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The effects of storytelling with or without social contextual information regarding eye gaze and visual attention in children with autistic spectrum disorder and typical development: A randomized, controlled eye-tracking study

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Abstract

This study examined the effects of storytelling with or without contextual information on children with autism spectrum disorder (ASD) and typical development (TD) using eye-tracker. They were randomized into 2 groups - the stories included and did not include social contextual information respectively. Training was delivered in groups, with eight sessions across four weeks, 30 minutes/session. Participants' fixation duration, visit duration, and fixation count on human faces from 20 photos and a video were recorded. Our findings revealed that storytelling with social contextual information enhanced participants' eye gazes on eyes/ faces in static information (photos) for both children with ASD and TD, but the same advantage could not be seen for children with ASD in regard to dynamic information (videos).

(Clinical trial registration number (URL: http://www.clinicaltrials.gov): NCT04587557)

(Words: 120)

Keywords: autism spectrum disorder, storytelling, social contextual information, eye tracking, occupational therapy

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Introduction

The direct human gaze is believed to be one of the most important elements of social interaction and communication (Csibra & Gergely, 2006). The mutual gaze of two people commonly establishes their "openness" to one another's communication. It represents a signal for two people to engage in interaction, while subsequent intermittent mutual gazes serve as signals to continue the interaction (Kendon, 1967). People with autism spectrum disorder (ASD) are characterized by persistent deficits in social communication and social interactions across multiple contexts (American Psychiatric Association, 2013). Deficits in verbal and nonverbal social communication skills (e.g., a lack of facial expression, eye contact, or understanding and use of gestures) (Karal & Wolfe, 2018) vary across different clients. People with ASD show atypical gazes, as compared with individuals with typical development (TD). They show reduced direct gaze (Senju & Johnson, 2009) and gaze maintenance (Wang, Xu, Jiang, Zhao, Hurlemann, & Adolphs, 2014). They often withdraw from direct eye contact and face-related tasks (Macrae, Hood, Milne, Rowe, & Mason, 2002), as well as face-to-face communication (Spezio, Adolphs, Hurley, & Piven, 2007). This social behavior is usually misunderstood as being "inattentive" by teachers. Recent literature concerning gaze and social attention reveals that this indistinguishable performance in regard to gazes and visual searches in individuals with ASD is probably due to amygdala lesions

(Wang et al., 2014); that is, their gaze-avoidance behaviors are innate deficits in their brain, rather than intentional in nature.

The method of Social Stories™ was first introduced by Carol Gray in 1993. It is described as a situation, concept, or specialized social skill that is meaningful for children with ASD (Gray & Garand, 1993). It aims to improve the social understanding of people with disabilities, enabling them to learn and perform social behaviors appropriately while reducing aggressive behaviors toward others, as well as other behaviors, such as inappropriate hugging. There are three approaches to implementing Social Stories™ (Gray & Garand, 1993): i) reading by caregivers, ii) presenting by means of audio equipment, such as a cassette tape, and iii) presenting by means of video equipment, such as a videotape, in the form of standard Social Stories™ (Quirmbach, Lincoln, Feinberg-Gizzo, Ingersoll, & Andrews, 2009; Bader, 2006, Feinberg, 2001, Romano, 2002), music-based storytelling (Schwartzberg & Silverman, 2013), computer-assisted storytelling (Pop, Simut, Pintea, Saldien, Rusu, Vanderfaeillie, David, Lefeber, & Vanderborght, 2013; Mancil, Haydon, & Whitby, 2009), and robot-assisted storytelling (Pop et al., 2013; Vanderborght, 2012). Therapists should choose the most appropriate form of implementation according to the needs of individual children. Standard social stories should be composed of two-to-five descriptive,

perspective, or affirmative sentences for every directive sentence in the story, and additional control and cooperative sentences should be added to the story (Gray, 2000). A systematic review of six controlled trials evaluating social stories aimed at people with ASD found that five out of six studies had positive outcomes; social stories may therefore be beneficial in terms of modifying target behaviors among high-functioning children with ASD (Karkhaneh et al., 2010).

Pierson and Glaeser (2007) found that both social stories and comic strip conversations assisted students with resolving difficult social situations in terms of increasing eye contact and voice volume when they greeted others. The social situation displayed in the story should be taken directly from each student's daily life, aiming to enhance their social skills in a specific social situation. Pierson and Glaeser concluded that either storytelling or social stories enable participants to generalize solutions to social situations and gain better self-perceptions of their behaviors in social situations. This study suggested that it is not social stories but rather the social contextual information of storytelling that enhances the targeted behaviors in children with ASD. The facilitation of children with ASD in regard to understanding a specific social situation can improve their pro-social behaviors, including eye gazes, on-task behaviors, and looking at others (Pop et al., 2013; Pierson & Glaeser, 2007; Soenksen & Alper, 2006).

