Socially oriented attention in young children with neurofibromatosis type 1: an eye-tracking study

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ORIGINAL ARTICLE

Socially oriented attention in young children with neurofibromatosis type 1: An eye-tracking study

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Abstract

Aim: To examine visual engagement to social stimuli and response to joint attention in young children with neurofibromatosis type 1 (NF1) and typically developing peers (controls).

Method: Forty-five preschool children were studied cross-sectionally (mean age [SD] = 4 years 3 months [10 months]), 25 with NF1 and 20 typically developing controls. Participants passively viewed two eye-tracking paradigms. The first measured participants' time to first social fixation and duration of attention to social stimuli. The second assessed response to joint attention by recording the time taken to fixate on the target of an actor's eye gaze and the percentage of time maintaining joint attention.

Results: Compared to typically developing controls, children with NF1 were slower to fixate on social information (Cohen's $d = 1.03$, 95% confidence interval [CI] = 0.40–1.65), spent less time attending to social stimuli ($d = -0.60$, 95% CI = −1.27 to −0.01), and were slower to establish joint attention (rank-biserial correlation $r = -0.49$, 95% CI = −0.79 to −0.19). Slower fixation to social stimuli was associated with elevated autism traits ($r = 0.41$, $p = 0.03$) and lower social adaptive functioning ($r = -0.49$, $p = 0.02$) in children with NF1.

Interpretation: Our findings in preschool children build on previous evidence of diminished attention to social information in school-age children with NF1 and could inform early interventions to ameliorate the impact of reduced social attention on everyday social functioning in this population.

Children with neurodevelopmental disorders such as autism often have difficulties with social attention, including detecting, interpreting, and responding to social cues.[1] A key aspect is joint attention, which involves intentionally shifting gaze to align with another person's focus.[2] Both social and joint attention are crucial for developing social skills, as well as facilitating language acquisition and social interactions.[3]

Eye-tracking studies that record gaze patterns to socially salient information have examined social attention in young autistic children.[4] These studies indicate that autistic infants and young children exhibit decreased attention to social stimuli compared to typically developing peers,[4] including a lack of preferential attention to socially salient information over non-social information.[5] In joint attention paradigms, autistic children have demonstrated difficulty interpreting the gaze cues of others, which are essential for establishing and maintaining joint attention.[5,6] Specifically, their gaze-following abilities are less accurate,[5,6] they are slower to focus on the target of another's attention,[6] and they spend less time viewing the target relative to developmentally age-matched peers.[5]

Abbreviations: AOI, area of interest; NF1, neurofibromatosis type 1.

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Social and joint attention have also been examined in monogenic syndromes associated with autism.[5] Examining gaze patterns in genetically homogeneous syndromes offers a complementary approach to studying idiopathic autism because it allows exploration of distinct phenotypes linked to specific genes and neurobiological pathways. Neurofibromatosis type 1 (NF1) is an autosomal dominant genetic condition associated with learning problems, social difficulties,[7] elevated autistic traits,[8] and atypical attention profiles.[9–11] In previous work, we demonstrated that school-age children with NF1 have atypical gaze behaviour when attending to faces,[9] which was associated with elevated autistic traits.[10] While these findings suggest that atypical social attention is central to the social cognitive phenotype of school-age children with NF1, it is unclear whether young children with NF1 display atypical social and joint attention gaze patterns compared to typically developing peers (controls). Understanding the social cognitive phenotype in young children with NF1 is crucial for early identification and stratification of those with difficulties, gaining deeper insights into the cognitive processes underlying social challenges in NF1 and comprehending the developmental trajectories of these difficulties to enable timely and effective early interventions.

