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Visual Preferences of Elementary School Children with Autism Spectrum Disorder: An Experimental Study

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***Abstract*—**Visual preferences, which can be assessed using eye tracking technologies, are considered one of the defining hallmarks of autism spectrum disorder (ASD). Specifically, children with ASD show a decreased preference for social images rather than geometric images compared to typically developed (TD) children. Such differences are already prevalent at a very early age and indicate the severity of the disorder: toddlers with ASD who preferred geometric images when confronted with social and geometric images showed higher ASD symptom severity than toddlers with ASD who showed higher social attention. Furthermore, the complexity of social images (one child playing vs. two children playing together) as well as the mode of stimulus presentation (video or image), are not decisive for the marker. The average age of diagnosis for ASD in Germany is 6.5 years, and visual preference data on this age group are missing. In the present study, we therefore investigated whether visual preferences persist into school age. We examined the visual preferences of 16 boys aged 6 to 11 years with ASD and unimpaired cognition as well as TD children (1:1 matching based on children's age and the parent's level of education) within an experimental setting. Different stimulus presentation formats (images vs. videos) and different levels of stimulus complexity were included. Children with and without ASD received pairs of social and non-social images and video stimuli on a screen while eye movements (i.e., eye position and gaze direction) were recorded. For this specific use case, KIZMO GmbH developed a customized, native iOS app (KIZMO Face-Analyzer) for use on iPads. Neither the format of stimulus presentation nor the complexity of the social images had a significant effect on the visual preference of children with and without ASD in this study. Despite the tendency for a difference between the groups for the video stimuli, there were no significant differences. Overall, no statistical differences in visual preference occurred between boys with and without ASD, suggesting that gaze preference in these groups is similar at elementary school age. One limitation is that the children with ASD were already receiving ASD-specific intervention. The potential of a visual preference task as an indicator of ASD can be emphasized. The article discusses the clinical relevance of this marker in elementary school children.

***Keywords*—**Autism spectrum disorder, eye tracking, hallmark, visual preference.

I. Introduction

Autism spectrum disorder (ASD) is a neurological condition that affects the development of children. Key characteristics of ASD are deficits in social interaction and communication [1]. A key symptom in children with ASD is the so-called abnormal social attention [2], [3], that is defined as a visual preference for non-social stimuli compared to social stimuli [3]. Examining the characteristics of visual preference for social and non-social stimuli in children with ASD may therefore foster the understanding of deficits in social interaction [3]. Visual preferences can be measured using eye-tracking technology [4]. As a methodical example, [5] has developed an eye-tracking algorithm that calculates the child's gaze preference for social and abstract scenes. The study shows that the algorithm correctly discriminates left/right side of the screen preference (social/abstract scenes) and identifies distractions [5].

Findings by [6] suggest that when images of faces are presented together with images of an object related to their circumscribed interests, children with ASD show significantly less preference for the faces. Thus, the social attention of preschool children with ASD appears to be modulated by the attractiveness of competing non-social stimuli [6]. In contrast, a study by [7] suggests that atypical social attention is present in young children with ASD regardless of the competing non-social object. Their observation is supported by [8], who examined the influence of competing objects on visual preferences for eyes in children with and without ASD. All named studies are consistent in reporting that the ASD group had a significantly lower preference for faces or eyes than a typically developing (TD) control group [7], [8]. Reduced preference for dynamic object images negatively correlated with severity of social interaction impairment and was positively associated with age; nevertheless, IQ was not decisive for preferences [3]. However, a study by [9] shows that limited attention to a social scene (e.g., an actress with various activities) is not associated with an increase in attention to objects [9]. This finding is also supported by [10], in which children with ASD performed significantly worse on a test of face processing skills, but did not show differences in attention to faces compared to objects.

