Variability of Stereoacuity in Intermittent Exotropia

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• PURPOSE: **Distance stereoacuity is used to monitor deterioration of intermittent exotropia (IXT), but variability of stereoacuity has not been studied rigorously. The purpose of this study was to assess the variability of stereoacuity over one day in children with IXT.**
• DESIGN: **Prospective cohort study.**
• METHODS: **Twelve children with IXT were recruited. Stereoacuity was assessed using the Frisby Davis Distance test and the Distance Randot test at distance, and the Frisby and Preschool Randot tests at near. Tests were repeated three or four times over the day, with at least two hours between assessments. The main outcome measure was variable stereoacuity defined as a change by two or more log levels between any two time points over the day.**
• RESULTS: **Variable stereoacuity at distance was found in five (42%) of 12 patients. Four (33%) of 12 patients demonstrated variable results using the Distance Randot test, three of whom also showed variable results using the Frisby Davis Distance test. One patient had variable results using the Frisby Davis Distance test only. Nine (75%) of 12 patients completed near stereoacuity testing; two (22%) of nine showed variable near stereoacuity. Two (22%) of nine showed variable results using the Preschool Randot test, one (11%) of whom also had variable results using the Frisby test. In some cases, stereoacuity changed from measurable stereoacuity on one assessment to nil on another.**
• CONCLUSIONS: **Nearly half of children with IXT show marked changes in stereoacuity over the course of a single day. When based on isolated measures, an apparent change in distance stereoacuity between visits should be interpreted with caution. (Am J Ophthalmol 2008; 145:556–561. © 2008 by Elsevier Inc. All rights reserved.)**

INTERMITTENT EXOTROPIA (IXT) IS A RELATIVELY COMmon form of childhood strabismus[1,2] characterized by intermittent divergent misalignment that often is greater at distance fixation. The natural history of IXT and indications for surgery are not yet well defined,[3–6] but previous authors have suggested that progression of the disease is characterized by an increase in the angle of deviation,[6,7] decreasing control,[8,9] and deteriorating distance stereoacuity.[8,10] Previous studies evaluating change in IXT over time have compared isolated measures of angle, control, and stereoacuity, implying that such isolated measures are sufficient to represent an individual patient at a given time. Nevertheless, in a recent study by our group,[11] we reported that control can vary considerably over one day in some patients with IXT. In the present study, we evaluated the variability of stereoacuity over the course of one day in children with IXT.

METHODS

WE PREVIOUSLY REPORTED[11] VARIABILITY OF CONTROL IN A cohort of 13 children with IXT enrolled prospectively from clinical practice. Twelve of these children (median age, eight years; range, three to 13 years) also underwent measures of stereoacuity three to four times over the course of the same day. As previously described,[11] we excluded patients with convergence insufficiency type exotropia (near angle, ≥10 prism diopters [PD] greater than distance) or coexisting ocular pathologic features. Assessments over the day were scheduled during the following intervals: 08:00 to 10:30, 10:31 to 13:00, 13:01 to 15:30, and 15:31 to 18:00, allowing a minimum of two hours between assessments. Measures of control, stereoacuity, and angle of deviation were performed at each assessment. At each testing point, the examiner did not have access to any results from prior examinations on the same day or on previous clinic visits. The median of the three to four angle measurements for each patient (a summary of the angle of deviation for each patient) ranged from 12 to 42.5 PD (median, 27.5 PD) at distance and 8 to 45 PD (median, 20 PD) at near by alternating prism cover test. All tests were performed in habitual refractive correction. No patient had amblyopia, which was defined as ≥0.2 logarithm of the minimum angle of resolution (logMAR) units of interocular difference and ≥0.3 logMAR units in one eye. Ability to comprehend all stereoacuity tasks was required for inclusion in this study. Testing was performed in the following order: Frisby Davis Distance test, Distance Randot test, Frisby test, and Preschool Randot test.