The aim of this study was twofold. First, we compared eye-gaze patterns during social and joint attention paradigms of young children with NF1 and typically developing controls. Second, we investigated the relationships between these gaze patterns and behavioural characteristics, including autistic traits and attention-deficit/hyperactivity disorder (ADHD) symptoms, and social adaptive functioning in NF1. We hypothesized that children with NF1 would (1) spend less time viewing social stimuli compared to typically developing controls; (2) exhibit reduced responding to joint attention compared to typically developing peers (controls); and (3) show associations between social and joint attention with autistic traits, ADHD symptoms, and social adaptive functioning.

What this paper adds

- Young children with neurofibromatosis type 1 (NF1) demonstrated reduced attention to socially relevant stimuli.
- Children with NF1 demonstrated a delay in rapidly establishing joint attention.
- Reduced attention to social stimuli is a consistent feature across childhood in NF1.
- Reduced social attention is associated with autistic traits and adaptive social functioning.
- Preschool children with NF1 may miss salient information for daily social interactions.

METHOD

Participants

Participants were 45 children aged 3 to 5 years, including 25 with NF1 and 20 typically developing controls. Children with NF1 (mean age [SD] = 4 years 3 months [7 months]) were drawn from a cross-sectional study examining the autistic phenotype in NF1.[12] All participants were diagnosed with NF1 by an expert neurologist or clinical geneticist using clinical diagnostic criteria.[13] They were recruited consecutively from the Neurofibromatosis Clinic at the Royal Children's Hospital, Melbourne, Australia, during the active phase of this substudy. All invited families agreed to participate. Data from the typically developing comparison group were obtained through a previous eye-tracking study examining social learning.[5] Typically developing controls (mean age = 4 years 3 months [12 months]) were recruited through the Community Children's Centre at La Trobe University. All participants had adequate vision to complete the eye-tracking paradigms and no symptomatic intracranial pathology. The study design originally included an additional comparison group with idiopathic autism; data were collected from this group but they were excluded from the final analysis because of marked cognitive differences relative to both the group with NF1 and the typically developing controls. This post hoc decision was made to preserve the interpretability of between-group comparisons and to avoid potentially misleading conclusions. This study was approved by the Royal Children's Hospital Human Research Ethics Committee (ref. no. 35118) and the La Trobe Human Research Ethics Committee (ref. no. 14–007). Written informed consent was provided by the parents or guardians of the participants.

Eye-tracking measures

Social attention paradigm

Visual attention to social versus non-social stimuli was assessed using an eye-tracking paradigm that presented a different photograph across five trials. Each was displayed for 5 seconds and depicted a naturalistic scene that included people engaging in a social activity along with several non-social objects. An area of interest (AOI) was created around each social stimulus, which was counterbalanced to the left or right side of the screen. We also recorded the time spent viewing the whole screen to adjust for inattention (Figure 1). From this task, two social attention variables were derived: (1) mean time to first social fixation, measured as the length of time in seconds for the first fixation to occur within the social AOI; (2) mean dwell time, measured as the time spent viewing the social AOI within a scene as a proportion of viewing time of the whole screen as a percentage.

Joint attention paradigm

We examined the ability to orient attention towards the target of an actor's attentional focus (Figure 2).[14] This task consisted of six videos, each lasting 11 seconds. In each video, the actor looked down for 3 seconds and established direct gaze for 2 seconds before shifting their gaze to look at one of the two objects for 6 seconds. The object the actor focused on was considered the congruent target. The position of the congruent target was counterbalanced between the left and right sides of the screen. An AOI was defined around (1) the congruent target; (2) the 'corridor of joint attention' (the actor's face, the congruent target, and the space between them); and (3) the whole screen (Figure 2). Joint attention variables used in the analysis included (1) fixation to the congruent target (1 second or 2 seconds), which measured the percentage of trials in which the participant viewed the congruent target within 1 second or 2 seconds of it being viewed by the actor. These percentages were then averaged across participants within each group (NF1 and control) to produce a group-level mean percentage; and (2) corridor of joint attention mean dwell time, which measured the mean time spent looking between the actor's face and the congruent target, expressed as a percentage of total on-screen time.