An important issue concerning analysis of visual preferences is the task used in experimental studies to measure this phenomenon. Reference [11] examined three different

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paradigms in terms of visual preference in children with ASD: (1) dancing people vs. dynamic geometric images, (2) biological motion of points of light vs. non-biological motion of points of light, and (3) a child playing with a toy vs. a child alone. Although all three paradigms discriminated between children with ASD and TD children, the first paradigm (dancing people vs. dynamic geometric images) was the most effective, as children with ASD showed a significantly higher preference for geometric patterns and had therefore the highest discrimination accuracy [11]. Similarly, the results of [12] support a preference of children with ASD for repetitive moving shapes compared to dancing children (social stimuli). However, when the social stimulus is minimized by a cartoon task that shows social and non-social cartoon stimuli with similar encounters, this visual preference cannot be demonstrated anymore [12]. A study by [13] also indicates a visual preference for non-social videos in children with ASD compared to TD children, even when the human faces were replaced with dog faces. In fact, preferring the non-social stimuli cannot solely be attributed to the avoidance of social stimuli [13].

Previous studies report a reduced preference in children with ASD for social images over geometric images compared to TD children [14]-[16], [11], [4]. As a key work in this field, [14] developed the GeoPref test to examine visual preference for social vs. non-social geometric videos. The social videos consist of children moving in dramatic manner and the geometric videos consist of animated, moving geometric shapes. In this task, a social video is presented simultaneously on one side of the screen and a non-social, geometric video on the other side of the screen. Results from [14] using the GeoPref test display significantly more time fixations on dynamic geometric images in toddlers with ASD ($n = 27$) at 14 months compared to TD ($n = 51$) and developmentally delayed toddlers ($n = 22$). The positive predictive value for accurately classifying a toddler as having ASD was 100% when the toddler spent more than 69% of their time fixating on geometric patterns [14]. Consequently, [15] argues that toddlers (10–49 months) with a greater preference for the geometric videos may be a marker for an ASD subtype with more severe symptoms (GeoPref effect). The children also showed reduced saccades (jerky backward eye movements after fixation) while watching geometric videos compared to TD children and other clinical groups [15]. The authors were able to show that the children with ASD who fixated on the geometric videos had significantly poorer cognitive, language, and social skills than the children with ASD who strongly preferred social videos [15]. Reference [16] used an adaptation of the GeoPref test to examine whether the GeoPref effect occurs in different levels of complexity of the social stimuli (higher complexity in the adaptation of the GeoPref test). The study reported that – regardless of the complexity of the social videos – prolonged fixations on geometric videos were associated with significantly higher severity of ASD symptoms in toddlers (12–48 months) [16]. Although, the GeoPref test was designed for infants under four years [14]-[16], a study by [4] showed that the children who fixated on the geometric images at that early age [15] also showed greater severity of ASD symptoms and reduced gaze shifts during the joint attention task at school age. Additionally, the study by [17] found a visual preference for repetitive movements over random movements in children with ASD, but not in controls. This preference for repetitive movements was related to the severity of repetitive behaviors in children with ASD [17].

On the one hand, an early indication of severe ASD symptoms can be found by comparing moving people with moving geometric shapes when children spend a longer period of time looking at the geometric shapes [15], [16], [4]. On the other hand, it may also be an early indicator of the severity of repetitive behavior [17]. The association of atypical visual preference with the severity of ASD symptoms and with repetitive behaviors leads to possible implications for diagnostic purposes. Additionally, a difference in fixation duration may be an additional indication of the presence of ASD, as described for adults without ASD who look more at social stimuli and for adults with ASD who show no difference in fixation between social and non-social stimuli [18].

In summary, the results of visual preference studies are not entirely consistent which may be explained by certain differences in the applied methodological paradigm. Key factors of methodical interest might be (1) contrast of social and non-social images, (2) complexity of the social images (one child playing vs. two children playing together; effects described by [16], contradictory results by [11] and [19]), (3) video stimuli (e.g., [11], [12], [20]) vs. image stimuli (e.g., [20], [6]). Unfortunately, an influence of the stimulus type (video vs. image) was not yet contrasted within one study. As a final aspect, (4) repetitive movements vs. random movements might be decisive for visual preferences giving the importance of repetitive movements for ASD-diagnosis. Previous studies have not differed systematically between these types of stimuli.

Regarding previously included age groups, visual preference has been studied primarily in infants, toddlers, preschoolers, and adults although visual preference may also be relevant criteria in the diagnosis of ASD (e.g., [4], [16], [15]). Since the age of diagnosis is often as late as elementary school age – especially in children with ASD and age-appropriate cognition – it is important to examine whether visual preferences are still apparent at school age. The average age of diagnosis for ASD in Germany is 6.5 years [21] and long waiting periods for diagnostic appointments occur. To ease this situation of families and professionals, the ongoing research project IDEAS (funding code: 13GW0584D) aims to develop a tablet-based, digital screening for ASD-associated behavior in school-aged children with age-appropriate cognitive abilities. The presented data collections and research questions are part of this greater research interest, aiming to identify specific tasks decisive for ASD-associated behavior when presented automatically on a tablet.