• ASSESSMENT OF DISTANCE STEREOACUITY: We tested distance stereoacuity in all 12 patients three or four times during the day using two relatively new tests, the Frisby Davis Distance test[12,13] and the Distance Randot test.[14] Both tests were administered according to previously

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TABLE. Levels of Stereoacuity Showing Equivalent Log Seconds of Arc Values and Where They Follow a Logarithmic Progression

Seconds of Arc	Log of Seconds of Arc	FD2 Test Levels	DR Test Levels	Frisby Test Levels	PSR Test Levels
20	1.30	✓*			
40	1.60	✓*		✓	✓
60	1.78		✓	✓	✓
80	1.90	✓*			
100	2.00		✓*	✓*	✓*
160	2.20	✓*			
200	2.30	✓	✓*	✓*	✓*
400	2.60	†	✓*	✓*	✓*
800	2.90		†	†	✓*
1600	3.20				†

DR = Distance Randot test; FD2 = Frisby Davis Distance test; PSR = Preschool Randot test.

The actual levels tested on FD2, DR, and PSR stereo tests are indicated by a checked box.

*Stereoacuity levels coinciding with logarithmic steps.

†Value assigned to represent nil because it follows the logarithmic progression. The next highest 0.3 log increment was chosen to represent nil for each test, because the highest measurable level differs between tests. Choosing the same log value to represent nil for all tests would introduce bias when comparing differences between tests, for example, the difference between the highest measurable level and nil.

described protocols,[13–15] but scores were converted to log seconds of arc to account for the nonlinear progression in levels tested (Table).

The Frisby Davis Distance test, a real depth test, was tested at disparities of 200, 160, 80, 40, and 20 seconds of arc. At each disparity level, two of two correct responses were required to pass. Threshold was recorded as the finest disparity at which two of two shapes were identified correctly, as reported by Holmes and Fawcett.[13] Because of the possibility of monocular cues providing false-positive responses at thresholds of 200 to 80 seconds of arc,[13] these levels were reassessed monocularly, as described previously.[13] This monocular testing phase, carried out after threshold had been reached, was performed to ensure that the threshold score reflected a binocular response. No patient in our study achieving a threshold of 200 to 80 seconds of arc was able to achieve this level monocularly, confirming that responses reflected true binocular stereoacuity. Patients unable to respond at the 200 seconds of arc level were recorded as having nil stereo. For analysis, nil stereo was assigned the next highest log level, that is, 2.60 log seconds of arc (Table).

The Distance Randot test, a Polaroid vectograph, was tested at disparities of 400, 200, 100, and 60 seconds of arc.[14,15] At each disparity level, two of two correct responses were required to pass. Threshold was recorded as the finest disparity at which two of two shapes were identified correctly. Patients unable to identify shapes at the 400 seconds of arc level were recorded as having nil stereo. For analysis, nil stereo was assigned the next highest log level, that is, 2.90 log seconds of arc (Table). A monocular testing phase was not performed for the Distance Randot test because it does not seem to have a problem with monocular cues.

Patients were classified as having variable stereoacuity if there was a change of two or more log levels (≥0.6 log seconds of arc) between any time points over the day on either the Frisby Davis Distance test or the Distance Randot test (Table). Patients who did not change by two or more log levels on either test were classified as stable.

• **ASSESSMENT OF NEAR STEREOACUITY:** Nine of 12 patients completed at least three measures of stereoacuity with both the Frisby and Preschool Randot tests over the course of the day. Both tests were administered according to previously described protocols,[15–17] and scores were converted to log seconds of arc for the purposes of analysis.

The Frisby, a real depth test, was administered at a range of distances (as previously described)[15,17] to yield disparities of 400, 200, 100, 60, and 40 seconds of arc. At each disparity level, two of two correct responses were required to pass. Threshold was recorded as the finest disparity at which two of two presentations were identified correctly. Patients unable to respond at the 400 seconds of arc level were recorded as having nil stereo. For analysis, nil stereo was assigned the next highest log level, that is, 2.90 log seconds of arc (Table).

