Near-point Findings in Children with Autism Spectrum Disorder and in Typical Peers

Rachel Anastasia Coulter, OD, MS, FAAO,[1]* Annette Bade, OD, MSCVR, FAAO,[1] Erin C. Jenewein, OD, MS, FAAO,[2] Yin C. Tea, OD, FAAO,[1] and G. Lynn Mitchell, MAS, FAAO[3]

SIGNIFICANCE: Clinicians can better diagnose and manage vision problems of autism spectrum disorder (ASD) children by establishing a standard of care for this population. Results also reinforce the importance of a comprehensive binocular vision evaluation in all patients with ASD.

PURPOSE: The purposes of this study were to compare near-point and ocular motility test findings in ASD children and typically developing (TD) peers and to compare findings among ASD children by level of verbal communication.

METHODS: Sixty-one children and adolescents (ASD, 34; TD, 27) aged 9 to 17 years completed an eye examination protocol including tests of distance and near phoria, near point of convergence, near fusional convergence and divergence, accommodative response, and Northeastern State University College of Optometry oculomotor testing. Testing was completed through refractive correction. Parents of ASD children provided information regarding subjects' verbal communication level (nonverbal, uses short words, verbal).

RESULTS: Distance phoria did not differ significantly between groups. Near phoria of ASD subjects was more exophoric (difference, 2.8 prism diopters). Mean near point of convergence break and recovery were 7.0 and 8.02 cm, respectively, in ASD subjects and 2.19 and 3.99 cm in TD subjects. Near fusional divergence and convergence showed no significant difference. Autism spectrum disorder subjects had significantly poorer stereoacuity ($P < .0001$) and, on Northeastern State University College of Optometry Oculomotor Testing, reduced fixation, poorer accuracy and stamina/ability, and increased head and body movement. Monocular estimation method retinoscopy results did not differ significantly between ASD and TD subjects. No significant differences in phoria, near point of convergence, and near fusional divergence or convergence were observed between ASD subgroups (nonverbal, uses short words, verbal).

CONCLUSIONS: Autism spectrum disorder children are more likely to show receded near point of convergence, poor fixation, inaccurate saccades, erratic pursuits, and exophoric posture. These differences occur, regardless of reported verbal communication level.

Author Affiliations:
[1]Health Professions Division, College of Optometry, Nova Southeastern University, Fort Lauderdale, Florida
[2]Pennsylvania College of Optometry, Salus University, Philadelphia, Pennsylvania
[3]The Ohio State University, College of Optometry, Columbus, Ohio
*staceyco@nova.edu

Autism spectrum disorder is a neurodevelopmental disorder characterized by deficits in communication and social interaction as well as repetitive behaviors.[1] Vision findings may be impacted directly, as part of the affected central nervous system, or indirectly, as vision testing results are affected by behaviors that accompany the condition. Reports of vision findings in individuals with autism spectrum disorder have steadily increased. Investigations describing binocular vision, accommodation, and ocular motility findings are emerging, although more information is needed to understand the clinical vision profile of the autism spectrum disorder patient.

Available reports suggest that autism spectrum disorder individuals are more likely to have binocular vision and accommodative conditions. Strabismus has been reported to be more prevalent in the autism spectrum disorder population, with estimates ranging from 10 to 60%.[2–5] Milne and colleagues[3] found that near point of convergence was receded in children with autism spectrum disorder, but this study had limitations. Subjects were tested wearing their habitual correction, not their current refractive error correction.

Investigations of stereoacuity in subjects with autism spectrum disorder are limited. One comparison of stereoacuity in autism spectrum disorder and typically developing children used the Frisby stereotest and found no difference between the two groups. However, a limitation was that the criterion set for normal stereoacuity (120 seconds) may have lacked the sensitivity to detect smaller differences.[3] Children with autism spectrum disorder have been shown to have significantly more accommodative deficits, as well as associated decreased near visual acuity, even when wearing habitual correction.[6]

Autism spectrum disorder individuals are more likely to demonstrate ocular motor deficits including abnormalities in voluntary pursuit movement and hypometric saccades with variable accuracy.[7,8] Meta-analysis of 28 studies of eye movements in autism spectrum disorder found evidence for saccade dysmetria, difficulty inhibiting saccades, and poor tracking of moving targets.[9] Walker and colleagues[10] investigated oculomotor skills in sensory processing disorder, a common co-occurring disorder in individuals

with autism spectrum disorder. They compared results of Northeastern State University College of Optometry oculomotor testing in sensory processing disorder and typically developing children and found sensory processing disorder children demonstrated decreased oculomotor skills on saccade and pursuit ability, accuracy, and overflow head and body movement.[10] Although this study included children with autism spectrum disorder, their data were not analyzed separately.

Currently, no prospective study has reported how clinical near-point test results in children with autism spectrum disorder compared with that of typically developing children. Eye care providers need this information to understand the profile of vision in the autism spectrum disorder population, as well as to better diagnose and manage their vision problems and to establish standards of care for autism spectrum disorder patients.

STUDY AIMS

The primary aim was to compare clinical findings of binocular vision, accommodation, and ocular motility testing of children with autism spectrum disorder with those of typically developing peers. The secondary aim was to compare these findings among autism spectrum disorder subgroups by parental report of verbal level.

METHODS

All investigators followed the tenets of the Declaration of Helsinki throughout the study. A parent or guardian (subsequently referred to as parent) of each subject gave written informed consent. Each participating subject completed the assent process according to the protocol. The Nova Southeastern University Institutional Review Board approved this research. Health Insurance Portability and Accountability Act authorization was obtained from parents.

Subject Selection

Recruitment and Eligibility Criteria

Subjects were between 9 and 17 years of age and met the criteria for typically developing or autism spectrum disorder groups. Subjects were recruited by distribution of recruitment fliers through several venues. For the autism spectrum disorder group, this included the University of Miami—Nova Southeastern University Center for Autism and Related Disabilities e-newsletter, the Broward County Chapter of the Autism Society of America, Denise's List (a Yahoo Listserv for parents of children with autism spectrum disorder), local therapy centers, and the assistance of the Interactive Autism Network Research Database at the Kennedy Krieger Institute and Johns Hopkins Medicine—Baltimore, sponsored by the Autism Speaks Foundation. Both typically developing and autism spectrum disorder subjects were recruited from Broward County public schools, local private schools, the Nova Southeastern University Health Professions Division clinics, and community health fairs. Parents contacted the principal investigator who completed a prescreening intake form. If the subject appeared to be eligible, an intake visit was scheduled with the parent only.