Studies also indicate that the social contextual information of different approaches and forms of training (e.g., Social Stories™ and comic strips) work in regard to the social cognition (Zilbovicius et al., 2006) of children with ASD. According to the Directed Attention Model (DAM) (Frischen, Bayliss, & Tipper, 2007), social contextual information increases gaze detection, as well as face identification. Therefore, the gaze direction of children with ASD and visual attention in response to storytelling with social contextual information (faces, eyes, or mouth) can be enhanced.

Our recent study showed that eye tracking is a useful way of identifying the immediate effects of colored overlays in regard to improving the ocular performance and reading speed of preschool children with ASD or TD (Fong et al., 2019). Therefore, the objectives of this study were to investigate the effects of storytelling with social contextual information on eye gaze and visual attention, using eye tracking, in regard to both children with ASD and children with TD, and to compare the effects of social contextual information or the lack of such information in the storytelling on children with ASD and their healthy counterparts. We also hypothesized that both domain-specific attention such as vigilance and visual attention, etc. and modality-specific attention - eye gaze, would improve after the interventions using storytelling in both populations.

Methods

Participants

This was a randomized, controlled study with a 2 x 2 x 2 design, involving two groups of participants: children with ASD and children with TD. Children with ASD and age matched children with TD were recruited by convenience sampling from a private center for child development and a mainstream primary school, respectively. They were further randomized into two training groups: storytelling with or without social contextual information. Therefore, there were four groups in the study: 1) ASD Group 1 – storytelling with contextual information; 2) ASD Group 2 – storytelling without contextual information; 3) TD Group 1 – storytelling with contextual information; and 4) TD Group 2 – storytelling without contextual information. The intervention was conducted by an occupational therapist in small groups consisting of three-to-five children, in a private clinic setting or in the school the children attended. Whenever six-to-10 children were recruited consecutively at a time, randomization by drawing lots was performed among all eligible participants by a therapist who was unaware of the purpose of the training. Participants and their caretakers were also unaware of the results of the group allocation. The subject recruitment and randomization were performed and repeated four times in both the ASD and TD groups, until all children

were recruited in each group. Demographic information was obtained from the children's parents by means of self-reporting. The IQ information of children in the ASD groups was reported by parents, based on their children's reports from clinical or educational psychologists in the public child assessment centers.

The inclusion criteria of the ASD groups were: 1) children aged between 6 and 12 years old; 2) had a previous diagnosis of ASD from medical professionals; 3) studied in mainstream primary school; 4) had a composite IQ score of 80 or above (caregiver-reported), based on the test results from the government's child assessment centers (low average (80-89); average or above (≥ 90)). The inclusion criteria for the TD groups were; 1) children aged between six and 12 years old; 2) had no developmental disorder or intellectual disability; 3) attended primary school. The IQs of the children with TD were considered as average or above (≥ 90) in the study. Informed and written consent was obtained from the children's parents or guardians before study participation began. The study was conducted according to the principles of the World Medical Association Declaration of Helsinki. Ethical approval was sought from the Human Study Ethics Committee of the [redacted] (ref. no.: HSEARS20160427001). The clinical trial registration number (URL: http://www.clinicaltrials.gov) is: [redacted].

Outcome Measures

Tobii Eye Tracker

Tobii X2-60 Eye Tracker is a comprehensive electronic device that is fixed on a computer, with an accompanying program Tobii Studio™ installed on the computer. The eye tracker was used to measure eye fixations on the visual display and to generate precise eye gaze data and the software is used to detect, record, and analyze eye gaze, eye movement, and eye tracking data. The eye tracker uses infrared illuminators to generate reflection patterns on the participant's corneas during tracking on a computer screen. It offers freedom of head movement and does not require fixing the participant's head during tracking. Its exceptional tolerance of substantial, dynamic head movement allows for minimal restrictions on the subjects' natural actions, particularly young children, who cannot sit still for long periods of time (Fong et al., 2019). A total of 20 photos were displayed to the children on a laptop. Of these photos, 10 were of objects and 10 were human facial expressions showing emotions in different social contexts. The time interval for the display of each photo was five seconds. A video of a person brushing the teeth, 113 seconds in length, was displayed after the photos. Area of interests (AOI) were set on the human faces, including eyes, mouths, facial expression, in the photos and videos. The reason of using a video based on a typical activity of daily

