ANALYSING INCLUSIVE GROUPS' PEER INTERACTIONS USING MOBILE EYE TRACKING IN EDUCATIONAL CONTEXT

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Abstract

Research abounds on deploying interventions to support peer interactions between children on the autism spectrum (AS) and neurotypical children. Technological advancements such as eye tracking devices have provided ample affordances to the field of autism research in terms of facilitating the collection of insightful data related to the gaze behaviour of children on the AS, making it possible to study the relationships between visual perception and action. Yet, further empirical understanding on how children interact within inclusive educational contexts is needed. We present our study set in a naturalistic inclusive school environment in which a small group of children interact playing a word-based boardgame, Alias, while wearing mobile eye tracking glasses. We analyse the gaze behaviour of each child from the perspective of the role taken during the gameplay: explainer, guesser, and observer. Results show promising insights on how mobile eye tracking technology can be used to analyse the gaze behaviour of children on the AS when compared with neurotypical peers, supporting the observation of a perceived sensitivity to the requirements of the game roles that the children play. Our work contributes towards empirical research implementations of mobile eye tracking glasses to understand natural peer interactions in inclusive educational environments. The insights obtained could assist teachers' classroom practises towards fostering children's collaborative work in inclusive educational contexts.

Keywords: gaze behaviour, naturalistic research environments, interactive collaborative games, children on the autism spectrum, inclusive learning environment.

1 INTRODUCTION

Studies reporting systematic observations of peer interactions in natural contexts between children on the autism spectrum (AS) and neurotypical children are well-documented in the literature. For example, Gilmore, Frederick, Santillan and Locke [1] reported a study observing the social behaviour (e.g., engagement and social communication with peers) of children on the AS during lunch and on the playground at school. The study presented insights on the children's challenges and successes during social interactions. The authors employed the Playground Observation of Peer Engagement (POPE) time-interval behaviour coding system as the data collection mechanism during observations [1]. The POPE coding system, introduced by Kasari, Locke, Gulsrud and Rotheram-Fuller [2], supports the structured observation of a target child that facilitates independent observers' recordings of the child's actions on the playground including behaviours of solitary, proximity, onlooking, parallel and parallel-aware playing, involvement in games with rules and joint engagement with peers. However, autism research in educational contexts has commonly focused on individuals' interactional challenges during free social encounters and has been criticised for failing to consider how social interactions are built in interaction with others (see for example [3], [4]).

Given the vast body of research documenting that people on the AS allocate less visual attention to people's faces and/or social actions [5], technology such as eye trackers could provide ample affordances when investigating social interactions in autism research [6]. Studies using mobile eye tracking technology and other novel eye tracking solutions have been able to examine gaze behaviours in relation to the interactions during which the participants' eye movements have been recorded (e.g., during conversational phases such as speaking or listening [7]), as well as to show how gaze allocation to other people and their faces is dependent on the task structure and social context [8]. However, interactions occurring in naturalistic settings have been rarely explored in detail. Dindar, Korkiakangas, Laitila and Kärnä [9] have pointed out how, for instance, an interactional partner's actions have received limited attention in prior research, which has prevented the more contextualised analysis of gaze that could consider how gaze not only reflects social visual attention but is also used for interactional purposes, such as to initiate interaction or to respond to others' initiations ([10], [11], [12]). Thus, there is still a gap in research towards the understanding of how social interactions between children on the AS and neurotypical children unfold in natural contexts while developing a collaborative school task within inclusive groups.

Addressing this gap, this paper presents our study using mobile eye tracking to explore how children use eye gaze during an interactive and collaborative boardgame, Alias, in a small inclusive group. Here we discuss the results and insights towards helping us to understand the social interactions practises between children and how to support them.

2 RELATED WORK

2.1 Mobile eye tracking in autism research

Eye tracking, as a data collection methodology, allows researchers to explore people's visual perception and attention by providing information of the user's eye movements. When analysed, these eye movements contain information such as where the user looks at, for how long, and how many times the user looked at specific areas ([13], [14]). However, eye tracking technologies in autism research have a set of methodological challenges [15]. Some of these challenges relate to the eye tracking equipment, testing environment and stimuli, followed procedure, and analysis. These challenges require particular attention to the needs of this population.

