, this difference was only significant when the partner was the researcher (*MD*=0.12, *p*=0.050, Cohen's *d*=0.26), but not with the familiar partner (*MD*=0.03, *n. s.*). In other words, the GR performance of the ASD group increased to the level of the TD-NCC when they engaged with their familiar partner in the gaze-cue on (Figure 3).

Verbal Analysis of Tangram Analysis Part 1

The number of words uttered by participants is considered a simple measure of participation where JA is initiated and maintained. When the same analysis was conducted on the number of words uttered, a significant main effect of Role [*F* (1,154)=239.03, *p*<0.001, η^2=0.61; presenters (*M*=219.21, *SE*=10.98) uttered significantly more words] and a significant main effect of Partner [*F* (1,154)=4.08, *p* <0.05, η^2=0.03; uttered more words when conversing with familiar partners] were observed (see Supplementary materials for the details and the figures of the results).

We observed a significant interaction effect between Group and Gaze-cue, *F* (1,154)=11.90, *p* <0.01, η^2=0.07, which is due to the significant increase in the number of words uttered by the ASD group when the gaze-cue was on versus off, compared to controls (Figure 4). Bonferroni corrected pairwise tests showed that when the gaze-cue was off, controls uttered significantly more words (*MD*=46.43, *p* <0.05, Cohen's *d*=0.32), but this difference was not significant when the gaze-cue was on (*MD*=36.0, *n. s.*). Significant three-way interactions between Group, Gaze-cue, and Partner, *F* (1,154)=5.53, *p* <0.05, η^2=0.04 and Group, Gaze-cue, and Role *F* (1,154)=6.46, *p* <0.05, η^2=0.04 were also found. These findings suggest that the ASD group uttered more words when engaged with their familiar partner with the gaze-cue turned on, while controls uttered more words when the gaze-cue was turned off. Additionally, when the gaze-cue was on, the ASD group uttered more words in the presenter role (*MD*=-74.23, *p* <0.01, Cohen's *d*=0.28), but the difference was not significant when they were in the operator role (*MD*=5.05, *n. s.*). (see Supplementary materials for the details).

Tangram Analysis: Part II

In this model, we excluded the partner variable to include participants who could not attend the experiment with a familiar partner, thereby covering our entire sample. For this purpose, only the Group, Role, and Gaze-cue were considered as predictors. The analysis revealed that a significantly higher percentage of GR occurred when the target participant assumed the operator role (*M*=0.28, *SE*=0.02) in contrast to the presenter role, *M*=0.37, *SE*=0.02), *F* (1,210.33)=26.94, *p* <0.001, η^2=0.11.

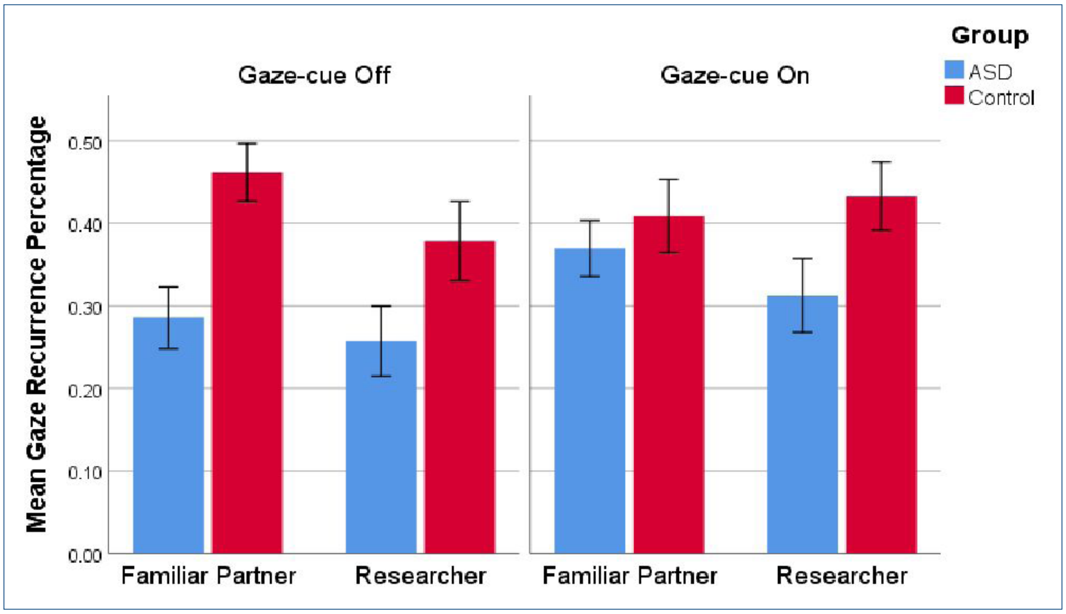

Figure 3. The average gaze recurrence percentage observed for ASD and control groups across Gaze-cue and Partner conditions.