living was that it could minimize any learning effect in situations with pure social context (e.g., greetings) which affected their gaze on faces and eyes in the video. Total fixation duration (TFD), total visit duration (TVD), and total fixation count (TFC) on the AOI were recorded, in seconds, using the Tobii eye tracker. TFD refers to the sum of duration for all fixations within an AOI; TVD is the duration of all visits within an active AOI while TFC measures the number of times the participants fixated on AOIs. These three indicators were chosen because TFD and TVD were measuring the time that children maintained their gaze at a point within AOIs and between two points within AOIs. They are important functional representations for a child to maintain their gaze at or between eyes, nose or mouth on a person's face.

Trail Making Test

The Trail Making Test (TMT) was developed and validated by Reiis (1971) primarily as a test of motor speed and visual attention in children aged nine years or above with brain damage (Gaudino, Geisler, & Squires, 2008). This measurement tool was adopted for young children aged between five and 14 years old, for normative data exploration and measurement tools in the literature (Arango-Lasprilla 2017; Bialystock, 2010; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012; Arango-Lasprilla, Ramos-Usuga, & Vergara-Moragues; 2017). In the Trail Making Test A (TMT-A),

children are asked to draw lines to connect 25 consecutive numbers in the correct order. They are not allowed to lift their pencils from the paper throughout the test. Time, in seconds, is recorded. In the Trail Making Test B (TMT-B), children are asked to draw lines to connect 12 numbers and 12 letters, alternatively. They are not allowed to lift their pencils from the paper throughout the test. Time, in seconds, is recorded. TMT-A is a test of visual attention to visually shift one's gaze from a number to another and visually search the next number in sequence, while TMT-B is a more complex task that demands one's attention to visually shift and search, and select between numbers and alphabets. Dugbartey, Townes, and Mahurin (2000) found no performance differences in ~~Part A of the~~ TMT-A and Part 1 of the Color Trails Test (CTT). Lee and Chan (2000) found that there was a strong correlation in ~~Part B of the~~ TMT-B and Part 2 of the CTT with equivalent constructs in [redacted]. T~~herefore, t~~he TMT is also a valid measurement tool in this study for children aged between six and 12 years, whereas the CTT is only useful for children aged between eight and 16 years.

Procedures

In the first session, participants immediately received the intervention after pretests. The intervention consisted of eight sessions across four weeks, two sessions per week, 30 minutes per session. During the fourth week, posttests were conducted immediately

after the last intervention. This study was a single-blinded study; parents and participants with ASD or TD were unaware of the purpose of the treatment provided and did not know which intervention groups they belonged to. All assessments were carried out by the investigators who are occupational therapists and were aware of the intervention's purpose.

Individual make-up sessions were provided to participants who were absent. However, there was one class suspension for all primary schools due to the seasonal influenza pandemic; 10 participants in the ASD group (five in each of the training groups) therefore only received seven training sessions in total.

Interventions

I) Training Group 1: Storytelling with social contextual information

A storytelling app (SAHK, 2013) was used: Four out of 100 stories that incorporated social contextual information and inter-personal skills were selected. The contents of the four stories involved: i) how to greet others; ii) what to do when someone talks to you; iii) what to do when you meet friends; and iv) how to make other people happy. Three of the four social stories involved the words "looking at others" or "direct gaze". All of the stories were read by a therapist in each session.

II) Training Group 2: Storytelling without social contextual information

Four out of 100 social stories from the same app (SAHK, 2013) were chosen under the category of "in the community". The social stories did not include social contextual information. Instead, the contents are daily activities without a social contextual component, which included: i) how to buckle a safety belt; ii) how to get in a car; iii) why we go to the doctor; and iv) how to see a doctor, etc. None of them mentioned any target social behaviors (e.g., saying hello, looking at others, or direct eye contact, etc.). The procedures, intensity, and duration of the intervention for the control group were the same as for the training group.

Statistical Analysis

Demographic data and baseline outcome measurements were compared between the ASD and TD groups. Intention to treat (ITT) with a last observation carried forward (LOCF) method was carried out for dropouts during the data analysis. Meanwhile, either a chi-square test or a t-test was used to check whether or not the baseline measurements (including TMT-A, TMT-B, TFD on photos and videos, TVD on photos and videos, and TFC on photos and videos) were comparable between the ASD and TD groups (Table 1). Any significant differences in the baseline measurements between the two groups were treated as co-variates of the repeated measures analysis of covariance (RANCOVA), to compare eye gazes on the AOI across the two interventions

(storytelling with and without social contextual information) and between the two groups (ASD and TD).