Confirmation of Autism Spectrum Disorder and Typically Developing Group Eligibility

A psychologist with expertise in autism spectrum disorder diagnosis determined eligibility and group status based on the presence or absence of an autism spectrum disorder diagnosis and symptoms consistent with autism spectrum conditions. Children were included in the autism spectrum disorder group if they held community diagnoses and their diagnoses were confirmed using *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* criteria based on review of previous evaluations combined with parent ratings of symptoms on the Social Communication Questionnaire. Children were included in the typically developing group if they had never received a diagnosis of autism spectrum disorder and they did not show any research evidence of an autism spectrum disorder–related disorder (i.e., did not exceed a cutoff score of 9 on the Social Communication Questionnaire).

Intake Visit

Subjects' parents provided information regarding the subject's sex, race, and ethnicity and identified any medications taken. Parents of children with autism spectrum disorder indicated if their child's speech communication level was best described as (1) nonverbal/minimally verbal, (2) uses short words/can answer questions partially, or (3) verbal/speaks fluently/able to answer questions completely.

Eye Examination Visit

All patients who met the criteria for the autism spectrum disorder or typically developing group were scheduled for an eye examination study visit. The assent process with the child or adolescent was conducted at the time of the eye examination before any procedures were initiated. An eye examination protocol was designed to maximize testability by incorporating visual, sensory, and communication supports and by incorporating tests that were less likely to elicit tactile defensiveness.[11] An example was testing vergences in free space using prism bars rather than phoropters. All subjects completed an eye examination using this protocol.

Examination Procedures

Upon completing a comprehensive eye examination, all subjects were corrected for refractive error. The patient's cycloplegic retinoscopy findings were compared with the study criteria to determine if a new or updated refractive correction was indicated (Table 1).

All subjects had worn their correction for at least 4 weeks before completing binocular vision, accommodation, and ocular motility

TABLE 1. Refractive error prescribing criteria

Identification and management of significant refractive error
A significant refractive error or change was defined as:
1.75 D or greater of hyperopia
0.50 D or greater of myopia
1.25 D or greater of astigmatism
1.00 D or greater of anisometropia in spherical equivalent, or 1.50 D or greater of anisometropia in any meridian (based on cycloplegic refraction)
Prescribing guidelines
For hyperopes, the investigator could reduce the prescription by up to 1.25 D
For myopia, full correction was required
For anisometropia and astigmatism, full correction was required

testing. This testing was completed before cycloplegic refraction and ocular health assessment. If the comprehensive eye examination found that comparing the subject's habitual correction to their cycloplegic retinoscopy findings indicated no significant difference, testing was completed at the first visit. If a significant difference was found, the subject wore the new refractive correction for at least 4 weeks and returned to complete vision, accommodation, and ocular motility testing.

The following tests were completed: cover/uncover (unilateral cover) test, alternate cover test with prism neutralization at distance and near, near point of convergence, Northeastern State University College of Optometry oculomotor testing, near fusional vergence (break and recovery), stereoacuity, and monocular estimation method retinoscopy. Testing at near was performed at 40 cm. Near point of convergence and near positive fusional convergence were performed three times, and the average of the trials was used for analysis. Testing procedures and testability have been reported previously in detail.[11]

For the cover test at distance fixation, a 20/30 isolated letter or symbol was used. For cover test at near fixation, near point of convergence, and near positive and negative fusional vergence, a 20/30 fixation stick (542055; Good-Lite, Elgin, IL) presenting either Sloan letters or Lea symbols was used. The examiners used common techniques to increase attention to the task, including moving the target slightly to the right or left while watching for a small pursuit movement to confirm the subject was attending to the target, as well as flipping the target to present a novel image and increase attention to the task and providing verbal encouragement.

For near point of convergence, the examiner held a ruler with the zero point of the ruler parallel and equal to the bridge of the patient's nose at the midline of the patient's body. The examiner presented target at the midline. The standard instruction set was accompanied by a visual demonstration card to depict "double" and "single" targets. The examiner moved the fixation target toward the subject at approximately 1 to 2 cm/s, until the examiner observed a loss of fusion. This point was considered the near point of convergence break. The distance from the break point to the bridge of the patient's nose was measured to the nearest centimeter. The target was then moved away from the subject until the examiner observed a recovery of fusion.

Near positive and negative fusional vergence were measured with the step (prism bar) vergence method using a horizontal prism bar with prisms from 1 prism diopter to 45 prism diopters (Gulden B-16 horizontal prism bar; Gulden Ophthalmics, Elkins Park, PA). The subject was instructed "Look here. Tell me when the letters/pictures become blurred or break into two, but try to keep the target single/one as long as possible. When it breaks, try to see one." The examiner showed a visual demonstration card depicting "blurred" and "broken fusion/double" target appearance. The examiner observed for a loss of fusion.

To test stereoacuity, a step approach was incorporated using three stereoacuity tests with the hardest test to complete presented first and then moving to easier tests if a result was not obtained. Stereoacuity testing was first attempted with the Random Dot 2 Stereotest (100750; Good-Lite). If the patient did not respond to the Random Dot 2 Stereotest, testing was attempted with the Random Dot E test (3700, Precision Vision, Woodstock, IL) using a forced choice presentation. If the patient did not respond to either the Random Dot 2 Stereotest or the Random Dot E test, testing was attempted with the Lang Stereotest 1 (Bernell, Mishawaka, IN). For the Lang Stereotest 1, the patient was allowed to match presented black and white pictures of the stereo targets to the Lang testing plate.