The current investigation aims to fill a research gap concerning visual preferences in children with ASD. This is done with a focus on school aged children for whom data are completely missing so far. The stimuli are specifically controlled for complexity and contrast between (static) images and videos to contribute to methodical questions concerning task characteristics. The aim of our investigation is to identify visual preferences in children with ASD that might differentiate them from TD children. Furthermore, characteristics of stimuli that are necessary to use this type of task in clinical screening contexts, shall be identified.

II. Method

A. Participants

We examined the visual preferences of 32 boys aged 6 to 11 years – 16 boys with ASD and without cognitive impairment and 16 boys with overall typical development (1:1 matching) – within an experimental setting. Matching criteria were the children's age and the parent's level of education. The average age of boys with ASD was 9.5 years (M = 9.06, SD = 1.81) and of TD boys 9.0 years (M = 8.75, SD = 1.65). On average, the highest level of education attained by the parents of both children with ASD and TD children was a high school diploma. Attention-deficit (hyperactivity) disorder (AD(H)D) is often comorbid with ASD [22]. We found that three children with ASD in our sample were also diagnosed with AD(H)D, one with impulse control and reactive attachment disorder. A total of three children with ASD also were diagnosed with impulse control disorder but no AD(H)D. One child with ASD was diagnosed with additional verbal developmental dyspraxia respectively with a sleep and perceptual disorder, whereas two children had comorbid tics. All children with ASD had already received ASD specific therapy, on average for 15.7 months (SD = 8.2; Range = 6-32 months). Although all children in the ASD group were formerly diagnosed with ASD, not all children met the screening threshold for suspected diagnosis of ASD on the German version of the Social Communication Questionnaire (FSK) [23] at the time of study participation. However, there is a significant negative correlation between the duration of ASD intervention and the score on the screening instrument (r = -0.68, p = .011; [24]).

B. Measures

The investigation was part of the IDEAS (Identification of Autism Spectrum Disorder using speech and facial expression recognition) research project (funding code: 13GW0584D). This project aimed to develop an automated digital screening for ASD. All participants passed a visual preference task in two different conditions, either as a human test administrator or a pre-recorded avatar as test administrator (details in [25]). Prior to the visual preference task, a calibration to relate eye movements with gaze direction in screen coordinates was performed. A social preference task included different stimulus presentation formats (images vs. videos) and different levels of stimulus complexity (one child vs. two children). Children with ASD and TD children saw pairs of social vs. non-social images – and video stimuli respectively – on a screen. For images, the social stimuli display one or more children playing whereas the non-social stimuli show images of the universe. For videos, the social stimuli present a man or a woman making dynamic grimaces, and the non-social stimuli consist of dynamic geometric shapes. This video material was initially applied by [26]. For each stimulus pair, the position of the social image/video on screen was altered systematically. During stimulus presentation of approximately 10 s duration per image and of approximately 18 s per video, eye movements (i.e., eye position and gaze direction) were captured and recorded with up to six frames per second. This approach was supported through a customized, native iOS app (KIZMO Face-Analyzer), developed by KIZMO GmbH for use on iPads. The iPad was located behind the screen during the task and a camera was placed directly to the left of the screen. The children were seated approximately 60 cm from the screen.

C. Data Analysis

Data from each recording were stored as numerical values for later MATLAB analysis [27]. For each image/video pair, the number of frames recorded in the left image/video (social or non-social) and the number of frames recorded in the right image/video (social or non-social) were analyzed using MATLAB (example in Fig. 1). For the purpose of this paper, frames were accumulated when stimulus pairs were the same for each group, and the mean was used for different counts of stimulus pairs. In addition to eye tracking, the children were asked to select their favorite image from six images (three social, three non-social) presented together on screen. The analyses do not account for the different conditions (human test administrator vs. pre-recorded avatar) used to collect the data, as the task is self-paced after a short introduction ("Now I'll show you images/videos. Look"). Descriptive and statistical analyses were performed using R (version 4.3.1) [28]. Due to the small sample size, Fisher's exact test was computed for statistical analysis of the data [29].