Results

Figure 1 shows that flowchart of participants in the study. A total of 26 children with ASD and 26 closely age-matched children with TD were recruited via convenience sampling from two centers in the community: a private development center and a mainstream primary school, respectively. One child in ASD Group 2 dropped out after the fourth session due to family issue, without completing a posttest. One child in TD Group 2 dropped out immediately after the baseline assessment. Table 1 shows the participants' demographics, including the age, gender, and IQ of each participant in the ASD and TD groups. There were significant differences in demographics between the ASD group and the TD group in regard to gender and IQ. More boys and lower IQ scores were found in the ASD group. A comparison of the baselines between the two groups showed that the total fixation duration (TFD) on photos and videos, and the total visit duration (TVD) on photos were significantly higher in the TD group than in the ASD group. Therefore, gender, IQ, baseline of TFD on photos and videos, and baseline of TVD on photos were used as co-variates during the RANCOVA.

Table 2 shows the mean differences in dependent variables between the social contexts of the ASD and TD groups. There were significant improvements in ASD Group 1 in regard to TFD – photo (p = 0.005) and TVD – photo (p = 0.031) using storytelling with a social context, compared to those in ASD Group 2. RANCOVA was used to evaluate the training outcome data (Table 3) and Wilk's Lambda test result in multivariate analysis was adopted. Results were analyzed by means of: i) eye gaze on photos and ii) eye gaze on videos on the AOI. With regard to eye gaze on photos, TFD on photos showed significant time vs training interaction effect~~within-group differences~~ (p = 0.008; effect size~~observed power~~ = 0.152~~0.775~~) ~~and between-group differences (p = 0.008; observed power = 0.775)~~. Second, significant time vs training interaction~~within-group differences~~ (p = 0.037; effect size~~observed power~~ = 0.097~~0.775~~) ~~and between-group differences (p = 0.037; observed power = 0.775)~~ were found in regard to TVD on photos. Finally, TFC on photos also showed significant~~ly~~ time vs training interaction~~increased within groups~~ (p = 0.043; effect size~~observed power~~ = 0.092~~0.53~~) ~~and between groups (p = 0.028; observed power = 0.604)~~.

With regard to gazes on the video, Wilk's Lambda test result was adopted. The interaction between time and group in TFD on videos was significant~~ly increased in both the ASD and TD groups~~ (~~F = 0.786;~~ p = 0.010; effect size~~observed power~~ =

0.145~~0.752~~), regardless of whether or not the interventions included contextual information. Second, the results of TVD on videos indicated that there were significant time vs group interaction~~within-group differences~~ (~~F = 0.439;~~ p = 0.002; effect size~~observed power~~ = 0.202~~0.896~~). ~~Third, TFC on videos increased marginally in the ASD group, more so than in the TD group (F = 1.349; p = 0.051; observed power = 0.502), but the results were not significant.~~ Last, TFC on the video shows a statistically significant time vs group vs training~~within-group subject~~ interaction effect (~~F = 1.349;~~ p = 0.046; effect size~~observed power~~ = 0.089~~0.520~~) across the two interventions in the two groups~~type of centers~~.

Regarding the results of TMT, there were no significant ~~within-group or between-group~~ differences between training and across time for the ASD and TD groups.

Discussion

This is the first randomized controlled study using eye tracking with two groups of children with ASD and TD, respectively, in regard to storytelling with and without social contextual information. This study adopted convenience sampling to recruit children with ASD or TD. Significant heterogeneity, including in regard to gender, IQ, TFD on photos and videos, and TVD on photos, was found in the baseline measurements among the ASD and TD groups. This was inevitable, since the prevalence of ASD is higher in males than females (around 4:1) (Maenner et al., 2020). It was therefore inevitable that there was a higher proportion of male children recruited in the ASD group, compared with the TD group. Moreover, 66% of children with ASD are associated with various severities of mental retardation. As a result, there was a much higher possibility of recruiting male children with ASD with lower IQs, compared with the children with TD in this study.