The Preschool Randot test, a Polaroid vectograph, was performed at 40 cm, testing disparities of 800, 400, 200, 100, 60, and 40 seconds of arc. At each disparity level, two of three correct responses were required to pass. Threshold was recorded as the finest disparity at which two of three shapes were identified correctly. Patients unable to identify shapes at the 800 seconds of arc level were recorded as having nil stereo. For analysis, nil stereo was assigned the next highest log level, that is, 3.20 log seconds of arc (Table). A monocular testing phase was not performed for either the Frisby or the Preschool Randot tests because previous studies have confirmed that these tests do not have a problem with monocular cues.[17,18]

As described for distance tests, patients were classified as showing variable stereoacuity if there was a change of two or more log levels (≥0.6 log seconds of arc) between any time points over the day on either the Frisby or the Preschool Randot tests. Patients who did not change by two or more log levels on either test were classified as stable.

• **ASSESSMENT OF ANGLE:** At each assessment, the angle of deviation was measured by alternating prism cover test at distance (3 m) and near (1/3 m) fixation. A change in angle was defined as a difference of ≥10 PD between any

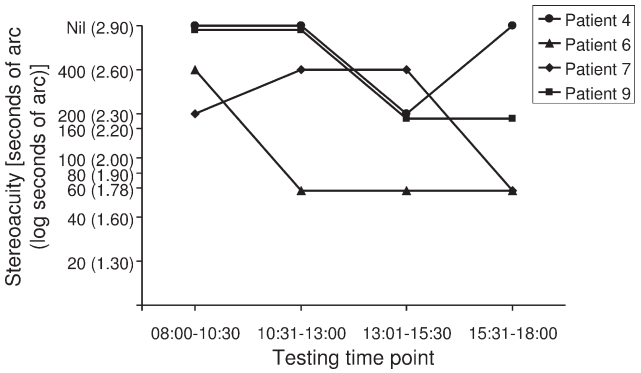

FIGURE 1. Graph showing variable stereoacuity using the Distance Randot test. Stereoacuity values are shown at four testing time points over one day in the four (33%) of 12 patients who showed variability using the Distance Randot test. Variable stereoacuity was defined as a change of two or more log levels (≥0.6 log seconds of arc) between any testing time points over the course of the day.

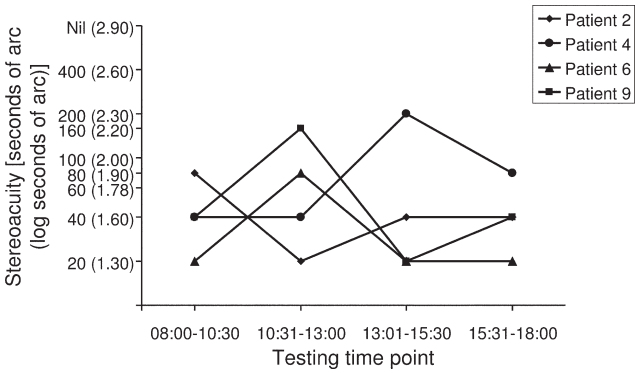

FIGURE 2. Graph showing variable stereoacuity using the Frisby Davis Distance test. Stereoacuity values are shown at four testing time points over one day in the four (33%) of 12 patients who showed variability using the Frisby Davis Distance test. Variable stereoacuity was defined as a change of two or more log levels (≥0.6 log seconds of arc) between any testing time points over the course of the day.

measurements over the day. Patients showing a change of ≥10 PD at distance or near fixation were classified as showing a variable angle of deviation.

• **ASSESSMENT OF CONTROL:** Control was assessed at each time point as described in our recent report.[11] Control was scored using a previously described scale for both distance (3 m) and near (1/3 m) fixation.[19] Control assessment followed the standard testing procedure reported previously,[11,19] commencing with observation for spontaneous tropia over a 30-second period (score 5 if constant tropia, score 4 if tropia >50% of observed time, score 3 if tropia <50% of observed time). If no spontaneous tropia was observed, recovery of phoria was rated as the poorest of three 10-second periods of occlusion (score 2 if >five-second recovery, score 1 if one to five-second recovery, score 0 if <one-second recovery). Patients were categorized as showing variable control if a change of two levels or more on the scale occurred over the course of the day.[11] Individual patients were analyzed to determine whether those showing variable distance control over the day also showed variable distance stereoacuity and whether those showing variable near control also showed variable near stereoacuity. In addition, for all patients, we assessed agreement between distance stereoacuity values and the distance control score and between near stereoacuity values and the near control score at each time point over the day.