III. Results

The descriptive analyses of image selection (social vs. non-social) for the 16 children with ASD show that out of 32 possible image comparisons, the non-social image was selected 20 times, the social image was selected six times, and six choices were missing or could not be correctly assigned (e.g., a child named both a social and non-social image as their favorite). For the 16 TD children, the children selected the non-social image 26 times, the social image five times, and one choice could not be correctly assigned.

When comparing the total fixation time on social vs. non-social stimuli (images and videos) between children with ASD and TD children, no significant differences were found (odds ratio = 1.09, p = .303; TD: social = 667.25, non-social = 449.06; ASD: social = 647.81, non-social = 477.31). Similarly, no significant differences were found between children with ASD and TD children in fixation duration of social vs. non-social images (odds ratio = 0.98, p = .86; TD: social = 336.06, non-social = 231.44; ASD: social = 384.63, non-social = 257.75) and social vs. non-social videos (odds ratio = 1.27, p = .059; TD: social = 331.19, non-social = 217.63; ASD: social = 263.19, non-social = 219.56). Furthermore, when looking at the frequency of preference for a non-social stimulus, no significant difference in stimulus presentation (images vs. videos) can be demonstrated between children with ASD and TD children (odds ratio = 2.9, *p* = .35; TD: non-social image = 4, non-social video = 3; ASD: non-social images = 3, non-social videos = 7). Similarly, there was no significant difference in children with ASD and TD children in the selection task in children's gaze fixation times on social vs. non-social images (odds ratio = 0.78, *p* = .197; TD: social = 115.06, non-social = 138, ASD: social = 113.75, non-social = 105.81). When analyzing visual preferences for the left vs. right screen side, regardless of whether they display social or non-social content, a significant difference appears (odds ratio = 1.31, *p* = .023). The average fixation time on the left images is 343.19 (*SD* = 132.17) for the TD children and 346.63 (*SD* = 95.33) for the children with ASD. The mean fixation time on the right images is 224.31 (*SD* = 102.21) for the TD children and 295.75 (*SD* = 139.55) for the children with ASD.