FIGURE 1 Example trial from the social attention paradigm highlighting the social area of interest (yellow).

Neuropsychological measures

Full-scale IQ, verbal IQ, and non-verbal IQ were assessed in children with NF1 using the Wechsler Preschool & Primary Scale of Intelligence, Fourth Edition.[15] For typically developing controls, cognitive abilities were assessed using the Mullen Scales of Early Learning.[16] Based on our previous study and those of others,[5,17] developmental quotient scores were calculated using the following formula: developmental quotient = (age-equivalent score / chronological age) × 100. The verbal developmental quotient averaged receptive and expressive language scores; the non-verbal developmental quotient averaged visual reception and fine motor scores converted to a standard scale (mean = 100, SD = 15). Across both measures, higher scores indicate better performance.

The parent-reported preschool version of the Social Responsiveness Scale, Second Edition[18] was used to assess autistic traits in the cohort with NF1. Higher scores are associated with more severe symptoms, while T scores of 60 or more indicate clinically significant problems in reciprocal social behaviour (mean = 50, SD = 10). ADHD traits in the cohort with NF1 were assessed using the Conners ADHD Diagnostic and Statistical Manual for Mental Disorders Scales (mean = 50, SD = 10).[19] Higher T scores indicate more severe ADHD symptoms with T scores of 65 or more considered clinically significant.[19]

Social adaptive functioning was assessed using parent report on the Adaptive Behavior Assessment System (Social domain score)[20] for NF1, and the Vineland Adaptive Behavior Scales (Socialization domain score)[21] for typically developing controls. Correlations between the Adaptive Behavior Assessment System (Social domain) and Vineland Adaptive Behavior Scales (Socialization domain) were very high (0.77), allowing data to be pooled.[20] Lower scores on both scales indicate poorer social adaptive functioning (mean = 100, SD = 15).

Procedure

Participants' eye movements were recorded using a Tobii T120 binocular eye tracker monitor (Tobii AB, Stockholm, Sweden) with an embedded camera (120 Hz, 1280 × 1024 pixel resolution, average precision of 0.5° visual angle), and analysed using frame-by-frame defined AOIs with the Tobii

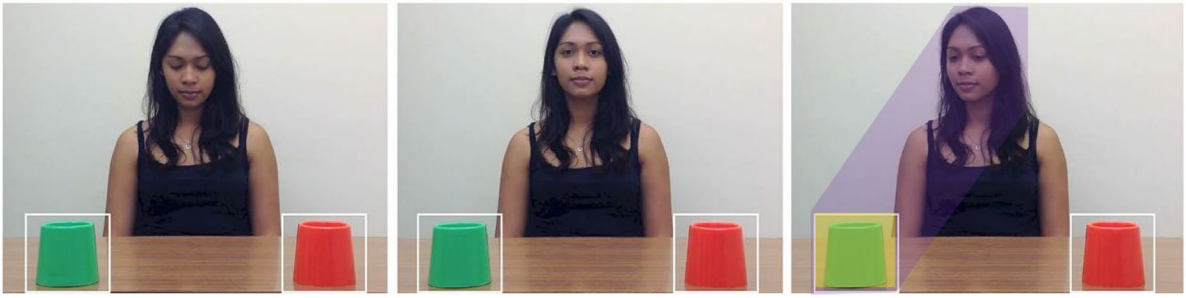

FIGURE 2 Example trial from the joint attention paradigm video providing screen shots of the three phases (gaze down, gaze up, and gaze shift), highlighting the congruent target (yellow shading) and the 'corridor of joint attention' (purple shading).

Studio analysis software. Fixation criteria were set to the Tobii Studio default settings of a 30-pixel dispersion threshold for 100 ms. During the eye-tracking task, participants were seated in a comfortable chair positioned 60 cm in front of the eye tracker monitor. Each participant's eye positioning to the screen was calibrated before the task. Participants watched video stimuli presented on the monitor and no explicit instructions were given.