Many studies have utilised eye tracking in autism research [6], typically using screen-based or head mounted eye trackers, e.g., in measuring speech comprehension [16], exploring human-robot interaction [17], or exploring early signs of autism [18] and difficulties in social interactions [19]. However, compared to screen-based eye trackers, mobile and head mounted eye trackers have a unique advantage of allowing to conduct research in "ecologically-valid contexts, including live social interaction" [14]. A recent study explored the use of mobile eye trackers within the autism diagnosis process of the Autism Diagnostic Observation Schedule (ADOS) for children and adolescents [20]. This combined use of mobile eye trackers and validated diagnosis measures in an ecologically valid setting provides insight into the gaze behaviour and face processing of diagnosed individuals. While mobile eye tracking methodologies are increasingly used in autism research and in more ecologically valid contexts, the literature is limited in exploring children's gaze behaviours in naturalistic interactions, specifically in inclusive classroom contexts.

2.2 Peer interactions in autism research

Many children on the autism spectrum have been reported to have difficulties in developing the social competence required for appropriately interacting with peers. However, considerable individual differences have also been documented between children on the AS in the quality and quantity of interaction with peers ([2], [21]). Regardless of the individual differences, research has shown that compared to neurotypical peers, children on the AS may experience greater loneliness and difficulties in developing satisfying friendships and social networks ([22], [23]). Some research even suggests that these children have the fewest friendships of all disabled groups [24]. Addressing this, many interventions have been developed for improving social skills for instance through training ([25], [26]). One of the goals of social skill training is to enable children to better cope with their peers [26]. Although social skill training interventions demonstrate improved social skills in clinical settings, the developed social skills are not necessarily applied in children's daily lives at school [27], nor its effects always transfer to practise. Thus, interventions that incorporate the peer-group context in natural settings could be more beneficial for improving social skills [28] and peer relationships [29].

In this vein, previous research shows the effectiveness of games to teach social skills to children on the AS ([30], [31]). Game playing is particularly suitable for children on the AS because it is a structured activity that systematically breaks down into clear steps that facilitate the understanding of what each step means and what is expected. This, in turn, helps the child to interpret the meaning of the activity ([32], p. 35). Therefore, in recent years games on mobiles devices, in particular, have been used to enhance interaction between children on the AS and their peers ([33], [34]). Some studies have also used mobile eye trackers to investigate the eye gaze of children on the AS during game playing. For example, Alvares, Chen, Notebaert, Granich, Mitchell and Whitehouse [35] developed and tested the efficacy of a novel attention bias modification paradigm to alter the orientation of children on the AS to faces. The children played either a social attention training or a control game for 15 minutes. Children playing the training game were reinforced for attending to and engaging with social characters, whereas children in the control group were equally rewarded for attending to both social and non-social characters. Eye-tracking measures were obtained before and after gameplay. According to the results, there was a significant increase in the percentage of fixations to faces among children playing the training game compared to the control group. This highlights some of the affordances that mobile eye tracking technology brings to the autism research arena. Our study brings forward an analysis of gaze behaviour during a boardgame play among children on the AS and neurotypical peers towards supporting social interactions in inclusive classrooms.

3 STUDY DESIGN AND IMPLEMENTATION

3.1 Participants

25 children (age 10–12 years, 4^{th}–5^{th} grade, 15 males) from 3 different schools in Finland participated in the study. For data analysis, children were divided into 2 categories: children with no diagnosis (n=19) and children on the autism spectrum (AS) or having autism spectrum traits based on Autism Spectrum Screening Questionnaire (ASSQ) scores (n=6) [36]. Table 1 shows the participants' descriptions details. In each school, children were divided in small groups of 3, familiar to each other.

Table 1. Participants' description

Group	Children on the AS (n=6)	Children without diagnosis (n=19)
Average age in years (range)	10,5 (10,25 – 11)	10,7 (10,33 – 11,2)
Gender	all male	10 female
ASSQ scores, average (range)**	44 (32 – 76)	3,1 (0 – 20)
Neurodevelopmental diagnosis***	4 ADHD or ADD 2 Asperger Syndrome 1 PDD-NOS (autism spectrum) 1 Mixed specific developmental disorder 1 Dysphasia 1 Motoric difficulty	No neurodevelopmental diagnosis
Level of support****	1 child in intensified 5 children in special support	17 children in general support 2 children in intensified support

** Autism Spectrum Screening Questionnaire, combined scores of teachers' and parents' evaluation, recommended cut off score in Finnish population is 30 points [36]

*** Diagnoses according to ICD-10 [37], definition for neurodevelopmental diagnoses from ICD-11 [38]. The same child may have several diagnoses.