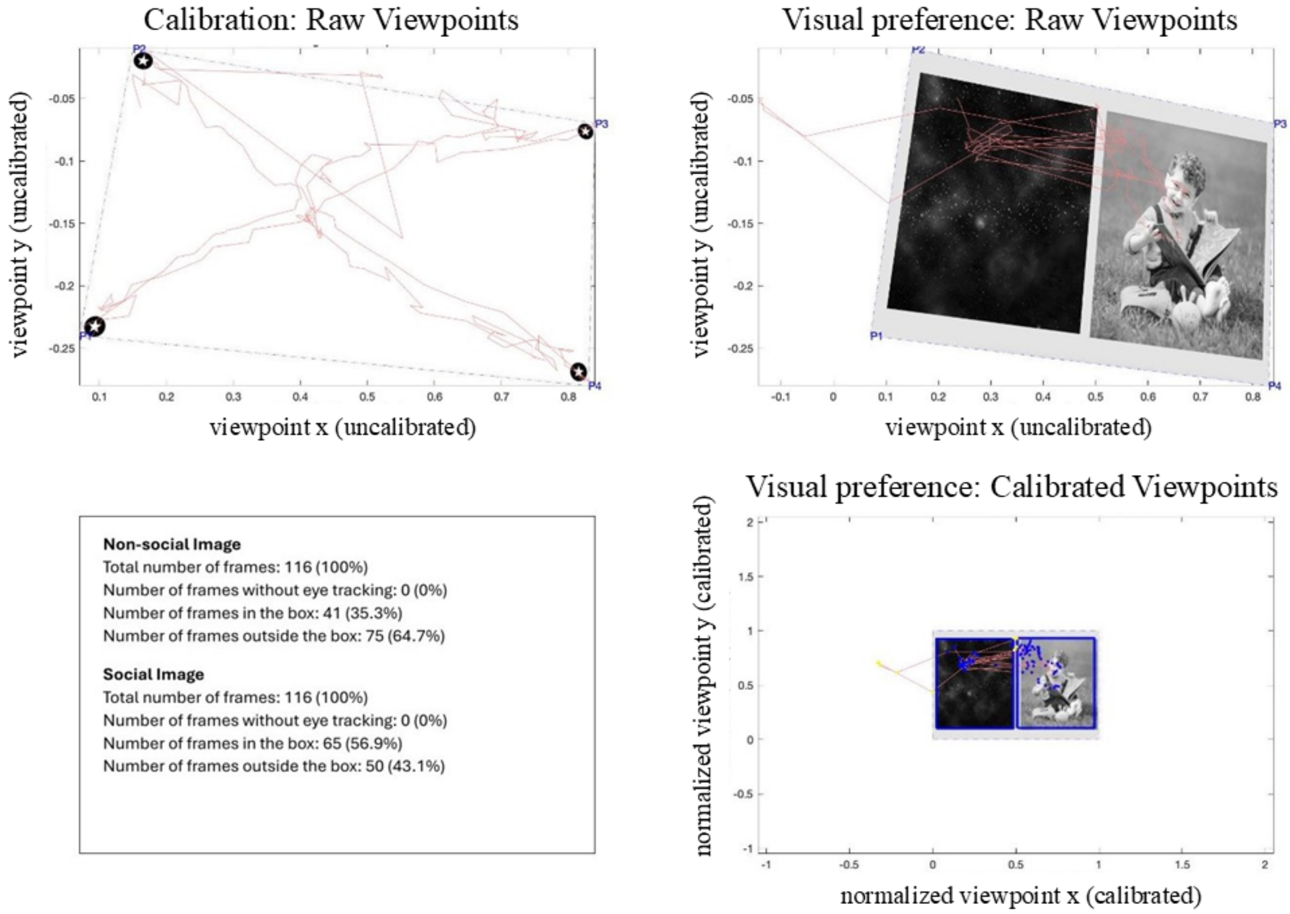

Fig. 1 Data analysis of visual preference based on the calibration with MATLAB (Screenshot from MATLAB R 2021b [27])

The social images were sorted in two groups for complexity (one child vs. two children displayed), resulting in no statistical difference in complexity between children with ASD and TD children (odds ratio = 0.74, *p* = .354; TD: complexity 1 = 49.61, complexity 2 = 34.41; ASD: complexity 1 = 64.34, complexity 2 = 31.81). There was a statistical difference in visual preference for the social images depending on whether they depicted a boy or a girl between children with ASD and TD children (odds ratio = 0.68, *p* = .011). On average, the fixation time for images of boys is 143.31 (*SD* = 47.98) for TD children and 200.44 (*SD* = 114.43) for children with ASD. For images of girls, the fixation time is 192.75 (*SD* = 69.59) for TD children and 184.19 (*SD* = 55.8) for children with ASD.

IV. Discussion

A. Visual Preference of Children with ASD

While other studies have shown a lower preference for social stimuli compared to non-social stimuli in infants and toddlers with ASD compared to those without ASD [4], [11], [14]-[16], this study suggests that there are no differences in visual preferences between boys with and without ASD at elementary school age. Although a simple inspection of the data might suggest a tendency that boys with ASD fixated the geometric videos more often than the non-social images compared to TD boys, no group differences can be demonstrated. Overall, the type of stimulus presentation did not result in any statistical effect on visual preferences.

Similarly, no statistical difference was evident when analyzing the complexity of the social stimuli (one person vs. two people). Thus, this study is in line with the findings of [16], who were also unable to show an effect of the complexity of the social images on visual preference, and thus also contradicts earlier findings such as those of [11] or [19]. A possible reason for the lack of effect could be that the number of images is too small to compare the complexity (four images with one person and two images with two people). However, this study demonstrates significant differences in preferences depending on the sex of the children depicted in the social images. It shows that TD boys have a higher fixation time on the social images depicting girls instead of those depicting boys. For boys with ASD, it is the other way around. Boys with ASD have a higher fixation time on the social images depicting boys instead of those depicting girls. The visual preference of boys with ASD is also consistent with the literature showing that people are attracted to media characters of the same sex, with this preference being more pronounced in men than in women [30]. Thus, this study demonstrates a significant difference between children with ASD and TD children in the fixation time on social images depicting boys or girls.