Statistical analysis

Data were analysed using Stata v18 (StatCorp, College Station, TX, USA); 7% of participants did not fixate within the social AOI. Hence, we winsorized their 'time to first social fixation' by imputing a value of three SDs above the respective group mean. Missing data for 'mean dwell time' consisted of 3% for social attention and 11% for the joint attention trials, where the participant was off-screen for the whole trial. One participant from the NF1 group was missing data across all joint attention trials because of low compliance; this participant was removed from the analysis. Missing data were evenly distributed across groups.

The normality of data distribution was assessed using visual inspection and the Shapiro–Wilk test. Group differences for normally distributed continuous variables were explored using an independent samples *t*-test with Cohen's *d* reported as a measure of effect size and interpreted using conventional guidelines (0.2 = small, 0.5 = medium, 0.8 = large).[22] Data derived from proportional counts (i.e. the 1-second and 2-second joint attention variables) were analysed with a Mann–Whitney *U* test (with rank-biserial correlation, *r*, reported as the effect size). A χ^2 test was used for categorical variables. For outcomes where data were only available for the group with NF1 (autistic traits and ADHD symptoms), a one-sample *t*-test was used to compare NF1 data to the population-based standardization sample.[18,19] In the group with NF1, the relationships between social and joint attention variables, behavioural characteristics (autism symptoms, ADHD traits, social adaptive functioning), and cognition were examined using a Pearson's product–moment correlation or Spearman's rank correlation (for proportion data). Potential outliers were assessed using visual inspection, with three identified in the proportional count variables from the joint attention paradigm. Given their potential influence, both comparisons, which are robust to outliers, were analysed using a Mann–Whitney *U* test. All valid data points were retained to maintain statistical power. For all analyses, significance was set at 0.05 and all tests were two-tailed.

RESULTS

Sample characteristics

Table 1 shows that there were no significant differences in age ($p = 0.95$) or sex ratios between the group with NF1 and the typically developing group ($p = 0.48$). The groups differed in IQ and social adaptive functioning scores (all, $p < 0.01$), with children with NF1 performing below typically developing controls. Relative to population norms, children with NF1 demonstrated elevated autistic traits and ADHD symptoms (all, $p < 0.01$).

Social attention

Figure 3a shows the mean time to first social fixation across all trials. The independent samples *t*-test revealed that children with NF1 took significantly longer to initially fixate on social stimuli relative to typically developing controls (1.3 seconds vs 0.6 seconds; $t_{(43)} = 3.43$, $p < 0.01$, $d = 1.03$, 95% confidence interval [CI] = 0.40–1.65; Table S1). As shown in Figure 3b, the group with NF1 spent significantly less time viewing the social AOI as a proportion of whole-screen time compared to typically developing controls (49% vs 43%; $t_{(44)} = -1.99$, $p = 0.05$, $d = -0.60$, 95% CI = −1.27 to −0.01).

Joint attention

Figure 4a shows the percentage of each group that established fixation on the congruent target within 1 second. A Mann–Whitney *U* test revealed that children with NF1 were significantly less likely to establish joint attention with the actor within 1 second compared to typically developing controls (25% vs 42%; $U = 128.5$, $p < 0.01$, $r = -0.49$, 95% CI = −0.71 to −0.19; Table S1). The percentage of trials in which individuals fixated on the congruent target within 2 seconds were equivalent between children with NF1 and typically developing controls (47% vs 58%; $t_{(43)} = -1.43$, $p = 0.16$, $d = -0.43$, 95% CI = −1.02 to 0.17; Figure 4b).

Figure 5 displays the mean dwell time between the actor's face and object as a proportion of total on-screen time. The independent samples *t*-test revealed that children with NF1 and typically developing controls spent a similar amount of time in the corridor of joint attention (73% vs 75% respectively; $t_{(42)} = -0.26$, $p = 0.79$, $d = -0.08$, 95% CI = −0.67 to 0.51).