**** According the three-tiered educational support system in Finland [39]

3.2 Setting and Procedure

43 data collection sessions of about 45 minutes each were carried out during 2020-2021 distributed among the 3 participating schools. Each session was divided so that the small group of children engaged for 10 minutes in a ludic task planned by the researchers and for 25 minutes in a curricular task planned by the teacher. Here we present the analysis of the 9 sessions during which the interactive Alias boardgame was implemented (approximately 10 minutes per session).

The Alias boardgame[1] is a word game during which a person guesses the word that another person is explaining through hints and tips. In our study we set the game using 3 roles: *an explainer*, as the person giving clues for *a guesser* to guess what the word is, while *an observer* watches the interactions. During the data collection session, these roles alternated among the 3 participating children so that each child was an explainer, a guesser and an observer during the game time, and the roles rotated clockwise. In each group, there was one child on the AS or that had another neurodevelopmental diagnosis (e.g., special linguistic difficulty, ADHD, etc.). The game was set up so that in front of each child, 20 Junior Alias playing cards were placed, face down. Each card included a word alongside a picture representing the word. The cards were ordered similarly in all groups to standardise the order of the words to be explained. The children could skip a card and choose the next one if they wanted. A researcher gave instructions on how to play the game and had an hourglass (3 minutes) to control each child's turn as an explainer, as well as the rotation of the roles.

[1] https://alias.eu/

3.3 Ethical considerations

As the study included children ethical issues received special attention in all stages of the research. The study followed the procedures of ethically sustainable research manifested in the principles of the Finnish National Advisory Board of Research Ethics. In addition, the study obtained ethical approval from the Ethics Review Board of the University of Eastern Finland before implementing the research activities. Information concerning the aims, methods, implementation and data management of the study were provided to informants before asking them for written informed consent to participate in the study. Children and teachers were recruited on a voluntary basis from inclusive schools. The informed consent was requested from parents/legal guardians, teachers and the children themselves. The participants were informed that they had the right to withdraw from the study at any stage. All methodological procedures were planned and carried out in collaboration with the teacher to include no risk of causing any psychological, social, legal or other harm to the participating children.

4 METHODOLOGY

Our research implements a multimethod approach to data collection with the aim to explore how children on the AS and neurotypical children interact in the context of inclusive classrooms. In the present study, which is a part of a larger research endeavour, we present the analysis of mobile eye tracking glasses while children interact during a ludic activity in a small inclusive group composed of three children, all of which are using mobile eye tracking glasses.

4.1 Eye Tracking Data Analysis

We used Tobii Pro Lab (version 1.171) to analyse the eye-tracking data collected during the sessions and used the default Tobii Pro IV-T (Attention) gaze filter for filtering raw gaze samples. We manually annotated the time of interest (TOI) points and dynamic area of interests (AOI) within the Tobii Pro Lab software. Four main TOI frames were created to specify the start and endpoints of the Alias game, categorised according to the child's following roles in the game: Explainer, Guesser, Observer. These TOI points allowed us to map the timeframes to each role of the child and measure the gaze that fell within these timeframes of the Alias game. To capture where children's gaze points fell while playing the Alias game, we analysed the video recordings using Tobii Pro dynamic AOI annotations. We created four dynamic AOI regions within the video recordings: Face Areas (Face Left, Face Right), Task Area, Environment. The regions were manually annotated for each recording time frame, using the Dynamic AOI Tool provided by the Tobii Pro Lab software. An example annotation for the dynamic AOI setting is presented in Fig. 1. Finally, we extracted the total visit duration for each AOI and TOI for our analysis. We calculated the *proportional looking time*, that is, the total time a child spent looking at e.g., the face areas when in a Guesser role divided by the total time spent in a Guesser role multiplied by 100. Proportional looking time values are thus comparable between the children despite possible differences in game roles.