Statistical Analysis

All statistical analyses were performed using Statistical Analysis Software version 9.3 (Cary, NC) defining statistical significance as $P < .05$. All nonmissing observations were used in statistical testing. For data that took the form of proportions, overall differences were evaluated using a χ^2 test, and multiple comparisons between individual pairs were done with the Marascuilo procedure. The difference between the typically developing and autism spectrum disorder groups with respect to interval-scaled measures was tested with a Student t test and reported using 95% confidence intervals. Because of the ordinal nature of the Northeastern State University College of Optometry measures, a Wilcoxon rank test was used to test the difference between the typically developing and autism spectrum disorder groups. Similarly, a Kruskal-Wallis test was used to test the difference in Northeastern State University College of Optometry Oculomotor Test measures among autism spectrum disorder subgroups. Given the small number of subjects in each autism spectrum disorder subgroup, post hoc power analyses were completed assuming an α level of 0.05 and two-sided hypothesis using PASS 2020 (NCSS Statistical Software, Kaysville, UT). Study power was greater than 80% for all omnibus comparisons of the three subgroups, assuming a between-group effect size of 0.75. Not surprisingly, the effect size that can be observed in pairwise comparisons of autism spectrum disorder subjects who are nonverbal and those who use short words to communicate is much higher at 1.5 (a large effect).

RESULTS

Between August 2010 and June 2012, 61 subjects (autism spectrum disorder, 24; typically developing, 27) were enrolled in the study.

Demographic Statistics for Typically Developing and Autism Spectrum Disorder Groups

There was no significant difference in the mean ± standard deviation age of participants in the two groups: autism spectrum disorder, 11.7 ± 2.8 years; typically developing, 11.2 ± 2.5 years ($P = .54$). Sex distribution was similar ($P = .53$) in each group: autism spectrum disorder, 58.8% male; typically developing, 66.7% male. Autism spectrum disorder subjects were more likely to be taking medications, although the between-group difference did not meet the criteria for statistical significance ($P = .06$). Fifty percent of subjects in the autism spectrum disorder group reported taking at least one medication compared with only 26% of the typically developing group.

Parent Report of Speech Communication Level of Autism Spectrum Disorder Patients

Among autism spectrum disorder patients, parental reports of verbal communication level indicated that 23.5% (n = 8) were nonverbal/minimally verbal; 26.5% (n = 9) used short words/could answer questions at least partially; and 50% (n = 17) were verbal, spoke fluently, and were able to answer questions.

Binocular Vision

Phoria

Distance phoria did not differ by direction ($P = .54$) or magnitude ($P = .56$). Not surprisingly, the greatest proportion of participants in both groups was orthophores, with 63% in the typically

developing group and 74% in the autism spectrum disorder group. Approximately 15% of participants in each group were esophoric. Twelve percent of autism spectrum disorder subjects were exophoric (ranging from 1 to 8 prism diopters), whereas exophoria (1 prism diopter) at distance was observed in 22% of typically developing subjects. Among autism spectrum disorder subgroups (verbal, n = 17; short words, n = 9; nonverbal, n = 8), phoria direction (*P* = .72) and magnitude (*P* = .87) did not differ at distance. In each subgroup, most subjects were orthophoric, ranging from 88% among nonverbal, 78% among those who use short words, and 65% of verbal autism spectrum disorder subjects.

Slightly more than half of autism spectrum disorder subjects were exophoric at near, whereas nearly 60% of typically developing subjects were esophoric (*P* = .06). In fact, 45% of autism spectrum disorder subjects were measured at 4 prism diopters or more exophoria compared with only 15% of typically developing subjects. Conversely, 18% of typically developing subjects were 4 prism diopters or more esophoric (maximum 8 prism diopters esophoria), whereas no autism spectrum disorder subjects exhibited that magnitude of near phoria. Not surprisingly, these differences in the distribution result in statistically significant difference in the magnitude of near phoria (*P* = .005). The mean near phoria was 2.12 exo (4.1) for autism spectrum disorder subjects compared with 0.70 eso (3.1) among typically developing subjects. As with distance, near phoria direction (*P* = .22) and magnitude (*P* = .45) did not differ between the autism spectrum disorder subgroups. Although not significant, those who use short words were far more likely to be exophoric at near (78%) compared with subjects who were nonverbal (38%) or verbal (47%). The eight nonverbal autism spectrum disorder subjects were spread almost equally between exophoria, orthophoria, and esophoria. The highest percentage of esophoria (41%) was observed in verbal autism spectrum disorder subjects.

Near Point of Convergence

As shown in Table 2, near point of convergence break was reduced for autism spectrum disorder subjects (mean, 7.01 cm) compared with typically developing subjects (mean, 2.19; *P* < .0001). Autism spectrum disorder subjects also demonstrated reduced recovery of fusion (mean, 8.02 cm) compared with typically developing subjects (mean, 3.99; *P* = .006). Among autism spectrum disorder subgroups, no difference was observed in near point of convergence break (*P* = .11) and recovery (*P* = .61).

Near Fusional Vergence

Autism spectrum disorder and typically developing subjects did not differ in any of the measures of near fusional vergence (Table 2). The mean negative fusional break and recovery measures were nearly identical with between group differences of 0.19 and –0.074 prism diopters, respectively. Larger but nonsignificant differences were observed for positive fusional vergence. Break and recovery means for the autism spectrum disorder group were lower than those found in the typically developing group by –3.82 prism diopters (95% confidence interval, –8.10 to 0.45) and –2.81 prism diopters (95% confidence interval, –6.55 to 0.94), respectively.

Among autism spectrum disorder subgroups (verbal, n = 17; short words, n = 9; nonverbal, n = 8), there were no differences in negative fusional vergence break (*P* = .89) and recovery (*P* = .96). The same was true for positive fusional vergence break (*P* = .39) and recovery (*P* = .91).

Stereoacuity

All typically developing subjects were able to complete the Random Dot 2 stereoacuity test. Of the 33 autism spectrum disorder subjects who completed stereoacuity testing, 30 completed the Random Dot 2 stereoacuity test. The three autism spectrum disorder subjects, who were unable to complete the Random Dot 2 test, completed alternate stereoacuity tests that were less sensitive in measuring stereoacuity. Two autism spectrum disorder subjects completed the Lang Stereotest I, for which the finest stereoacuity measure possible was 550 seconds. One autism spectrum disorder subject completed the Random Dot E at a test distance of 50 cm; this corresponded to 504 arc seconds of disparity. Autism spectrum