Relationships between social attention and autism or ADHD traits, social functioning, and cognition

Table 2 shows the correlations between the social and joint attention measures and autistic traits, ADHD symptoms, social adaptive functioning, and cognitive ability in the group with NF1. Regarding the social attention paradigm, there were significant associations between mean time to first social fixation and both autism traits ($r = 0.41$, $p = 0.03$), and social adaptive functioning ($r = -0.49$, $p = 0.02$). Social and joint attention variables were not significantly associated with verbal or non-verbal cognitive ability (all, $p > 0.11$).

TABLE 1 Descriptive characteristics of the study participants.

Characteristic	Group with NF1 ($n=25$)	Controls ($n=20$)	Cohen's d
Age, years:months	4:3 (0:7) (3:0–5:8)	4:3 (1:0) (3:2–5:6)	0.03
Sex, *n* (%)			
Male	15 (60)	14 (70)	NA
Female	10 (40)	6 (30)	NA
Autism diagnosis, *n* (%)	8 (32)	0 (0)	NA
Full-scale IQ[a]	88.6 (13.0) (70–118)	104.5 (13.8) (72–136)	−1.2**
Verbal IQ[a]	88.6 (14.0) (68–113)	104.3 (16.0) (64–137)	−1.0**
Non-verbal IQ[a]	90 (11.2) (67–114)	104.7 (13.9) (81–136)	−1.2**
Autistic behaviours[b]	60.1 (14.7) (39–91)	NA	1.0**
Social adaptive functioning[c]	89.8 (12.2) (70–116)	106.7 (16.5) (77–120)	−1.2**
ADHD inattentive[d]	66.8 (18.5) (41–90)	NA	1.7**
ADHD hyperactive/impulsive[d]	62.9 (18.7) (40–90)	NA	1.3**

Note: Data are shown as the mean (SD) (range), unless stated otherwise. **$p<0.01$.

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; NA, not applicable; NF1, neurofibromatosis type 1.

[a]Standard score (mean = 100, SD = 15; higher scores indicate better performance); the Wechsler Preschool & Primary Scale of Intelligence, Fourth Edition or Mullen Scales of Early Learning (controls) were used.

[b]T score (mean = 50, SD = 10; higher scores indicate elevated difficulties); the Social Responsiveness Scale, Second Edition was used.

[c]Standard score (mean = 100, SD = 15; higher scores indicate better performance); the Social domain score of the Adaptive Behavior Assessment System, Third Edition or the Socialization domain score (controls) of the Vineland Adaptive Behavior Scales, Second Edition was used.

[d]T score (mean = 50, SD = 10; higher scores indicate elevated difficulties); the Conners ADHD Diagnostic and Statistical Manual for Mental Disorders Scales were used, with effect sizes quantifying the differences between the group with NF1 and population norms.