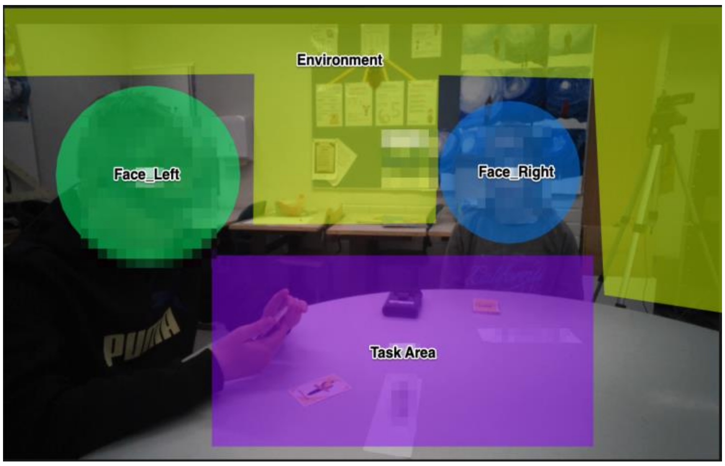

Fig. 1. Areas of interest designated for analysis: face area (left and right, corresponding to the faces of the other 2 participants), task area and environment area. ©PEICAS Project 2022

4.2 Statistical Analysis

The statistical analysis of the data was carried out using IBM SPSS Statistics. Given the notable size difference between the samples and the overall small number of participants, we used nonparametric tests for an exploratory analysis to examine the distribution of gaze within the groups of children on the AS and children without diagnosis. The within-group comparisons were conducted with related samples Friedman's two-way analysis of variance by ranks, with Dunn's pairwise post hoc test with Bonferroni correction.

5 RESULTS

Fig. 2 shows the overall percentage of time that each group (i.e., children without diagnosis and children on the AS) focused on each designated area of interest (i.e., face area, environment area and task area). During the entire gameplay (the three roles combined), children without a diagnosis tended to look more at other children's faces and at the task area than at the environment (with statistical significance, $p < 0.05$). A similar pattern can be observed in the children on the AS group.

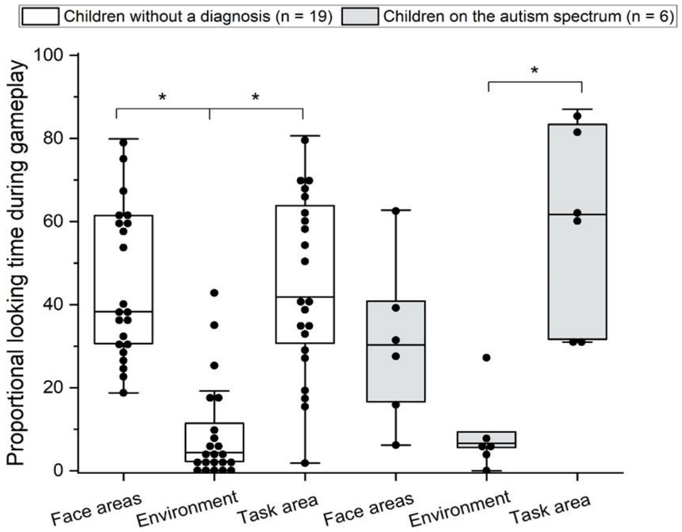

Fig. 2. Overall attention time distribution (in percentage) during Alias gameplay

Fig. 3 shows the percentage of time that each group of analysis spent focusing on a given area of interest during each role taken (i.e., explainer, guesser, observer) during Alias gameplay. A similar pattern is observed for the explainer role as in the analysis looking at the entire gameplay (Fig. 3, Left). During the guesser role, a similar overall pattern as for the entire gameplay is maintained, however both groups appear to reduce their attention time at the task area and increase their attention time at the face area (Fig. 3, Centre). The overall gameplay pattern is also shown during the observer role (Fig. 3, Right), however, the time looking at the environment slightly increased for both groups as compared to the explainer role, suggesting that both groups are sensitive to the fact they are not active participants in the game at the given moment.