This study hypothesized that storytelling with social contextual information improved the visual attention or gaze direction of children with ASD. However, we found that the TFD, TVD, and TFC on the AOI of photos increased in both the ASD and the TD groups after the intervention. This demonstrated that storytelling with social contextual information was also useful to children with TD regarding eye gazes on eyes or faces in social contexts. We combined the visualization (e.g., the use of pictures or

photographs and computerized-presented social stories) and gaze cues to enhance children's attention to faces or eyes in this study. The method worked for both children with ASD and children with TD. This is consistent with the findings of Seydyn (2017), who investigated the preferences of children with ASD and TD in regard to board-maker images and photographs, and found that the ASD group looked less at the eyes in pictorial and photographic social stories than the TD group did. Even though there was more improvement in the eye gaze on the AOI of photos in the ASD group (ASD Group 1) than in the TD group (TD Group 1), the general time for TFD, TVD, and TFC was much less for the children with ASD than for the children with TD.

However, the TVD, TFD, and TFC on the AOI of photos showed a more significant increase in the social context group than the group without social context in regard to both children with ASD and children with TD. When we looked into the details of the pretest and posttest mean times across both populations, it was found that the TFD and the TFC on videos increased in the ASD group and decreased in the TD group. Social stories, regardless of the presence of social contextual information, preliminarily enhanced the dwell time on face or eyes in regard to video of children with ASD. However, further investigations and research should be carried out to validate this discovery. O'Handley, Radley and Whipple (2015) found that both social stories and

video modeling assisted students with resolving difficult social situations in terms of increasing eye contact when they greeted others. The facilitation of children with ASD with regard to understanding a specific social situation can improve their pro-social behaviors, including eye gazes, on-task behaviors, and looking at others, etc. (Pop et al., 2013). In the first place, children with ASD orient their gazes less toward areas containing social information (e.g., mouth and eyes versus the body of a person) (Chawarska, Macari, & Shic, 2013; Klin Jones, Schultz, Volkmar, & Cohen, 2002). They prefer instead to orient their gazes, visual fixation, and visual attention to areas within a photo containing less social information. Social Stories™ teaches children with ASD to cognitively understand appropriate social skills or social behaviors within a particular social situation (Ozdemir, 2010). Social contextual information in the intervention in this study was used to teach children with ASD to re-allocate their eye gaze toward more useful information, especially the faces and eyes of a person, when they greet others. These gaze cues directed the children's attention in photographic complex scenes (Freeth, Chapman, Ropar, & Michell, 2010). Karal (2018) stated that the visualization of pictures is a more effective means to catch attention than only written texts for children with ASD.

One of the important findings of this study was that storytelling with a social context had a significant intervention effect on the gaze of faces in photos, but not on the gaze of faces in videos in children with ASD. Moreover, e~~E~~ye gaze in regard to TFD and TVD on videos showed significant differences between the ASD and TD groups, regardless of the intervention. The TFC at the AOI on videos also showed borderline differences between the ASD and TD groups. The ASD groups demonstrated less eye gazes at faces or eyes in videos than the TD group did. This finding is consistent with the study results of Grossman, Zane, Merten, and Mitchell (2019)~~. Grossman et al. (2019) found~~ that children with ASD showed significantly less gazing at faces than the neurotypical group in the study when viewing a social video. Grossman et al. also discovered that children with ASD showed significantly more dwell time on the moving background than children with TD did in a screen-based task. Our finding was consistent with another study that showed young adults with ASD demonstrated better performance in static stimuli than dynamic stimuli for identifying the face emotion (Enticott et al., 2014). Cilia et al. (2019) also found ASD children showed similar visual exploration to identify precisely more AOIs in photos but not in videos when compared with children with typical development. One~~This might be o~~ne of the reasons why children with ASD showed less gaze on faces in videos than photos ~~the children with TD did in our study~~ is that bimodal dynamic stimuli – sound and movement, requires

more attentional resources and children with ASD might lose interest in a video stimulus when it featured both movements and verbalizations (Cilia et al., 2019).

It was disappointing to find that there was no significant difference in the results regarding TMT in the children's visual attention after the interventions. There are two channels of attention, domain-specific modulation become responsive to arousal levels and cognitive state while modality-specific modulation refers to tasks of selective attention such as focusing on a visual task but filtering out the irrelevant auditory distractions (Mesulam, 2000). Gaudino et al. (1995) stated that the TMT is an assessment of motor speed and visual attention. Visual attention refers to a set of cognitive operations that mediate the selection of relevant information and the filtering out of irrelevant information from cluttered visual scenes (McMain & Kastner, 2009). Our findings show that storytelling with a social context might have a significant intervention effect on improving modality-specific attention in both children with ASD and TD, but not on the domain-specific attention. Moreover, t~~T~~he assessment that takes place in TMT involves a high proportion of motor speed in terms of paper-and-pencil tasks, and executive function in terms of planning, working memory, and cognitive flexibility in TMT-B. However, in our interventions, children (with TD or ASD) selected the faces or eyes (AOI) and maintained their gaze on the AOI in the photos and

videos with different backgrounds and contexts, which might not have involved any motor speed, cognitive flexibility, or task alternation.