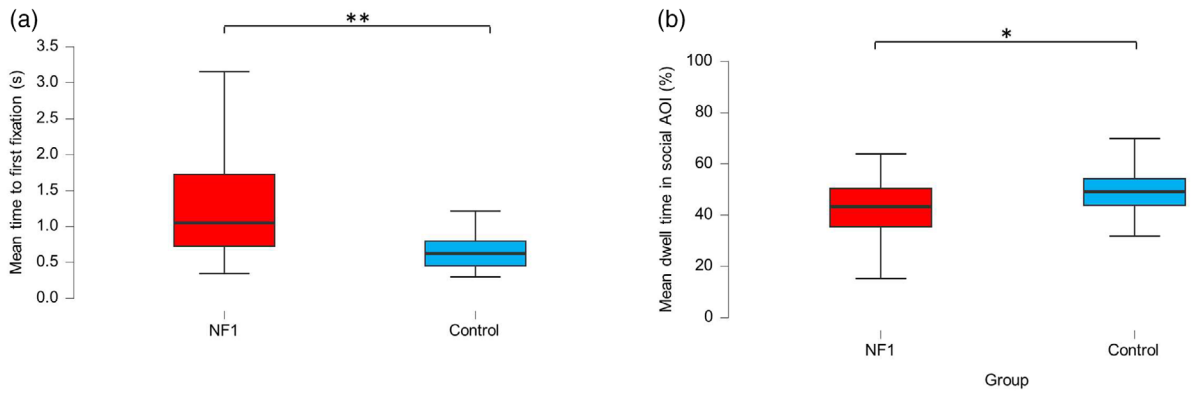

FIGURE 3 Social attention box plots representing the mean time to the first social fixation to the area of interest (AOI) (a) (group with neurofibromatosis type 1 [NF1], $n=25$; controls, $n=20$) and the mean dwell time in the social AOI between groups (b) (group with NF1, $n=24$; controls, $n=20$). *$p<0.05$, **$p<0.01$.

DISCUSSION

This study aimed to investigate visual attention patterns in young children with NF1 in response to social stimuli and in establishing and maintaining joint attention, and the relationships between social attention and the behavioural characteristics of autism, ADHD, and social adaptive functioning. We found that children with NF1 showed reduced preferential attention to social stimuli compared to typically developing controls. Children with NF1 were initially slower to respond to joint attention but maintained joint attention over time like typically developing controls.

The current findings support our first hypothesis that the social attention of young children with NF1 would be characterized by reduced time spent viewing social stimuli compared to typically developing peers. We specifically accounted for general attention difficulties by excluding off-screen behaviour, thereby addressing the elevated 'off-task behaviour' commonly observed in children with NF1.[23,24] These findings are consistent with our previous study in school-age children with NF1, which showed reduced dwell time to faces as a proportion of total time spent viewing the entire scene image.[10] However, the current study extended these findings by examining attention to social scenes versus non-social images rather than faces in isolation. We found that preschool children with NF1 were slower to initially fixate on social information compared to typically developing controls. Considering prior evidence of social cognitive deficits in older

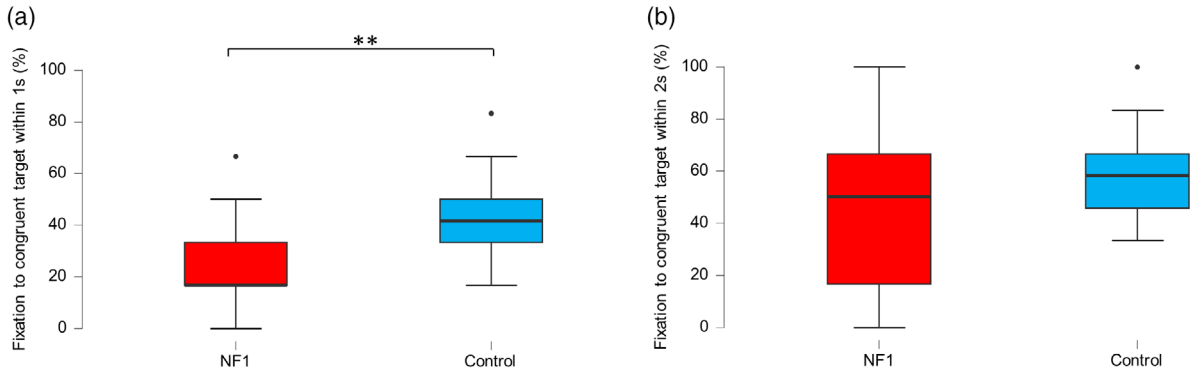

FIGURE 4 Joint attention box plots representing the percentage of each group that had established fixation to the congruent target within 1 second (a) (group with neurofibromatosis type 1 [NF1], $n = 25$; controls, $n = 20$) and the percentage of each group that had established fixation to the congruent target within 2 seconds (b) (group with NF1, $n = 25$; controls, $n = 20$). $^{**}p < 0.01$. The black dots represent outliers.