RESULTS

• **DISTANCE STEREOACUITY:** Five (42%) of 12 patients showed variable stereoacuity on either the Frisby Davis Distance or Distance Randot tests over the course of the day (see Supplemental Table 1 available at AJO.com): four (33%) of 12 were variable using the Distance Randot test, three of whom also varied using the Frisby Davis Distance test. Of the four who varied using the Distance Randot test, two changed between no measurable (nil) and subnormal stereoacuity (Figure 1). Similar, marked variability was seen using the Frisby Davis Distance test (Figure 2), but not to the level of nil. For both tests, change was not consistently in the direction of either progressive improvement or progressive deterioration. The age of those with variable stereoacuity was not significantly younger than those with stable distance stereoacuity (median, 10 vs eight years; $P = .6$, Wilcoxon).

• **NEAR STEREOACUITY:** Two (22%) of nine patients showed variable near stereoacuity over the day. Both children varied using the Preschool Randot test; one also varied using the Frisby test (see Supplemental Table 2 available at AJO.com). Of the two who varied with the Preschool Randot test, one changed from nil to measurable stereoacuity.

• **ANGLE OF DEVIATION:** Three (25%) of the 12 patients showed a change in angle (≥10 PD) either for distance or near fixation over the day. Of the three showing variability, all three varied at near and one also varied at distance. No correlation was found between distance angle of deviation and either Frisby Davis Distance stereoacuity ($r = -0.04$; $P = .8$, Spearman) or Distance Randot stereoacuity ($r = 0.2$; $P = .2$). No correlation was found between near angle of deviation and either Frisby stereoacuity ($r = 0.2$; $P = .2$) or Preschool Randot stereoacuity ($r = 0.3$; $P = .08$).

• **CONTROL:** Of the five patients showing variable stereoacuity using distance tests, none showed variable distance control over the day. Of the two patients showing

variable stereoacuity using near tests, one (50%) of two showed variable control at near over the day. Among all patients, there was no correlation between the stereoacuity scores on the Frisby Davis Distance test and the distance control score at the same assessment time point ($r = -0.09$; $P = .5$, Spearman) or between stereoacuity on the Distance Randot test and distance control scores at the same assessment time point ($r = -0.2$; $P = .1$). Likewise, there was no correlation between the near control score and stereoacuity scores on the Frisby test ($r = 0.08$; $P = .7$). There was marginal correlation between near control score and stereoacuity measured using the Preschool Randot test ($r = 0.35$; $P = .05$).

DISCUSSION

DISTANCE STEREOACUITY VARIES CONSIDERABLY OVER the course of one day in some patients with IXT, including change from absent (nil measurable) on one assessment to measurable on another. The pattern of change was not consistently toward improvement over the day, suggesting this was not a practice effect, or toward deterioration, suggesting it was not the result of fatigue. Variability occurred on the real-depth Frisby Davis Distance and Frisby tests as well as on the random dot Distance Randot and Preschool Randot tests.

Worsening distance stereoacuity has been suggested as an objective measure of change in the underlying severity of IXT and as a means of evaluating the need for surgery.[8–10,20] Nevertheless, we found marked variability in stereoacuity measures within a single day. Changes from 20 to 80 seconds of arc, 40 to 200 seconds of arc, and 200 seconds of arc to nil occurred in our subjects, changes that previously might have been considered clinically significant. Our findings suggest that isolated measures of stereoacuity may not be a reliable means of representing severity or of detecting change over time in an individual patient with IXT.

Previous studies examining distance stereoacuity in IXT used a different method of measuring stereoacuity[10,20,21] (Mentor B-VAT, [Medtronic; Xomed Solan Ophthalmics, Jacksonville, Florida, USA] which is no longer commercially available) and showed improvements in distance stereoacuity after surgery. A recent study by our group also found that, using the Frisby Davis Distance and Distance Randot tests in a cohort of patients with IXT, overall distance stereoacuity thresholds improved after surgery.[22] Nevertheless, the findings of this present study suggest that isolated measures of stereoacuity should be interpreted with caution and that multiple measures may be needed to capture true stereoacuity status and guide surgical decision making better.