In the task in which the boys were asked to actively choose their favorite image from six images (three social, three non-social), no statistical difference appears in the choice of participants with ASD compared to TD participants. Both groups spent about the same amount of time looking at the social and non-social images. Thus, these results also did not confirm the findings of various studies that children with ASD focus more on non-social stimuli than TD children [4], [11], [14]-[16]. Here, both groups most often selected a non-social image, although group differences were not apparent in the fixation time. One possible reason for the attractiveness of the social images also in ASD children could have been a higher perceived complexity of the social images compared to the non-social depicting the universe as the former include more variation in detail. This explanation would be consistent with the other findings demonstrating that children with ASD often have weak central coherence and therefore strongly focus on details [31]. Another possible reason for missing group differences might have been the split screen paradigm. In both groups, fixation time on the right side was shorter than on the left side, regardless of whether it was a social or non-social image (stimuli fully counterbalanced for presentation side). This finding might be explained by the reading direction from left to right, so that the left image was proceed first and with more time. Thus, if the left image presents social content with more detail, it could have taken longer to look at it, hereby confounding screen side with content. Finally, the fact that the iPad's camera is located on the left side of the screen may also explain why fixation times were longer for the stimuli presented on the left. Eye tracking works slightly better when you are looking close to the iPad's camera than when you are looking at the other side of the screen, which is facing away from the camera.

B. Limitations and Future Research Considerations

The main limitation of this study lies in the technicality for detecting gaze. Calibration prior to the visual preference task worked differently for each child, so there was some variance in gaze direction, and it was not always possible to determine exactly where the children were looking. Moreover, it was extremely challenging to reduce the children's stronger body and head movements for eye tracking, which are associated with ASD or ADHD. Here, age might have played a disturbing role. Another limitation is the size of the sample. Only 16 children with ASD and 16 TD children participated in this study. As the descriptive analysis of fixation scores indicates expected group differences, statistical power might have been too small.

One limitation of the visual preference task with images is the different complexity of the social and non-social images, as the social images show a higher number of presented details. Although the children should only look at the images, some of them started describing them. Since there were more details in the social images to describe, longer fixation time was needed.

In addition to the different complexity of the social and non-social images, coloring also differs between those stimuli. Social images have rather warm and bright colors (yellow, green, white), whereas the non-social images have dark and rather cold colors (dark blue, black). Given that ASD is associated with sensory atypicalities [32], sensory input might have been rather incomparable. The same limitation applies to the videos, as the background of the social videos is white and the background of the non-social videos is black. For example, [18] adjusted the backgrounds of the videos and conducted the study with adults with and without ASD. They found differences in visual preference for social and geometric motion even in adulthood [18]. However, the occurring difference is no longer that people with ASD look more at the non-social videos, as is the case in infancy [3], [11], [13], [15], [16]. Instead, the difference in adults is that adults without ASD show a strong preference for the social motion, whereas adults with ASD show no clear preference for social or non-social stimuli [18]. For this reason, perhaps the question we should be asking is not whether children with ASD look at the non-social images more than TD children, but rather whether there is a difference in preference for TD children and no difference for children with ASD. Looking at the two groups individually, we see a significantly greater difference in fixation times for TD boys than for those with ASD in this study. Boys fixate longer on the social video. In addition, this study focused almost exclusively on total fixation times. Further analyses should examine the extent to which the frequency of gaze shifts from social to non-social may be a marker of ASD. In addition, many studies show that longer fixations in young children with ASD are associated with greater symptom severity [4], [15], [16]. However, the boys in this study are already receiving ASD-specific therapy, the duration of which is negatively associated with ASD screening scores, and therefore some children no longer show severe symptoms. This could be a reason why the analyses for higher gaze preference for non-social stimuli in children with ASD compared to TD children did not reach significance. Therefore, it makes sense to conduct this study with children with ASD who do not receive ASD-specific services.

With these experiences it becomes clear that pretesting stimuli for complexity or novelty is of utmost importance.

Although it is almost impossible to render totally comparable stimuli (social vs. non-social) with regard to other information qualities, we strongly recommend considering similar sensory input (coloring), similar amount of detail, fully counterbalanced stimulus presentation and similar characteristics where only the social input varies (e.g., a person and repetitive stereotypical movements, and geometric figures and repetitive stereotypical movements).