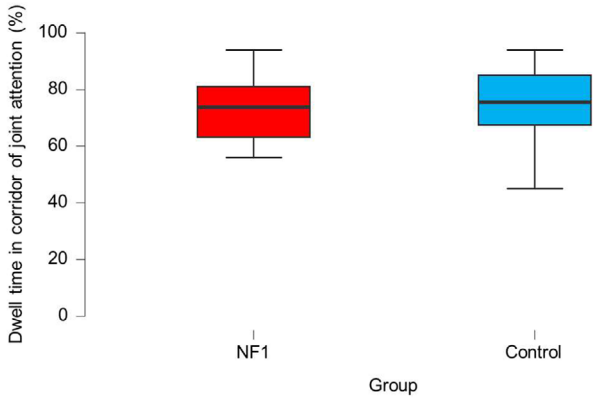

FIGURE 5 Box plot representing the mean dwell time for each group in the corridor of joint attention (group with neurofibromatosis type 1 [NF1], $n = 25$; controls, $n = 20$).

children with NF1,[9,25] these findings suggest that early changes in attention to social stimuli could be a contributing factor to later emergence of social difficulties in NF1.

Regarding joint attention, children with NF1 were significantly less likely to establish joint attention with the actor within 1 second, doing so on only 25% of trials compared to 42% for typically developing controls. This difference was not observed at the 2-second mark. Taken together, these findings suggest that young children with NF1 have a reduced referential understanding that objects gazed at by another person have a 'special status', which is similar to the pattern observed in idiopathic autism.[6] However, like typically developing controls, children with NF1 spent a comparable amount of time attending to the space between the actor's face and the object of their gaze. These findings suggest that children with NF1 show initiation difficulties in following another person's referential gaze, but with more time, they can maintain joint attention in a similar way to their typically developing peers.

Our final hypothesis was supported, with longer times to initially fixate on social stimuli associated with elevated autistic traits and poorer social adaptive functioning in young children with NF1. These findings suggest that a delayed first fixation on socially rich stimuli is related to daily social functioning and autistic behavioural features in children with NF1. While previous research linked autistic traits with sustained attention to social stimuli and joint attention abilities,[5] these associations were not observed in our sample with NF1. This may indicate that social attention difficulties in NF1 are more strongly driven by impairments in initial orienting to social cues rather than difficulties maintaining social engagement. One possibility is that the underlying mechanisms of social attention in NF1 differ from those in idiopathic autism, potentially reflecting broader attentional control deficits rather than domain-specific social impairments. This hypothesis could be further explored by examining eye-tracking patterns in a subgroup of children with NF1 and co-occurring autism, allowing for a more precise understanding of whether social attention difficulties in NF1 align with or diverge from those observed in idiopathic autism.

Previous studies showed strong correlations between ADHD symptoms, autistic traits, and social functioning in children with NF1,[7,26] suggesting shared mechanisms and overlapping variance between attention and social difficulties. While not reaching the threshold of significance in the current study, ADHD symptoms showed medium effect sizes with some eye-tracking variables from the social attention task. Given the high prevalence of ADHD in children with NF1,[25] general inattentiveness may further exacerbate the challenges young children with NF1 have with navigating their social environments and detecting social cues.[27] These challenges could contribute to missing initial social signals, which are often brief in nature (e.g. a wink, an initial reaction), as well as other important aspects of social interactions. Reduced social learning opportunities may, in turn, disrupt developmental trajectories and contribute to the well-documented difficulties in forming reciprocated friendships and the increased peer rejection observed in older children with NF1.[28,29] Future research should further explore the interplay between general and social attention to better understand their combined impact on social development in NF1.

Our current findings have important implications for clinicians designing interventions for social difficulties in children with NF1 and suggest that it may be of benefit

TABLE 2 Correlation coefficients between eye-tracking variables and neurodevelopmental outcomes (group with NF1, $n = 25$).