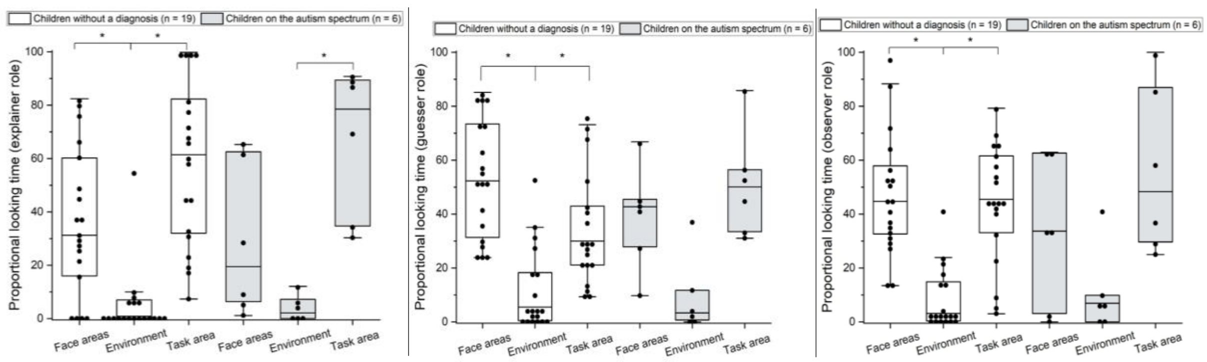

Fig. 3. Attention time distribution (in percentage) according to game role.
Left) explainer role; Centre) guesser role; Right) observer role

We wanted to explore the portion of time the children spent looking at the environment during gameplay to observe the subtleties of each game role. Fig. 4 indicates a within-group difference in the children without a diagnosis group between the amount of time spent looking at the environment when in the observer or guesser role as compared to the explainer role. That is, the children in this group spent longer attention time looking at the environment when in the observer or guesser roles compared to the explainer role. On the other hand, such a difference was not observed in the children on the AS.

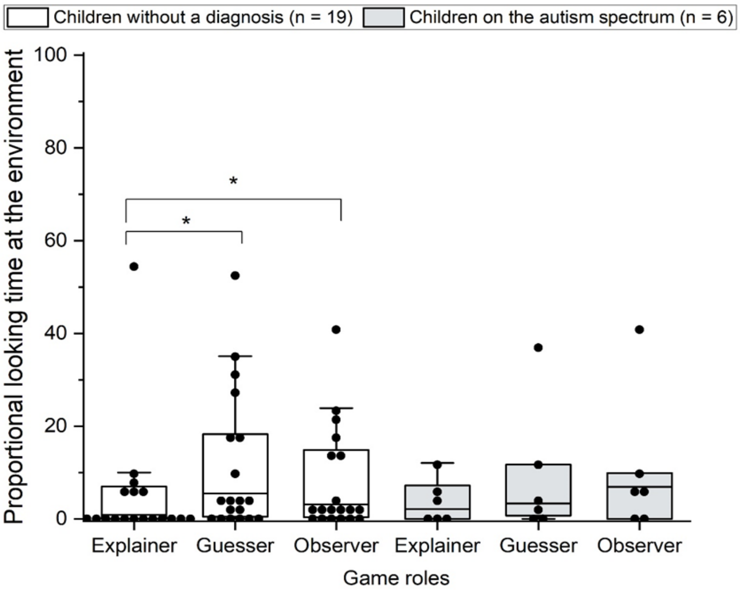

Fig. 4. Groups' overall time spent looking at the environment during each role taken

6 DISCUSSION

6.1 Importance of implementing eye tracking research

Studies using mobile eye tracking technology have been able to examine gaze behaviours in relation to the interactions during which the participants' eye movements have been recorded [7]. However, interactions occurring in naturalistic settings still could benefit from further empirical research. In our study, we addressed this by analysing the gaze behaviour of children in inclusive groups while working on a shared ludic task. Mobile eye tracking allowed us to explore the ways in which children on the AS use their gaze while interacting with peers while taking different roles that demand more, or less, of their visual attention. Previous research has already shown that how people look at other people's faces in face-to-face interactions is dependent on both the task carried out and the behaviour of the interactive partner ([8], [40]). In our work, despite the literature indicating reduced visual social attention in people on the AS [5], our findings suggest that the gaze behaviour of children on the AS is sensitive to the demands of the role taken during the interaction: *speaker*, i.e., explainer in the game; *active listener*, i.e., guesser in the game; or *passive listener*, i.e., observer in the game. Furthermore, in this study we observed that both neurotypical children and children on the AS displayed high attention to and engagement with the task at hand, as indicated by the amount of time looking at the task area (Fig. 2) and little time spent looking at the environment (Fig. 4). Our findings, therefore, demonstrate the usefulness of examining social attention and gaze allocation in its more detailed social context, as from an interactive perspective the timing of the gaze is also as important as the target of the gaze ([40], [41]).