Note. Error bars indicate standard error.

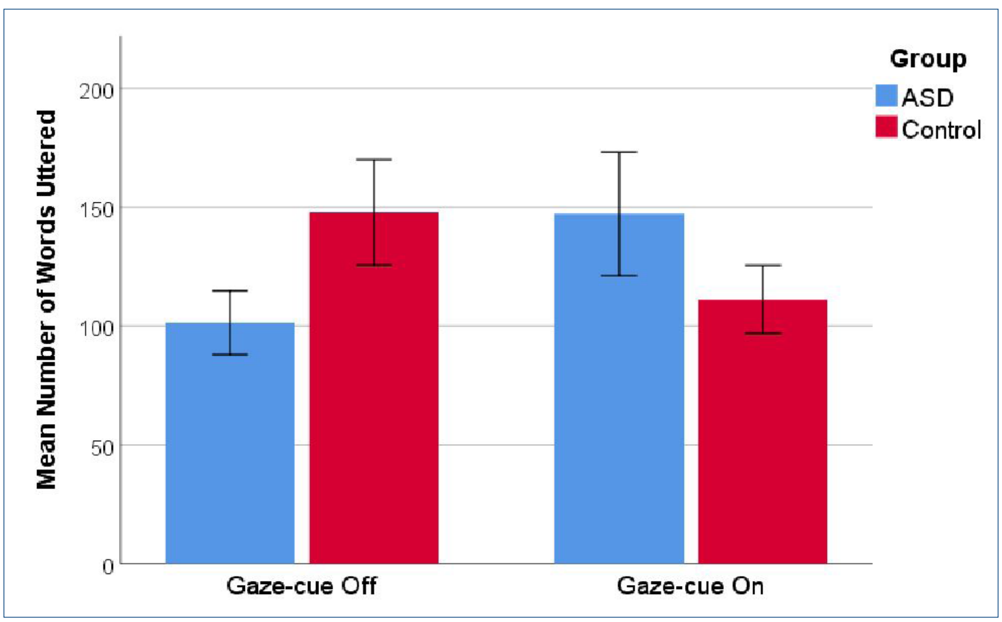

Figure 4. The average number of words uttered by the ASD and control groups across Gaze-cue conditions.

Note. Error bars indicate standard error.

The interaction between Group and Gaze-cue turned out to be insignificant when the Partner was removed from the analysis, *F* (1,210.31)=1.91, *p*=0.085, η^2=0.01 (one-tailed). However, we observed a similar trend where the ASD group increased their GR percentage when the gaze-cue was on, which did not make such a difference for the TD-NCC group (Figure 5). Furthermore, Bonferroni-corrected pairwise comparisons also indicated that the controls had significantly higher GR than the ASD group when the gaze-cue was turned off (*MD*=0.07, *p*=0.0505 (one-tailed), Cohen's *d*=0.21).

Verbal Analysis of Tangram Analysis Part 2

The presenters (*M*=235.40, *SE*=8.08) uttered significantly more words compared to the operators (*M*=31.53, *SE*=8.08), *F* (1,220.71)=443.342, *p*<0.001, η^2=0.67. Consistent with our first analysis, significant interactions were also observed among Group and Gaze-cue, *F* (1,220.71)=10.08, *p* <0.01, η^2=0.04, and between Group, Gaze-cue, and Role, *F* (1,220.71)=5.59, *p* <0.05, η^2=0.03, (see Supplementary materials for the details).

DISCUSSION

This study employed a dual eye-tracking setup within a gaming context to assess JA performance among adults with ASD and TD-NCC group.

The major finding is that JA performance (i.e., the ratio of gaze recurrence, GR) was significantly lower in individuals with ASD than in the TD-NCC group. According to the literature, during JA, intensive social information processing is thought to involve a combination of self–reference information (body posture, movements, thoughts, desires, and intentions), other–reference information (the other's posture, movement, affect, intention, and manner of calling) and spatial processing of the reference object, sensory and non-sensory information [(familiarity, innovation), (33)] suggesting difficulties in integrating multiple sources of information compared to controls. This finding might argue that the TD-NCC group was able to combine multiple sources of information more efficiently than the adults with ASD, thereby exhibiting better JA performance.