Eye-tracking variable	Autistic behaviours	Social functioning	ADHD inattentive	ADHD hyperactive/impulsive	Full-scale IQ	Verbal IQ	Non-verbal IQ
Mean time to first fixation to social AOI[a]	0.41*	−0.49*	0.34	0.40	−0.11	−0.06	−0.12
Percentage mean dwell time to social AOI[a]	−0.24	0.09	0.37	0.40	0.11	0.03	0.23
Percentage fixation to congruent target AOI (1 second)[b]	−0.01	−0.16	0.21	0.04	−0.29	−0.28	−0.17
Percentage fixation to congruent target AOI (2 seconds)[b]	−0.01	−0.03	−0.01	−0.16	−0.18	−0.13	−0.20
Percentage mean dwell time to corridor of joint attention AOI[a]	0.14	0.09	0.07	−0.24	0.26	0.15	0.10

Note: *$p < 0.05$.

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; AOI, area of interest; NF1, neurofibromatosis type 1.

[a]Pearson's product–moment correlation.

[b]Spearman's rank correlation.

to specifically treat attention deficits and provide explicit instruction to allocate attention towards social information. Indeed, previous evidence demonstrated that gaze-contingent training programmes are effective in reducing diminished attention towards social information (faces of on-screen social characters) in preschool children with idiopathic autism.[30] It remains to be determined whether social gaze training protocols are similarly effective in ameliorating the reduced preferential attention to social stimuli, as well as improving their everyday functioning in daily social interactions.

The current study has several limitations. Small sample sizes limited our ability to compare social and joint attention profiles in subgroups of children with NF1 with and without autism, and to determine whether anomalous social attention patterns vary across subtypes of these conditions. Sample size was determined based on feasibility rather than a formal power calculation, given the exploratory nature of the study. Although this sample size is comparable to previous eye-tracking studies in rare genetic conditions,[5,9,10] future studies with larger samples and longitudinal designs are necessary to identify unique predictors of developmental outcomes in children with NF1. In addition, while the use of video-recorded stimuli in this study allowed for precise and standardized eye-tracking measurements, it presents a potential limitation. Real-world social interactions are dynamic and reciprocal, involving subtle cues such as shared affect, real-time feedback, and interactive engagement, which may influence social attention differently than pre-recorded stimuli. Thus, the patterns of social and joint attention observed in this study may not fully reflect how children with NF1 engage in everyday social exchanges. Future research using live and interactive paradigms could help clarify how these attentional processes manifest in naturalistic social environments. Next, although children in the group with NF1 demonstrated a lower average IQ than children in the typically developing group, this difference is consistent with the typical cognitive profile of children with NF1.[31] Our focus was on assessing social attention in typical NF1 rather than exploring the relationship between IQ and social attention, making this comparison appropriate. In addition, although data were collected from children with idiopathic autism, this group was excluded from the present analyses because of a lack of comparative cognitive ability with the children with NF1 and typically developing controls. Future studies including well-matched NF1 and idiopathic autism groups will be important for delineating shared versus distinct mechanisms underlying atypical social attention. Finally, a limitation was the use of different measures to assess adaptive and cognitive functioning across groups, which may have affected direct comparisons between children in the NF1 group and typically developing controls. However, given the strong convergent validity of these measures and the fact that between-group comparisons in adaptive function were not a primary aim of this study, we believe this limitation does not affect the interpretation of our eye-tracking findings.

In conclusion, our findings suggest that young children with NF1 demonstrate a social attention profile characterized by slower orienting of attention to static social stimuli. We also found that children with NF1 were less likely to initially respond to an adult's bid for joint attention but were able to maintain joint attention if provided with enough time. Future avenues for research should examine diminished attention to social information using dynamic or real-life stimuli and examine whether these eye-tracking metrics could predict a later autism diagnosis and reduced everyday social functioning in children with NF1.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

The following additional material may be found online:

Table S1. Descriptive statistics and group comparisons for social and joint attention variables in NF1 and control groups.

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