Limitations

This study investigated the pretest and posttest results of two types of intervention (social stories with social contextual information and social stories without social contextual information). A 2 x 2 x 2 (two clienteles x two interventions x two assessment times, pretest and posttest) design was used. There was no follow-up measurement in this study to explore the generalization of treatment effects across time. Further investigations in regard to follow-up measures are suggested in future studies. Second, there was no sample size estimation before the study; we therefore do not know if the sample size limited the power of the study's results. A larger sample size is highly recommended. Third, although the participating children and their parents were blinded to the intervention, the investigators and administrator who carried out the interventions were aware of the intervention's aims. Future studies might consider double-blinding all those involved, so as to minimize potential bias. On the other hand, other eye-tracker indicators, such as first gaze time in AOIs and first gaze point order (i.e., the order of AOI's first gaze among all the gaze points), had not been used in this study. These data should be useful to see whether the intervention can change the order of processing of

face and non-face areas in children with ASD. Finally, we did not measure eye gaze in real life. The gaze behavior of the children with ASD during the screen-based tasks was therefore not significantly correlated with their gaze behavior during live interactions (Grossman et al., 2019). The generalization of attention and gaze behavior during real-life face-to-face social situations would be much more difficult to measure than that during pictorial or video social scenarios.

Conclusion

We found that storytelling with social contextual information improved the gaze behavior at faces or eyes (AOI) in both children with ASD and children with TD when both were assessed with photos (static information) displayed on a screen, but the same advantage could not be seen for children with ASD in regard to screen-based videos (dynamic information). Children with TD demonstrated more gazing behavior on the AOI than children with ASD did when both of them were assessed with 20 photos and one video displayed on a computer, regardless of the types of interventions – storytelling with and without social contextual information. Future studies with larger sample sizes and follow-up measurements investigating the effects of storytelling with social contextual information on eye gaze in children with ASD using eye trackers should be further explored.

(Words: 4,124)

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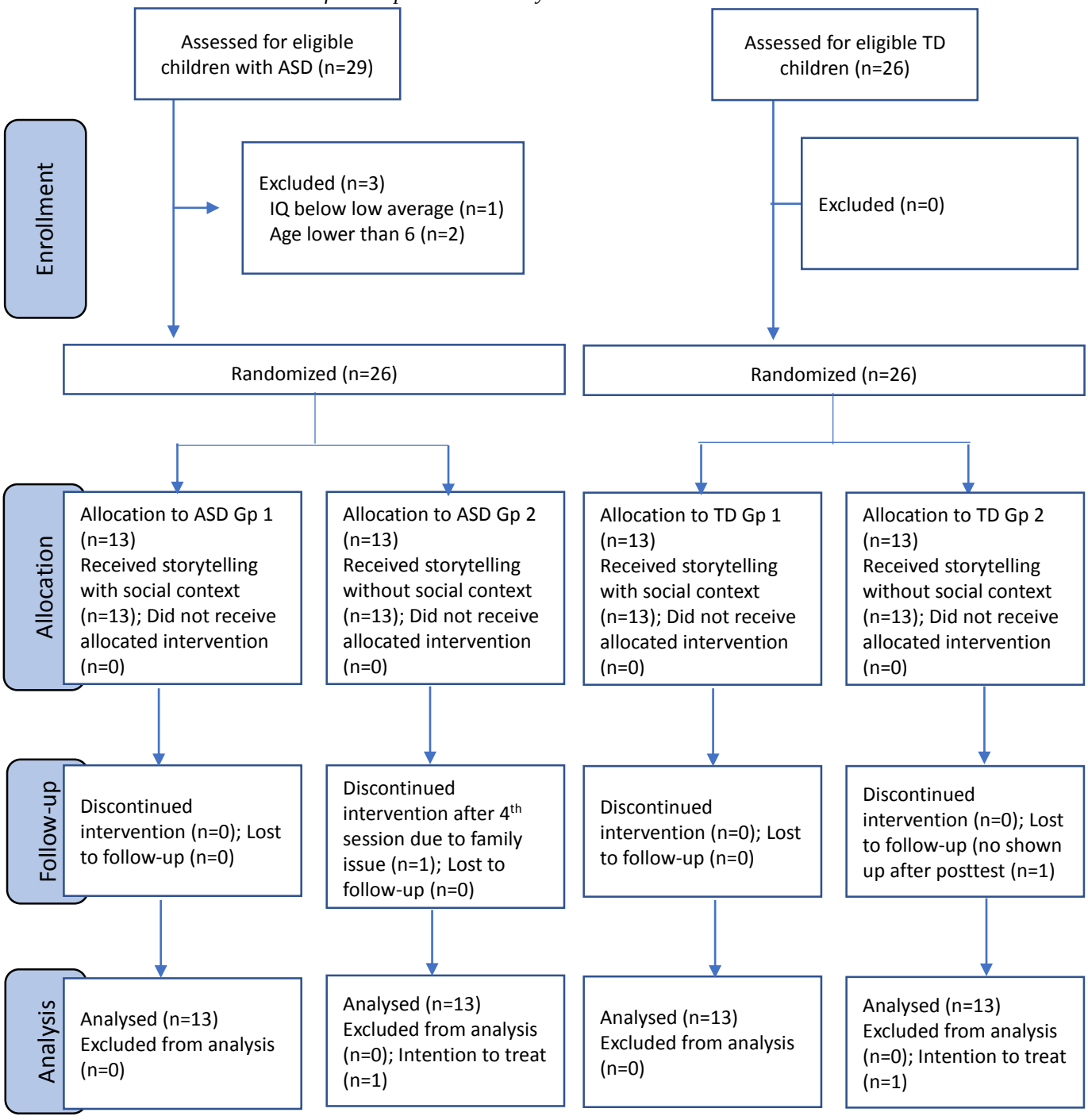
Figure 1