TABLE 2. Findings from functional vision testing at near for ASD and TD children

Measure	ASD children, mean (SD)	TD children, mean (SD)	Difference* (95% CI)	*P*
NPC				
Break (cm)	7.01 (5.5)	2.19 (2.7)	4.82 (2.64–7.01)	<.001
Recovery (cm)	8.02 (6.3)	3.99 (4.5)	4.03 (1.14–6.93)	.006
Negative fusional vergence				
Break (Δ)	12.16 (5.0)	11.96 (5.8)	0.19 (–2.62 to 3.01)	.89
Recovery (Δ)	8.00 (4.9)	8.07 (5.8)	–0.074 (–2.92 to 2.78)	.96
Positive fusional vergence				
Break (Δ)	17.77 (8.4)	21.59 (8.0)	–3.82 (–8.10 to 0.45)	.08
Recovery (Δ)	13.55 (7.6)	16.35 (6.5)	–2.81 (–6.55 to 0.94)	.14
MEM retinoscopy (sphere)				
OD (D)	+0.27 (0.46)	+0.35 (0.24)	–0.086 (–0.28 to 0.11)	.37
OS (D)	+0.28 (0.46)	+0.35 (0.24)	–0.070 (–0.27 to 0.13)	.46
Stereoacuity†	121.97 (139.63)	31.65 (15.27)	90.32 (40.51–140.14)	<.001

*ASD mean – TD mean. †Stereoacuity measured by Randot 2 stereotest in seconds of arc. Δ = prism diopters; ASD = autism spectrum disorder; CI = confidence interval; MEM = monocular estimation method; NPC = near point of convergence; SD = standard deviation; TD = typically developing.

Ocular Motility

Fixation

Autism spectrum disorder children were significantly less likely to maintain fixation for at least 10 seconds than typically developing subjects ($P = .05$). Of the typically developing subjects, 96.3% were able to maintain fixation compared with 78.8% autism spectrum disorder subjects (Fig. 1). Among the autism spectrum disorder subgroups, the ability to maintain fixation for at least 10 seconds was poorer among subjects who were nonverbal or responded in short answers ($P = .01$) than for verbal autism spectrum disorder subjects. Sixty-three percent of nonverbal subjects and 55.6% of subjects who responded in short answers were able to maintain fixation compared with all autism spectrum disorder subjects who were verbal.

Saccadic Eye Movements

Autism spectrum disorder subjects demonstrated saccades that were less accurate ($P < .001$), showed less stamina/ability ($P < .0001$), and showed more compensatory head and body movement ($P < .0001$) than typically developing subjects. All 27 typically developing subjects were able to complete 5 round trips compared with 60.6% of the 33 autism spectrum disorder subjects (Fig. 2A). Conversely, 21.2% of autism spectrum disorder subjects were unable to complete two round trips. Gross overshooting or undershooting accuracy was observed in slightly more than one-third of the autism spectrum disorder subjects, whereas no overshooting or undershooting was observed in 70.4% of typically developing subjects (Fig. 2B). Similar findings were observed for compensatory head and body movements

(Fig. 2C). Large to moderate movements were observed in 37.5% of the autism spectrum disorder group compared with only 3.7% of the typically developing subjects.

Saccadic measures of ability ($P = .002$), accuracy ($P = .01$), and head/body movements ($P = .02$) from Northeastern State University College of Optometry oculomotor testing were significantly different between the autism spectrum disorder subgroups (Table 3). Verbal autism spectrum disorder subjects showed greater stamina when compared with either of the other two subgroups. Whereas 88.2% of verbal children completed five round trips, approximately half that number (44.4%) of subjects who use short words and 14.3% of nonverbal autism spectrum disorder subject showed that level of ability. At least moderate overshooting or undershooting was observed in nearly four times as many nonverbal autism spectrum disorder subjects as verbal autism spectrum disorder subjects (85.7% vs. 23.5%) and nearly 30% higher than autism spectrum disorder subject who use short words (66.6%). Both the nonverbal autism spectrum disorder subjects (57.1%) and those who use only short words (44.4%) showed more compensatory head and body movements when compared with verbal autism spectrum disorder subjects (11.8%).