Near stereoacuity generally is expected to be normal in patients with IXT,[10,15,20,23] although it may be reduced in cases with coexisting monofixation syndrome.[24] Although mostly within normal limits and stable in our study, it is of note that some patients showed variability even of near stereoacuity over the day.

One possible explanation for variable stereoacuity is variability of angle, but none of the five patients with variable distance stereoacuity had a variable angle of deviation at distance fixation. At near, one (50%) of two patients with variable near stereoacuity had a variable angle at near fixation, and so overall, there seemed to be no relationship between variable angle and variable stereoacuity.

Another possible explanation for the variable stereoacuity found in this study is that changes reflect test–retest reliability. There are limited data on the test–retest reliability of stereo tests in children, but Fawcett and Birch, studying the Preschool Randot test, reported the 95% limits of agreement for interobserver reliability to be approximately 0.3 log seconds of arc.[25] This value falls well within the ≥0.6 log seconds of arc range chosen to define variability in our study, suggesting we did indeed detect real change in stereoacuity values. Establishing limits of agreement based on test–retest data in pediatric populations for the Frisby, Frisby Davis Distance, and Distance Randot stereotests would enable more accurate identification of real changes in stereoacuity. An alternative explanation for our findings is that subtle, but real, sensory changes occur throughout day and that this fluctuation is a normal but previously unreported feature of IXT. If this were true, one might expect to find associated changes in other parameters such as the angle of deviation or ability to control.

Although we recently reported variability of control in some of these cases,[11] we did not find it to be associated with changes in stereoacuity. It remains uncertain whether control and stereoacuity are interrelated: some authors[10,23,26,27] suggest that the level of stereoacuity is indeed correlated to the degree of control, and others[10,15] suggest that it is not. In the present study, we generally did not find a relationship between the degree of control and the level of stereoacuity, with the exception of a marginal correlation between near stereoacuity measured by Preschool Randot and near control. In addition, for a given patient, variable control did not necessarily coexist with variable stereoacuity; in fact, most patients with variable control had stable stereoacuity or vice versa. We observed that some patients with constant exotropia at distance (control score 5) during the control assessment appeared straight when testing stereoacuity seconds later. Therefore, simultaneous assessment of control and stereoacuity may be needed to evaluate a potential relationship between stereoacuity and control. The possibility of a relationship between stereoacuity and angle of deviation has not been extensively studied in IXT, but our findings seem to be consistent with other reports[26,28] that there is no obvious correlation between the two.

The findings of this study highlight one of the primary ongoing challenges for studies of IXT: the lack of well-defined measures of severity. If stereoacuity and control can vary considerably over one day, it would seem impossible for clinicians to be sure they are capturing real change in a patient's underlying condition when such assessment is based on an isolated measure from visit to visit. Further work establishing reliable outcome measures is necessary before embarking on much-needed natural history and interventional studies.

There are a number of weaknesses to our study. A small number of patients were studied, which, although unlikely to alter our main finding that stereoacuity varies over one day in a proportion of patients, may have limited our ability to detect relationships between stereoacuity and angle or control. In light of what we now know about variability of control,[11] the possibility of a relationship between control and stereoacuity may be better addressed by measuring control and stereoacuity simultaneously. The young age of the patients in our study may have contributed to variability in attention, which may have led to variable stereoacuity. As suggested in our previous report on variable control,[11] the lack of progressive deterioration toward the end of the day argues against a marked effect of attention or fatigue. Nevertheless, we did not monitor whether children rested between assessments, which, had they done so, may have negated any effect of fatigue. Whether stereoacuity and control vary because of attention, fatigue, test–retest reliability, or some other reason, some patients show marked changes in stereoacuity and control over short periods. It may be that such fluctuations are an integral part of childhood IXT.

Our finding of variable stereoacuity over one day in some patients with IXT suggests that isolated measures of stereoacuity cannot be relied on to represent severity or change in severity over time. For individual patients with IXT, isolated measures of stereoacuity should be interpreted with caution.