CONSORT Flowchart of Participants in the Study



Note: ASD – Autism Spectrum Disorder;

TD – Typically Developed

Intervention A denotes Social stories with contextual information, experimental arm

Intervention B denotes Social stories without contextual information, comparator arm

Intention to treat (ITT) was undergone in dropouts during data analysis.

Table 1 Demographics and Baselines for All Participants

	ASD Group (n = 26) Mean (SD)	TD Group (n = 26) Mean (SD)	Levene's test for equality of variances	p[a]
Age (months)	92.27 (16.15)	98.77 (18.78)		0.467
Gender, n (%)				**0.035**[#*]
Male	24 (92.31%)	18 (69.23%)		
Female	2 (7.69%)	8 (30.77%)		
IQ				**0.000**[#**]
Average or above, n (%)	14 (53.85%)	26 (100%)		
Low average, n (%)	12 (46.15%)	0 (0%)		
TMT-A (sec)	54.27 (34.77)	39.42 (19.10)	0.045	0.062
TMT-B (sec)	110.42 (64.51)	104.04(59.26)	0.881	0.712
TFD – photo (sec)	1.32 (0.35)	1.66 (0.42)	0.278	**0.003****
TFD – video (sec)	18.00 (6.62)	22.63 (6.11)	0.605	**0.012***
TVD – photo (sec)	1.43 (0.35)	1.74 (0.42)	0.234	**0.005****
TVD – video (sec)	20.86 (6.38)	23.71 (6.29)	0.481	0.320
TFC – photo	5.33 (1.12)	5.63 (1.03)	0.868	0.111
TFC – video	69.40 (21.13)	76.51 (26.51)	0.089	0.290

Note: [a]t-test; [#]chi-square; *p < 0.05; **p < 0.01; ASD = autism spectrum disorder; TD = typical development; TMT-A = Trail Making Test A; TMT-B = Trail Making Test B; TFD – photo = total fixation duration – photo; TFD – video = total fixation duration – video; TVD – photo = total visit duration – photo; TVD – video = total visit duration – video; TFC – photo = total fixation count – photo; TFC – video = total fixation count – video.