Concerning the clinical aim of the overarching IDEAS project to develop a tablet-based screening for ASD in school children, this study demonstrates that a visual preference task using an iPad with depth sensing can easily be implemented, requires little time and effort and therefore can be feasible for instance in medical practices for a first indication of ASD symptoms. Nevertheless, additional research is needed to allow for clinically relevant differentiations between children with and without ASD.

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References

[1] American Psychiatric Association, Diagnostic and statistical manual of mental disorders. Arlington. American Psychiatric Publishing, 2013.
[2] Z. Ambarchi, K. A. Boulton, R. Thapa, E. E. Thomas, M. M. DeMayo, and N. J. Sasson, et al., “Evidence of a reduced role for circumscribed interests in the social attention patterns of children with Autism Spectrum Disorder,” Journal of autism and developmental disorders, vol. 53, pp. 3999–4011, 2023.
[3] X. Gong, X. Li, Q. Wang, S. P. Hoi, T. Yin, and L. Zhao, et al., “Comparing visual preferences between autism spectrum disorder (ASD) and normal children to explore the characteristics of visual preference of ASD children by improved visual preference paradigm: a case-control study,” Translational pediatrics, vol. 10, pp. 2006–2015, 2021.
[4] E. C. Bacon, A. Moore, Q. Lee, C. Carter Barnes, E. Courchesne, and K. Pierce, “Identifying prognostic markers in autism spectrum disorder using eye tracking,” Autism, vol. 24, pp. 658–669, 2020.
[5] N. I. Vargas-Cuentas, A. Roman-Gonzalez, R. H. Gilman, F. Barrientos, J. Ting, and D. Hidalgo, et al., “Developing an eye-tracking algorithm as a potential tool for early diagnosis of autism spectrum disorder in children,” PloS one, vol. 12, e0188826, 2017.
[6] N. J. Sasson and E. W. Touchstone, “Visual attention to competing social and object images by preschool children with autism spectrum disorder,” Journal of autism and developmental disorders, vol. 44, pp. 584–592, 2014.
[7] J. Vacas, A. Antolí, A. Sánchez-Raya, C. Pérez-Dueñas, and F. Cuadrado, “Visual preference for social vs. non-social images in young children with autism spectrum disorders. An eye tracking study,” PloS one, vol. 16, 2021.
[8] Q. Wang, S. P. Hoi, C. Song, T. Li, C. M. Lam, and Y. Wang, et al., “Circumscribed Interest Modulates Attention to Eyes in Boys with and Without Autism Spectrum Disorder,” Frontiers in psychiatry, vol. 12, p. 627365, 2021.
[9] K. Chawarska, S. Macari, and F. Shic, “Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders,” Biological psychiatry, vol. 74, pp. 195–203, 2013.
[10] J. Parish-Morris, C. Chevallier, N. Tonge, J. Letzen, J. Pandey, and R. T. Schultz, “Visual attention to dynamic faces and objects is linked to face processing skills: a combined study of children with autism and controls,” Frontiers in psychology, vol. 4, 2013.
[11] J. Kou, J. Le, M. Fu, C. Lan, Z. Chen, and Q. Li, et al., “Comparison of three different eye-tracking tasks for distinguishing autistic from typically developing children and autistic symptom severity.,” Autism research, vol. 12, pp. 1529–1540, 2019.
[12] F. Robain, M. Godel, N. Kojovic, M. Franchini, F. Journal, and M. Schaer, “Measuring social orienting in preschoolers with autism spectrum disorder using cartoons stimuli,” Journal of psychiatric research, vol. 156, pp. 398–405, 2022.
[13] C. M. Gale, S. Eikeseth, and L. Klintwall, “Children with Autism show Atypical Preference for Non-social Stimuli,” Scientific reports, vol. 9, p. 10355, 2019.
[14] K. Pierce, D. Conant, R. Hazin, R. Stoner, and J. Desmond, “Preference for geometric patterns early in life as a risk factor for autism.,” Archives of General Psychiatry, vol. 68, pp. 101–109, 2011.