Pursuit Eye Movements

Autism spectrum disorder subjects also demonstrated pursuits that were less accurate ($P < .0001$), showed less stamina/ability ($P < .0001$), and showed more compensatory head and body movement ($P < .0001$) in Northeastern State University College of Optometry pursuit testing than typically developing subjects. All 27 typically developing subjects were able to complete five round trips compared with one-third of autism spectrum disorder subjects (Fig. 2C). Conversely, more than half of autism spectrum disorder subjects (54.5%) were unable to complete more than three round trips. Gross overshooting or undershooting inaccuracy was observed
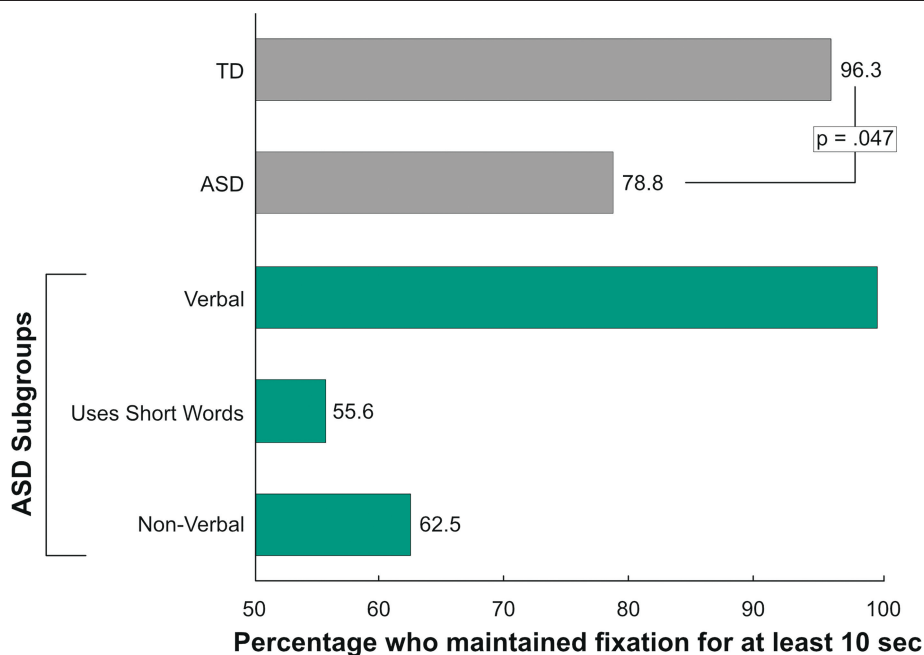
FIGURE 1. Fixation testing results—TD and autism spectrum disorder subjects and among autism spectrum disorder subgroups. TD = typically developing.
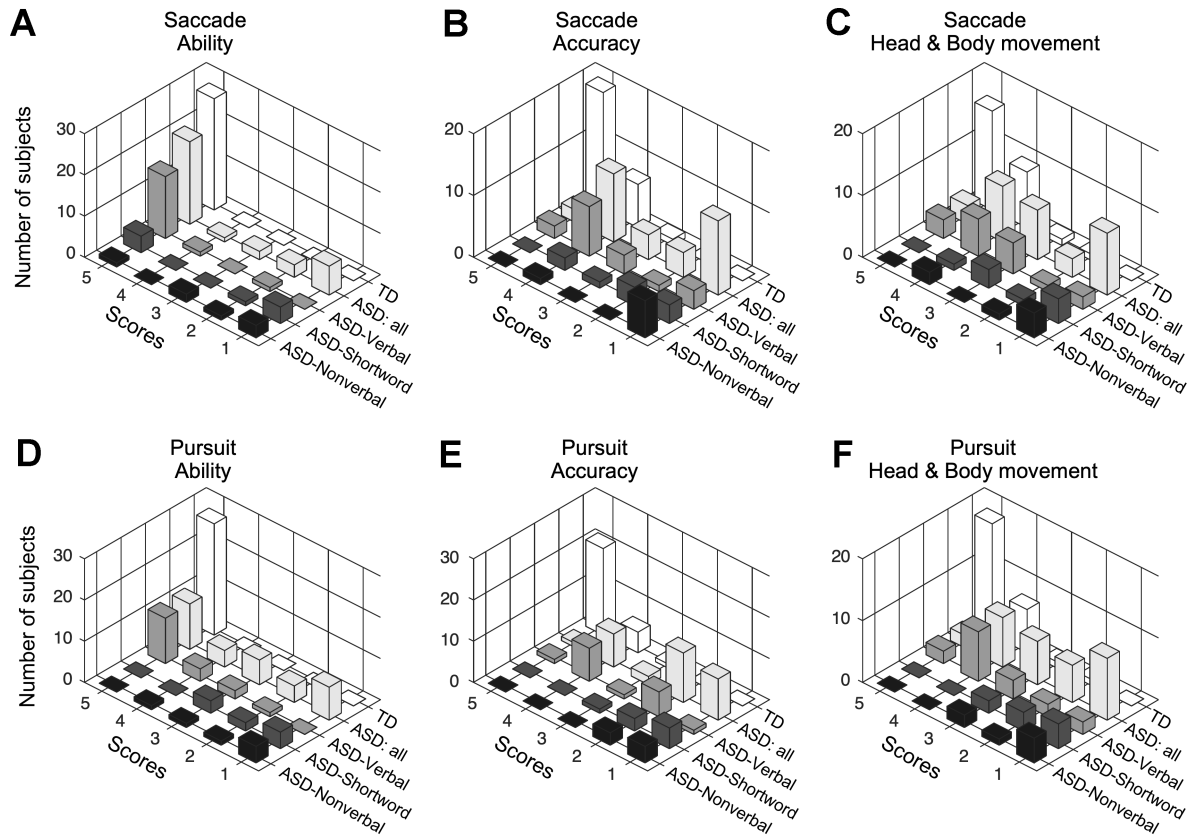
FIGURE 2. Northeastern State University College of Optometry Saccades and Pursuits Test Results—TD and autism spectrum disorder subjects: (A) saccades ability, (B) saccades accuracy, (C) saccades head and body movement, (D) pursuits ability, (E) pursuits accuracy, (F) pursuits head and body movement. TD = typically developing.

in 30.3% of the autism spectrum disorder subjects, whereas no overshooting or undershooting was observed in 77.8% of typically developing subjects (Fig. 2D). Large to moderate head and body movements were observed in 48.4% of the autism spectrum disorder group compared with only 3.7% of the typically developing subjects (Fig. 2E).

As with saccades, performance on pursuits testing was also significantly different among the autism spectrum disorder subgroups. Both nonverbal subjects and those who use short words showed less stamina ($P < .0001$), were less accurate ($P < .001$), and exhibited more head and body movement ($P = .002$) than verbal autism spectrum disorder subjects. Whereas more than 80% of verbal autism spectrum disorder subjects were able to complete two rotations, 71.4% of nonverbal subjects and 66.6% of autism spectrum disorder subjects who communicate with short words were unable to complete more than one-half of a rotation. All nonverbal autism spectrum disorder subjects, along with 88.9% of autism spectrum disorder subjects using short words to communicate, had to refixate at least five times compared with only 41.2% of verbal autism spectrum disorder subjects. More than half (58.9%) of verbal subjects showed no to only slight (<50%) hand and/or body movements during the task, whereas all other autism spectrum disorder subjects had at least slight movements more than 50% of the time.

Accommodative Response

Accommodative response, as measured by monocular estimation method retinoscopy, did not differ significantly between autism spectrum disorder and typically developing groups (Table 2). The mean monocular estimation method retinoscopy response in the right eye was +0.35 D (0.24) in the typically developing group and +0.27 D (0.46) in the autism spectrum disorder group. Comparable results were found using findings from the left eye. One autism spectrum disorder subject showed a high accommodative lag of +1.50 D sphere on monocular estimation method retinoscopy and corresponding decreased near visual acuity.

Adverse Events

No adverse events were reported during this study.

DISCUSSION

Study results provide additional detail regarding the clinical vision profile of children with autism spectrum disorder. Accurate accommodation, vergence, and ocular motility skills are all required for many academic and therapeutic tasks, including reading, writing, and work on a computer or personal device. This study was prospective and compared findings to a control group similar in age and sex. Our autism spectrum disorder study population included more females than typical in the general autism spectrum disorder population. Our sample provides more data on female children with autism spectrum disorder who are often underrepresented in the literature. Vision testing was performed with subjects wearing their current refractive correction, not habitual, thus controlling for uncorrected refractive error as a