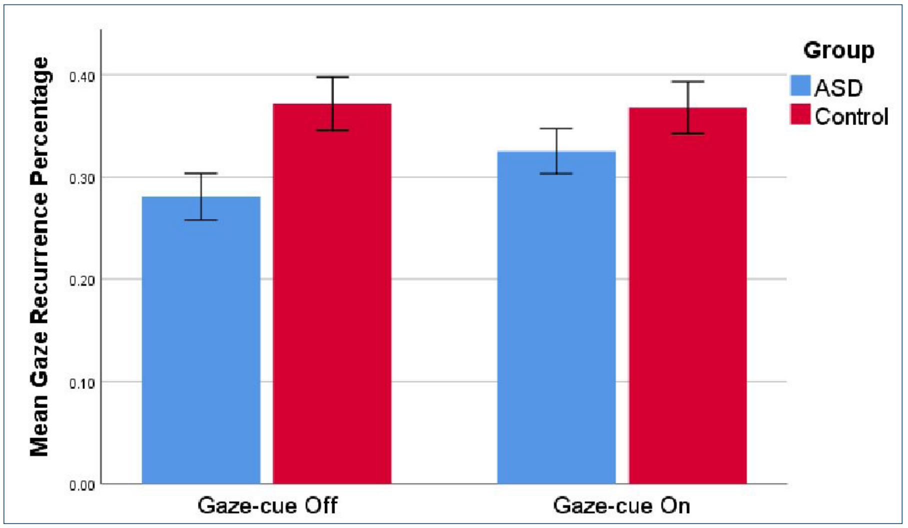

Figure 5. The average gaze recurrence percentage observed for ASD and control groups across Gaze-cue conditions with all participants. Note. Error bars indicate standard error.

The second major finding is that the JA performance significantly improved when participants were in the operator role. This outcome may be partly due to the way partners' communication was mediated via screen sharing during the experiment, in contrast to a face-to-face setting. Foundational studies on dyadic interaction suggest that participants in the speaker/presenter role (Initiating JA, IJA) tend to look away from the partner when they begin speaking until they finish their turn in the conversation (34). Another finding in the literature is that individuals with ASD respond to JA (RJA) as successfully as typically developing controls, but they have difficulty initiating JA (35).

The third major finding of our study is the significant increase in number of words used in JA performance among individuals with ASD during the gaze-cue-on condition, in contrast to the control group where no such difference was observed. This result may be interpreted as these individuals' tendency to employ the gaze cue to enhance communication, particularly given the difficulties they experienced during the task. While individuals with ASD tended to talk more in the gaze-cue-on condition, the control group used more words in the gaze-cue-off condition. Previous research indicates that social interaction and communication are the domains where individuals with ASD often face difficulties [e.g. (3), (35)]. Therefore, the availability of a non-living object/cue might have allowed these individuals to engage less avoidably, thus helping them cope with those challenges of social interaction.

A novel aspect of our study is its focus on the familiar partner effect on JA performance. According to this, the TD-NCC group's JA performance surpassed that of the ASD group when solving the tangram with a familiar partner and without gaze cues. Individuals with ASD demonstrated similar GR levels to TD-NCC when the gaze cue was available, but only with familiar partners. The ASD group also spoke more when interacting with familiar partners and when gaze cues were present. In contrast, the control group spoke less with the gaze cue, likely due to the reduced need for verbal referencing given the visual cue of their partner's gaze. However, no such reduction in speech was observed in ASD individuals interacting with familiar partners.

Notably, when interacting with unfamiliar partners, the ASD group did not show the same improvement in JA performance with gaze cues. This highlights the novel aspect of our study—its focus on the familiar partner effect on JA. To the best of our knowledge, only a few studies considered partner familiarity as a variable in interactive JA tasks in the related literature and those focused on neural bases rather than behavioral outcomes (12,36). Our use of a real familiar partner, as opposed to a virtual character, and the exploration of factors such as partner familiarity and gaze cues, contribute to the ecological validity of our study and set it apart from existing research.

Finally, our study applied the zero-gap paradigm to control the possible effect of eye pathophysiology on JA. Nevertheless, no significant difference was found between the groups suggesting that such oculomotor functions might not differ markedly between ASD and TD-NCC individuals.

The study's limitations include its controlled experimental setup, which may have prevented the creation of an ecological environment. The absence of direct face-to-face interaction and reliance on verbal and symbolic cues could dilute the natural dynamics of JA.

Despite these constraints, our findings highlight the nuanced nature of social attention in ASD and suggest that interactive, visually-supported tasks could offer valuable insights into the mechanisms of social cognition in this population. Future research should consider larger, more diverse samples and integrate more naturalistic settings to better understand the complexities of JA in adults with ASD.

As a result, Joint attention deficits are critical indicators of social communication challenges from early childhood into adulthood. Despite limited research on adult manifestations, our findings suggest that collaborative multiplayer games are effective tools for assessing areas of social difficulty and developing appropriate interventions. These interventions could include specific tasks aimed at reducing social attention difficulties in daily life for individuals of all ages with ASD. This study not only sheds light on JA in adults with ASD but also encourages further exploration of gaming as a therapeutic medium to enhance social interactions and cognitive functions in this group.

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SUPPLEMENTARY

https://www.noropsikiyatriarsivi.com/uploads/NPA_28839_EN_SUPPL.pdf

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