[15] K. Pierce, S. Marinero, R. Hazin, B. McKenna, C. C. Barnes, and A. Malige, “Eye Tracking Reveals Abnormal Visual Preference for Geometric Images as an Early Biomarker of an Autism Spectrum Disorder Subtype Associated with Increased Symptom Severity,” Biological psychiatry, vol. 79, pp. 657–666, 2016.
[16] A. Moore, M. Wozniak, A. Yousef, C. C. Barnes, D. Cha, and E. Courchesne, et al., “The geometric preference subtype in ASD: identifying a consistent, early-emerging phenomenon through eye tracking,” Molecular autism, vol. 9, 2018.
[17] Q. Wang, Y. Hu, D. Shi, Y. Zhang, X. Zou, and S. Li, et al., “Children with Autism Spectrum Disorder Prefer Looking at Repetitive Movements in a Preferential Looking Paradigm,” Journal of autism and developmental disorders, vol. 48, pp. 2821–2831, 2018.
[18] M. Matyjek, N. Bast, and S. Soto Faraco, Is there a social motion preference in autistic adults? Frankfurt am Main, Mar, 2024.
[19] L. Shi, Y. Zhou, J. Ou, J. Gong, S. Wang, and X. Cui, et al., “Different visual preference patterns in response to simple and complex dynamic social stimuli in preschool-aged children with autism spectrum disorders,” PloS one, vol. 10, e0122280, 2015.
[20] L. Strathearn, S. Kim, D. A. Bastian, J. Jung, U. Iyengar, and S. Martinez, et al., “Visual systemizing preference in children with autism: A randomized controlled trial of intranasal oxytocin,” Development and psychopathology, vol. 30, pp. 511–521, 2018.
[21] J. Höfer, F. Hoffmann, I. Kamp-Becker, L. Poustka, V. Roessner, and S. Stroth, et al., “Pathways to a diagnosis of autism spectrum disorder in Germany: a survey of parents,” Child and adolescent psychiatry and mental health, vol. 13, 2019.
[22] C. Lord, T. S. Brugha, T. Charman, J. Cusack, G. Dumas, and T. Frazier, et al., “Autism spectrum disorder,” Nature reviews. Disease primers, vol. 6, 2020.
[23] S. Bölte and F. Poustka, FSK. Fragebogen zur Sozialen Kommunikation - Autismus-Screening. German version of the Social Communication Questionnaire (SCQ) von Michael Rutter, Anthony Bailey und Catherine Lord. Göttingen. Hogrefe, 2006.
[24] P. Sedgwick, “Pearson's correlation coefficient,” BMJ, vol. 345, 2012.
[25] L. Pliska, I. Neitzel, M. Buschermöhle, and U. Ritterfeld, “Comparison of Different Interaction Formats for Automatized Analysis of Symptoms in Children with Autism Spectrum Disorder,” in Universal Access in Human-Computer Interaction. HCII 2023. M. Antona, C. Stephanidis, Eds. Cham: Springer, 2023.
[26] L. Polzer, C. M. Freitag, and N. Bast, “Pupillometric measures of altered stimulus-evoked locus coeruleus-norepinephrine activity explain attenuated social attention in preschoolers with autism spectrum disorder,” Autism research, vol. 15, pp. 2167–2180, 2022.
[27] The MathWorks Inc., MATLAB (Software), https://de.mathworks.com/products/matlab.html?s_tid=hp_ff_p_matlab, 2021.
[28] R Core Team, R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing (Computer Software). Vienna, http://www.R-project.org/, 2023.
[29] H.-Y. Kim, “Statistical notes for clinical researchers: Chi-squared test and Fisher’s exact test,” Restorative Dentistry & Endodontics, vol. 42, pp. 152–155, 2017.
[30] C. A. Hoffner, “Same-Gender Characters: Appeal and Identification,” in The International Encyclopedia of Media Psychology. J. v. d. Bulck, Ed.: Wiley, 2020, pp. 1–5.
[31] J. Hemmers, C. Baethge, K. Vogeley, and C. M. Falter-Wagner, “Are Executive Dysfunctions Relevant for the Autism-Specific Cognitive Profile?,” Frontiers in psychiatry, vol. 13, 2022.
[32] M. Chita-Tegmark, “Social attention in ASD: A review and meta-analysis of eye-tracking studies,” Research in developmental disabilities, vol. 48, pp. 79–93, 2016.