TABLE 3. Percentage in each category on NSUCO Oculomotor Test, by ASD subgroup

	Nonverbal (n = 7)	Uses short words (n = 9)	Verbal (n = 17)	*P*
Saccades				
Ability				
Completes <2 round trips	42.9	44.4	0	.002
Completes 2 round trips	14.3	11.1	5.9	
Completes 3 round trips	28.6	0	0	
Completes 4 round trips	0	0	5.9	
Completes 5 round trips	14.3	44.4	88.2	
Accuracy				
Large overshooting or undershooting	85.7	33.3	17.7	.01
Moderate overshooting or undershooting	0	33.3	5.9	
Constant slight (≥50% of time) overshooting or undershooting	0	11.1	17.7	
Intermittent slight (<50% of time) overshooting or undershooting	14.3	22.2	47.1	
No overshooting or undershooting	0	0	11.8	
Head and/or body movements				
Large movement	57.1	44.4	11.8	.02
Moderate movement	14.3	11.1	5.9	
Slight movement (≥50% of time)	0	33.3	29.4	
Slight movement (<50% of time)	28.6	11.1	35.3	
No movement	0	0	17.7	
Pursuits				
Ability				
Cannot complete ½ rotation in either direction	57.1	44.4	0	<.001
Completes ½ rotation in either direction	14.3	22.2	5.9	
Completes 1 rotation in either direction	14.3	33.3	11.8	
Completes 2 rotations in one direction only	14.3	0	17.7	
Completes 2 rotations in each direction	0	0	64.7	
Accuracy				
No attempt to follow or >10 refixations	57.1	55.6	5.9	<.001
Refixations 5 to 10 times	42.9	33.3	35.3	
Refixations 3 to 4 times	0	11.1	5.9	
Refixations 2 times or less	0	0	47.1	
No refixations	0	0	5.9	
Hand and/or body movements				
Large movement	57.1	44.4	11.8	.002
Moderate movement	14.3	33.3	11.8	
Slight movement (≥50% of time)	28.6	22.2	17.7	
Slight movement (<50% of time)	0	0	47.1	
No movement	0	0	11.8	

ASD = autism spectrum disorder; NSUCO = Northeastern State University College of Optometry.

confounding factor. There are several limitations to acknowledge and questions to be answered by future investigations.

Study Limitations

There are several limitations linked to study design. Nonrandomized sampling was used, as it is cost-effective, efficient, and simple to implement and provides valuable information particularly in preliminary stages of investigation. It does have multiple shortcomings including limited generalizability to the population as a whole and may interject potential biases. Examiners were unmasked as to whether the subject was in the typically developing or autism spectrum disorder group, because of observed communication and social

interaction abilities. Groups were matched by age, not by standardized measure scores such as intelligence quotient. Matching by intelligence quotient scores potentially excludes autism spectrum disorder lower-functioning individuals, as traditional testing has been known to underestimate their abilities.[12] This approach is consistent with clinical presentation, in which intelligence quotient scores are rarely provided when patients present for care. Practically, management of these children usually centers on comparison based on age, grade level, or sex.

In dividing the autism spectrum disorder into subgroups, the investigators used parental report of verbal level in place of an ability scale score. Ability scale scores offer consistency, validity, and agreement of interpretation but are only one approach used to subgroup the autism spectrum disorder population. Investigators have also classified subjects based on their scores of a measure of autism severity, sensory profiles, genetic types, presence of co-occurring medical conditions, phenotype presentation, neuroanatomical structures, and level of special educational needs support.[13–16] Eventually, a universal classification system may be created. In the interim, investigators need to communicate clinical research findings. Parental report of verbal level is a simple, efficient, and practical, if imperfect, approach to communicate information to clinicians. Although parental report may be limited by consistency and agreement of interpretation and validity, there is some evidence that parents of autism spectrum disorder children are generally reliable reporters of their children's language abilities.[17]

Confounding Factors

Investigations of vision in autism spectrum disorder children face unique challenges because social and communication deficits are at the core of the condition. The differences between the autism spectrum disorder and typically developing groups in near phoria, near point of convergence break and recovery, stereopsis, and ocular motility findings may be attributed to nonvisual factors including effort, fatigue, motivation, attention, distractibility, cognitive differences, and sensory issues (specifically autism spectrum children not liking items near their face). Typically developing children also display differences in effort, distraction, and motivation. It is true that typically developing children may be more able to follow directions. The fact that children with autism may struggle more to follow directions, however, does not negate the vision findings that are obtained. Testability using this examination protocol in typically developing and autism spectrum disorder has been reported in a previous publication.[11] Attention and sensory issues may be part of autism spectrum disorder, but we still need to understand visual coexisting conditions.

Autism spectrum disorder is a neurologic condition with high comorbidities including attention deficit, cognitive impairment, food intolerances, and allergies, all of which have genetic components. Likewise, binocular or accommodative conditions arise from differences in neuromuscular feedback systems. The binocular, oculomotor, and accommodative deficits measured clinically in this study are just as likely to be biological as behavioral. Just as one would not fail to diagnose attention deficit in an autism spectrum disorder child, because of his or her autism spectrum disorder–related behaviors, optometrists should not neglect to diagnose binocular, accommodative, or oculomotor conditions. We acknowledge that correlation does not equate to causation.

In considering the underlying cause of these differences, medications are a confounding factor. Of the typically developing participants, no participants took medications linked to diplopia or known to affect the accommodative response. Of autism spectrum participants, three took medications for which diplopia was a potential adverse effect, and three took medications that could possibly affect the accommodative response.

Interpretation of Binocular Vision, Accommodation, and Oculomotor Findings

In agreement with Milne and colleagues,[3] we found near point of convergence in children with autism spectrum disorder to be more receded than in typically developing peers, even when subjects are examined and tested through their current refractive correction. Because the components of near point of convergence, break and recovery, are related, it is consistent that these subjects showed a receded near point of convergence break, and near point recovery was also receded. In contrast to the findings of Milne and colleagues,[3] we found that near fusional vergence was not significantly different in autism spectrum disorder and typically developing children, nor was it different among autism spectrum disorder subgroups. Different measures of fusional vergence between the two studies may account for these different findings. To measure fusional vergence, Milne et al.[3] used a 33-cm testing distance, whereas we used the optometric standard of 40 cm. In addition, in the protocol of Milne et al.,[3] when a subject could not sustain attention long enough for the examiner to test with a prism bar, a single 20-prism diopter prism was used to test for the presence of a convergence reflex. Results showed that none of the four subjects tested by this method showed a normal convergence response. This technique has several critical limitations. A 20-prism diopter base-out test is not a standardized test; therefore, normative data are unavailable. It also differs from classical optometric fusional vergence testing in which fusional demand is gradually increased. Milne et al.[3] reported that none of the typically developing subjects were tested in this manner. It is possible that this approach skewed results to show a difference in prism fusional vergence results between the autism spectrum disorder and typically developing groups. We report near phoria, as measured by cover testing, to be significantly more exophoric and larger in children with autism spectrum disorder; this has not been reported elsewhere.