Furthermore, our analysis showed the nuances of the gaze behaviour of children on AS during peer interactions, which was possible through mobile eye tracking as to achieve a deeper understanding and empirical evidence of how children on the AS, as well as neurotypical children, see the world. This calls for the need to rethink the "naturalness" of eye contact during interaction – even when eye contact is limited, this might not be an indication of lack of attention or concentration for children on the AS, as they might well be involved in developing the given task, in their own way. Therefore, this manner of interacting should be paid attention to, acknowledged and accepted. Moreover, looking at the perspective of children's play in educational contexts, mobile eye tracking research could be very beneficial for understanding the interactions that occur during gameplay.

6.2 Importance of supporting teachers' classroom management

Research has reported that well-designed inclusion strategies, e.g., when planning educational lessons, can be beneficial for everyone involved (see for example the Universal Design for Learning framework [42]). Research in the education realm also highly benefits from design-based research carried out in natural contexts, as otherwise the results would not properly reflect the complexity of the processes that occur in educational environments [43]. From these perspectives, developing research in naturalistic educational contexts can provide empirical evidence also for teachers to better understand the behaviour of children on the AS and how to recognise when they are engaged in their own interactive ways and the strategies that the children use (e.g., focusing more on the task area than of the peers' faces).

This has also implications for teaching development in terms of using different kinds of instructional materials as well as visual and verbal cues to support children's interactions efficiently and successfully in inclusive educational environments. In an earlier study, for instance, teachers reported no significant differences in the use of instructional materials between students on the AS and the remainder of their class [44]. Supporting this, mobile eye tracking technology may provide a more nuanced understanding on the ways students use instructional material in learning. In addition, another area to explore, furthering our observations, is the idea of gamification of the learning experience within inclusive environments, as children could learn more efficiently through gaming – using board games, as in our study, or through digital games. We noticed that providing a clear structure of the goals of the game supported the children to work logically and facilitated their collaboration.

6.3 Limitations

In terms of the data, the relatively small sample size of our study (n=25) was due to limited number of eye tracking equipment availability and challenges in accessing schools in the time of the COVID-19 pandemic. Therefore, the statistical analysis is exploratory and should be interpreted with caution, particularly in regard to the group of children on the AS. This group was heterogeneous because only half of children had an official AS diagnosis and almost all children had also another neurodevelopmental diagnosis, e.g., ADHD. Therefore, there are limitations about how well our results represent *purely autistic* gaze behaviour. Nevertheless, it is very common that other neurodevelopmental diagnoses co-occur with autism [45]. From that perspective, our data reflect the reality of inclusive classrooms, as the autistic traits measured by ASSQ were clearly higher in the group of children on AS. Gender distribution was also very different within this group, although this is in line with the reported literature that autism is much less diagnosed in girls than boys [46]. Due to this, however, our results may not represent the gaze behaviour of female children on the AS or any possible gender differences within this group.

In terms of the physical environment, to ensure the quality of the audio data and that there was enough space for the research equipment, our study was not carried out in the children's own classroom but in a separate room at their school. Carrying out research in classrooms would require permissions for all students' parents, including also non-participating children, which this study did not have. Even though these aspects may limit the transferability of the findings to gaze behaviour in everyday school activities, the research setting was as naturalistic as possible since the school room was familiar to the children, and therefore we argue that the findings' transferability could be higher than if the research would have been carried out in a laboratory setting. In addition, though the Alias game was a ludic activity selected by the researchers, not a teacher-designed curriculum-based activity, it was a familiar activity to most of the children and some of them mentioned that they had played it during school lessons. This can also support the naturalness of the participating children's gaze behaviour.

7 CONCLUSIONS

The results of this study showed that mobile eye tracking allows us to explore how children interact in a playful school environment. In addition, as all children were wearing eye tracking during gameplay it was possible to get a holistic view of the interaction from all participants' perspectives and to capture the complex dynamics between children as they occurred. This study contributes to the growing eye tracking research literature on the gaze behaviour of children on the AS, answering the call to carry out studies in naturalistic inclusive educational contexts. This kind of investigation could facilitate teachers' understanding of the behaviour of children on the AS, to recognise these children's interactive ways and strategies. This can result in the efficient development and successful implementation of teaching practises and materials that support social interactions among all children in inclusive educational environments.

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