Table 2 Mean Differences in Dependent Variables between Social Contexts among ASD and TD Groups

	Pretest measurement						Posttest measurement					
Group	ASD Gp 1 (n = 13)	ASD Gp 2 (n = 13)		TD Gp 1 (n = 13)	TD Gp 2 (n = 13)		ASD Gp 1 (n = 13)	ASD Gp 2 (n = 13)		TD Gp 1 (n = 13)	TD Gp 2 (n = 13)	
Context	With social context	Without social context	p[a]	With social context	Without social context	p[a]	With social context	Without social context	p[a]	With social context	Without social context	p[a]
Variable	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
TMT - A (sec)	60.31 (35.46)	48.23 (34.39)	0.387	39.31 (21.63)	39.54 (17.10)	0.976	45.08 (22.41)	32.77 (12.28)	0.095	32.00 (15.28)	34.77 (15.72)	0.653
TMT - B (sec)	115.92 (62.56)	104.92 (68.49)	0.673	108.77 (73.97)	99.31 (42.38)	0.693	108.00 (67.71)	83.62 (72.48)	0.384	72.69 (34.53)	83.54 (49.14)	0.521
TFD – photo (sec)	1.36 (0.31)	1.27 (0.39)	0.538	1.59 (0.41)	1.73 (0.43)	0.436	1.63 (0.37)	1.19 (0.36)	**0.005****	1.70 (0.39)	1.57 (0.42)	0.388
TFD – video (sec)	18.07 (6.42)	17.92 (7.08)	0.956	21.95 (5.83)	23.30 (6.55)	0.584	18.41 (3.28)	17.76 (4.59)	0.684	21.88 (6.02)	23.29 (5.70)	0.544
TVD – photo	1.47 (0.30)	1.39 (0.40)	0.605	1.65 (0.42)	1.83 (0.41)	0.280	1.72 (0.39)	1.39 (0.35)	**0.031***	1.78 (0.41)	1.69 (0.43)	0.564
TVD – video	20.98 (5.62)	20.74 (7.29)	0.926	22.76 (5.82)	24.66 (6.83)	0.453	20.58 (3.37)	19.58 (5.49)	0.583	23.06 (4.85)	24.24 (5.28)	0.556
TFC – photo	5.61 (1.05)	5.06 (1.17)	0.221	5.49 (1.18)	5.78 (0.89)	0.479	5.75 (1.35)	4.98 (1.08)	0.123	6.09 (1.03)	5.35 (0.82)	0.052
TFC – video	69.88 (15.17)	68.92 (26.45)	0.910	72.23 (26.05)	80.79(27.31)	0.832	67.00 (18.21)	72.51 (18.80)	0.455	79.08 (24.26)	71.63 (19.72)	0.399

Note: [a]t-test; *p < 0.05; **p < 0.01; ASD: autism spectrum disorder; TD: typical development; TMT-A: Trail Making Test A; TMT-B: Trail Making Test B; TFD – photo = total fixation duration – photo; TFD – video = total fixation duration – video; TVD – photo = total visit duration – photo; TVD – video = total visit duration – video; TFC – photo = total fixation count – photo; TFC – video = total fixation count – video.

Table 3

Results of RANCOVA Repeated Measures

	Box's test of equality of covariance matrices	Interaction	p	Effect size
TMT - A	F = 3.247	Time*Group	0.360	0.020
	p = 0.001	Time *Training	0.770	0.002
		Time *Group*Training	0.312	0.024
TMT - B	F = 3.928	Time *Group	0.396	0.017
	p = 0.000	Time *Training	0.741	0.003
		Time *Group*Training	0.090	0.065
TFD – photo	F = 0.188	Time *Group	0.368	0.019
	p = 0.995	Time *Training	**0.008****	0.152
		Time *Group*Training	0.343	0.021
TFD – video	F = 0.786	Time *Group	**0.010***	0.145
	p = 0.630	Time *Training	0.789	0.002
		Time *Group*Training	0.849	0.001
TVD – photo	F = 0.402	Time *Group	0.581	0.007
	p = 0.935	Time *Training	**0.037***	0.097
		Time *Group*Training	0.608	0.006
TVD – video	F = 0.439	Time *Group	**0.002****	0.202
	p = 0.915	Time *Training	0.810	0.001
		Time *Group*Training	0.604	0.006
TFC – photo	F = 0.475	Time *Group	**0.029***	0.106
	p = 0.892	Time *Training	**0.043***	0.092
		Time *Group*Training	0.149	0.048
TFC – video	F = 1.349	Time *Group	0.051	0.086
	p = 0.206	Time *Training	0.731	0.003
		Time *Group*Training	**0.046***	0.089

Note: at-test; *p < 0.05; **p < 0.01; ASD: autism spectrum disorder; TD: typical development; TMT-A: Trail Making Test A; TMT-B: Trail Making Test B; TFD – photo = total fixation duration – photo; TFD – video = total fixation duration – video; TVD – photo = total visit duration – photo; TVD – video = total visit duration – video; TFC – photo = total fixation count – photo; TFC – video = total fixation count – video.

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