We found no significant difference in accommodative response measured by monocular estimation method retinoscopy between autism spectrum disorder and typically developing children. These findings diverge from those of Anketell and colleagues,[6] who found a more significant lag in children with autism spectrum disorder by modified Nott retinoscopy using an Ulster-Cardiff Accommodation Cube. The comparison of accommodative response using monocular estimated method and Nott retinoscopy remains unsettled. No difference was found by Nguyen and colleagues[18] in an investigation of 26 children, 7 to 16 years old, and no difference was found by Casser Locke and Somers[19] in 10 healthy adults. del Pilar Cacho and colleagues[20] found increased lag by monocular estimation method retinoscopy in 50 young adults. Alternatively, these findings are consistent with the idea of Thibos and colleagues[21] that monocular estimation method retinoscopy may not be a measurement of lag but of best focus at near considering the eyes aberrations. Monocular estimation method retinoscopy may not be adequately sensitive to assess accommodative response in the autism spectrum disorder population.

Differences in eye movement are well established in the autism literature. In view of dozens of laboratory studies of eye movement in mostly high-functioning autism spectrum disorder individuals, it would be hard to deny that they are not present. Common clinical

oculomotor test findings have not been reported. Unlike the visual-verbal tests including the developmental eye movement test and the King-Devick test, the Northeastern State University College of Optometry Oculomotor battery requires minimal language. The patient is not required to say anything. The instructions are simple and minimal. It is relatively quick, does not require that the patient wear goggles or equipment, and is a commonly used and available clinical test that is normed for children who are between 5 and 14 years old. The authors acknowledge that cognition and attention may also influence the results.

Clinical Significance

Decreased convergence and accommodation abilities, as well as inaccurate oculomotor accuracy, may be associated with symptoms and decreased near-point task performance. Cohen et al.[22] found that asthenopic symptom score correlated with the near point of convergence. Symptoms including visual discomfort,[23–25] asthenopia,[26,27] visual fatigue,[28,29] and visual stress[22,30] make near activities uncomfortable and challenging. A symptomatic child may not complete near-point tasks or may choose to avoid these tasks altogether.[31]

This study did not quantify symptoms. Although children with autism spectrum disorder are more likely to have convergence and oculomotility problems, it may be challenging to determine how symptomatic they are. Bade and colleagues[32] found that the severity of signs of convergence insufficiency did not correlate with symptom severity in neurotypical children. Alternate measures of symptom severity for the autism spectrum disorder pediatric population may be needed, as these patients may not always be able to report their symptoms. Potential measures could rely on observations or structured checklists provided by others, including parents, teachers, and therapists. Structured analysis of an autism spectrum disorder patient's near-point task performance may also be useful.

Regarding treatment including lenses, vision therapy/orthoptics, or neurorehabilitation, study findings may be interpreted in multiple ways. It is possible that children with autism spectrum disorder have a primary vision problem that interferes with near work. Treatment of this condition could improve both vision and tasks performed at near. Another explanation is that these children avoid near work because of other facets of the autism condition. Treatment of the vision condition, even if it results in visual improvement, may not result in functional gains. The third explanation is that autism and vision problems are co-occurring. Treatment of vision problems may not result in improvement in vision, nor may it result in functional academic gains. Clinicians managing these patients should have a frank discussion with parents before embarking on treatment.

Although children with autism spectrum disorder vary greatly in their severity and functional level, all benefit from education and therapeutic interventions that enable them to function fully and independently in society. In addition to targeting academic abilities, these interventions develop capacities in communication, social interaction, life skills, behavior, choice making, and vocational areas. Interventions are usually multidisciplinary in nature and require coordination of care. Regardless of their cognitive or verbal communication abilities, children with autism spectrum disorder are required to complete numerous tasks that require accurate accommodation, convergence, and ocular motility skills. In addition to reading, writing, and arithmetic, students often work on laptop computers, tablets, smartphones, and other assistive technology devices. Vocational programs require students to process near detailed targets including picture schedules, reading labels, and step-by-step

checklists. Other programs target functional life skills and include such near-point tasks as reading food and clothing labels, fastening buttons and zippers, reading measuring cups and spoons, interpreting food prices and labels to shop, and operating kitchen appliances such as a microwave.

For children who have findings of poor convergence and oculomotility and who are symptomatic, at the least, optometrists should educate teachers, parents, therapists, and tutors of signs and symptoms commonly associated with the patient's particular findings. Collaborative discussion can determine if the condition is likely to impact academic achievement and therapeutic progress. Accommodations should be identified and discussed with the child's teachers, therapists, tutors, and individualized education program team.

Accommodations for reduced convergence may include the following:

- *Allow for visual breaks during sustained near-point work.*

- *Make sure learning materials are well-spaced and well-organized on the page.*

- *Allow extended time on timed tests.*

- *Use a line guide or a bookmark to keep place while reading.*

- *Receive a copy of notes or information presented on the board.*

When double vision from poor convergence is reported or suspected, clinicians should educate parents, teachers, and therapists on how diplopia may impact vision and why compensations such as covering an eye, turning to the side, or occluding an eye should be permitted.

Accommodations for oculomotility deficiencies may include the following:

- *Allow extra time for tasks that require sustained accurate reading eye; movements such as reading, copying from the board, or completing a Scantron.*

- *Allow the use of a finger or straight edge to follow along the line of print when reading.*

- *Allow the student to use a guided reader or line guide to facilitate smooth tracking.*

- *Provide a desk copy of material presented at the front of the classroom.*

- *Allow the student to answer directly in testing booklet, eliminating need to transpose answers to a separate testing booklet or to fill in bubbles on Scantron sheets.*

- *Use lists and bulleted points instead of narrative text.*

CONCLUSIONS

In summary, this study extends our knowledge of clinical near-point vision findings in autism spectrum disorder children. Children with autism spectrum disorder had near point of convergence

break and recovery that are significantly more receded, as well as poorer fixation, accuracy, and stamina on saccade and pursuit performance on Northeastern State University College of Optometry oculomotor testing and increased compensatory body and head movement. Monocular estimation method retinoscopy may be a relatively insensitive test to measure accommodative lag in autism spectrum disorder children. Additional research is needed to determine if poor convergence and oculomotor abilities are associated with increased levels of symptoms. Management of poor convergence and oculomotility skills should be coordinated with the autism spectrum disorder child's multidisciplinary team of educators, therapists, tutors, and other care providers.