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SUPPLEMENTAL TABLE 1. Frisby Davis Distance and Distance Randot Stereoacuity Measured over One Day in Children with Intermittent Exotropia

	Time 1		Time 2		Time 3		Time 4		Time 1		Time 2		Time 3		Time 4	
	Frisby Davis Distance								Distance Randot							
	08:00 to 10:30		10:31 to 13:00		13:01 to 15:30		15:31 to 18:00		08:00 to 10:30		10:31 to 13:00		13:01 to 15:30		15:31 to 18:00	
Patient No.	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log
1	20	1.30	—	—	40	1.60	20	1.30	60	1.78	—	—	60	1.78	200	2.30
2†	80	1.90	20	1.30	40	1.60	40	1.60	100	2.00	100	2.00	100	2.00	100	2.00
3	40	1.60	40	1.60	40	1.60	80	1.90	60	1.78	60	1.78	60	1.78	60	1.78
4†*	40	1.60	40	1.60	200	2.30	80	1.90	nil	2.90	nil	2.90	200	2.30	nil	2.90
5	20	1.30	20	1.30	40	1.60	20	1.30	200	2.30	200	2.30	60	1.78	100	2.00
6†*	20	1.30	80	1.90	20	1.30	20	1.30	400	2.60	60	1.78	60	1.78	60	1.78
*7	40	1.60	40	1.60	20	1.30	20	1.30	200	2.30	400	2.60	400	2.60	60	1.78
8	20	1.30	20	1.30	20	1.30	20	1.30	60	1.78	—	—	60	1.78	60	1.78
9†*	40	1.60	160	2.20	20	1.30	40	1.60	nil	2.90	nil	2.90	200	2.30	200	2.30
10	20	1.30	20	1.30	20	1.30	40	1.60	60	1.78	60	1.78	60	1.78	60	1.78
11	40	1.60	20	1.30	40	1.60	20	1.30	nil	2.90	nil	2.90	nil	2.90	nil	2.90
13	20	1.30	20	1.30	20	1.30	40	1.60	60	1.78	60	1.78	60	1.78	60	1.78

Sec arc = seconds of arc; — = not tested.

*Patients with variable distance stereoacuity, defined as a change of two or more log levels (≥0.6 log seconds of arc) over the day, using the Distance Randot test.

†Patients with variable distance stereoacuity, defined as a change of two or more log levels (≥0.6 log seconds of arc) over the day, using the Frisby Davis Distance test.

SUPPLEMENTAL TABLE 2. Near Frisby and Preschool Randot Stereoacuity Measured over One Day in Children with Intermittent Exotropia

	Time 1		Time 2		Time 3		Time 4		Time 1		Time 2		Time 3		Time 4	
	Frisby								PSR							
	08:00 to 10:30		10:31 to 13:00		13:01 to 15:30		15:31 to 18:00		08:00 to 10:30		10:31 to 13:00		13:01 to 15:30		15:31 to 18:00	
Patient No.	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log	Sec arc	Log
2	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	60	1.78	40	1.60	60	1.78
4†*	60	1.78	200	2.30	400	2.60	200	2.30	nil	3.20	100	2.00	100	2.00	100	2.00
5	40	1.60	40	1.60	40	1.60	40	1.60	100	2.00	40	1.60	40	1.60	—	—
6	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60
7	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60
9	60	1.78	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60
10	40	1.60	40	1.60	40	1.60	40	1.60	60	1.78	60	1.78	60	1.78	60	1.78
11*	60	1.78	40	1.60	40	1.60	40	1.60	200	2.30	100	2.00	100	2.00	400	2.60
13	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60	40	1.60

PSR = Preschool Randot test; Sec arc = seconds of arc; — = not tested.

*Patients with variable near stereoacuity, defined as a change of two or more log levels (≥0.6 log seconds of arc) over the day, using the Preschool Randot test.

†Patients with variable near stereoacuity, defined as a change of two or more log levels (≥0.6 log seconds of arc) over the day, using the Frisby test.