REFERENCES

1. Sanchak KE, Thomas CA. Autism Spectrum Disorder: Primary Care Principles. Am Fam Physician 2016;94:972–9.

2. Ikeda J, Davitt BV, Ultmann M, et al. Brief Report: Incidence of Ophthalmologic Disorders in Children with Autism. J Autism Dev Disord 2012;43:1447–51.

3. Milne E, Griffiths H, Buckley D, et al. Vision in Children and Adolescents with Autistic Spectrum Disorder: Evidence for Reduced Convergence. J Autism Dev Disord 2009;39:965–75.

4. Scharre JE, Creedon MP. Assessment of Visual Function in Autistic Children. Optom Vis Sci 1992;69:433–9.

5. Denis D, Burillon C, Livet MO, et al. Ophthalmologic Signs in Children with Autism. J Fr Ophthalmol 1997;20:103–10.

6. Anketell PM, Saunders KJ, Gallagher SM, et al. Accommodative Function in Individuals with Autism Spectrum Disorder. Optom Vis Sci 2018;95:193–201.

7. Goldberg MC, Lasker AG, Zee DS, et al. Deficits in the Initiation of Eye Movements in the Absence of a Visual Target in Adolescents with High Functioning Autism. Neuropsychologia 2002;40:2039–49.

8. Takarae Y, Minshew NJ, Luna B, et al. Pursuit Eye Movement Deficits in Autism. Brain 2005;127:2584–94.

9. Johnson BP, Lum JA, Rinehart NJ, et al. Ocular Motor Disturbances in Autism Spectrum Disorders: Systematic Review and Comprehensive Meta-analyses. Neurosci Biobehav Rev 2016;69:260–79.

10. Walker K, Redman-Bentley D, Remick-Waltman K, et al. Differences in Oculomotor Function between Children with Sensory Processing Disorder and Typical Development. Optom Vis Sci 2019;96:172–9.

11. Coulter RA, Bade A, Tea YC, et al. Eye Examination Testability in Children with Autism and in Typical Peers. Optom Vis Sci 2015;92:31–43.

12. Sansone SM, Schneider A, Bickel E, et al. Improving IQ measurement in Intellectual Disabilities Using True Deviation from Population Norms. J Neurodev Disord 2014;6:16.

13. Lefort-Besnard J, Vogeley K, Schilbach L, et al. Patterns of Autism Symptoms: Hidden Structure in the ADOS and ADI-R Instruments. Transl Psychiatry 2020;10:257.

14. DeBoth KK, Reynolds S. A Systematic Review of Sensory-based Autism Subtypes. Res Autism Spectr Disor 2017;36:44–56.

15. Lord C, Jones RM. Annual Research Review: Re-thinking the Classification of Autism Spectrum Disorders. J Child Psychol Psychiatry 2012;53:490–509.

16. Weitlauf AS, Gotham KO, Vehorn AC, et al. Brief Report: *DSM-5* "Levels of Support": A Comment on Discrepant Conceptualizations of Severity in ASD. J Autism Dev Disord 2014;44:471–6.

17. Miller LE, Perkins KA, Dai YG, et al. Comparison of Parent Report and Direct Assessment of Child Skills in Toddlers. Res Autism Spectr Disord 2017;41-42:57–65.

18. Nguyen A, Wayne JL, Ravikumar A, et al. Accommodative Accuracy by Retinoscopy versus Autorefraction Spherical Equivalent or Horizontal Meridian Power. Optom Vis Sci 2018;101:778–85.

19. Casser Locke L, Somers W. A Comparison Study of Dynamic Retinoscopy Techniques. Optom Vis Sci 1989;66:640–4.

20. del Pilar Cacho M, García-Muñoz A, García-Bernabeu JR, et al. Comparison between MEM and Nott Dynamic Retinoscopy. Optom Vis Sci 1999;76:650–5.

21. Thibos LN, Bradley A, López-Gil N. Modelling the Impact of Spherical Aberration on Accommodation. Ophthalmic Physiol Opt 2013;33:482–96.

22. Cohen Y, Segal O, Barkana Y, et al. Correlation between Asthenopic Symptoms and Different Measurements of Convergence and Reading Comprehension and Saccadic Fixation Eye Movements. Optometry 2010;81:28–34.

23. Conlon E, Lovegrove W, Chekaluk E, et al. Measuring Visual Discomfort. Vis Cogn 1999;6:637–66.

24. Howarth PA, Distance HO. The Validity of Subjective Reports of Visual Discomfort. Hum Factors 1986;28:347–51.

25. Sheedy JE, Hayes JN, Engle J. Is All Asthenopia the Same? Optom Vis Sci 2003;80:732–9.

26. U.S. Centers for Disease Control (CDC), National Center for Health Statistics (NCHS). International Classification of Disease, Ninth Revision, Clinical Modification: Physician ICD-9-CM. Hyattsville, MD: Division of Data Services, National Center for Health Statistics; 2003. Available at: https://www.cdc.gov/nchs/icd/icd9cm.htm. Accessed February 25, 2021.

27. Watten RG. Reinvention of Visual Fatigue: Accumulation of Scientific Knowledge or Neglect of Scientific History? Ophthalmic Physiol Opt 1994;14:428–32.

28. Tyrrell RA, Leibowitz HW. The Relation of Vergence Effort to Reports of Visual Fatigue following Prolonged near Work. Hum Factors 1990;32:341–57.

29. Singleton C, Henderson LM. Computerized Screening for Visual Stress in Children with Dyslexia. Dyslexia 2007;13:130–51.

30. Wilkins AJ. Visual Stress. Oxford, United Kingdom: Oxford University Press; 1995.

31. Storey EP, Master SP, Lockyer JE, et al. Near Point of Convergence After Concussion in Children. Optom Vis Sci 2017;94:96–100.

32. Bade A, Galloway M, Scheiman M, CITT Study Group. Relationship between Clinical Signs and Symptoms of Convergence Insufficiency. Optom Vis Sci 2013;90:986–95.