

A New 3D Monitor–Based Random-Dot Stereotest for Children

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PURPOSE. Objective testing for random-dot stereovision in preverbal children requires some type of dissociating glasses. Drawbacks of such methods are the alteration of natural visual conditions and sometimes nonacceptance of the glasses. For this reason, a new, natural method for random-dot stereopsis measurement was developed and tested.

METHODS. Random-dot circles (diameter 10 cm, crossed disparity of 0.34°) were generated on an autostereoscopic display and presented to 18 normal children (mean age, 5.1 ± 1.1 years), 8 with anisometropic amblyopia (mean age, 4.9 ± 1.3 years), 14 with infantile essential esotropia (mean age, 5.3 ± 0.7 years), and 16 with primary microstrabismus (mean age, 5.2 ± 1.4 years). While the position of the stimulus randomly changed among four possible locations, eye positions were recorded by infrared photo-oculography. If two or more consecutive saccades ends corresponded to the stimulus coordinates, a positive response was assumed. The results with the new test were compared with the ability to recognize the Lang I random-dot stereotest.

RESULTS. Twenty-four of 26 Lang I–positive children had positive responses (sensitivity of 92.3%), 29 of 30 Lang I–negative children had negative three-dimensional (3D) stimulus responses (specificity, 96.7%). The positive predictive value of the new test was 0.96 (95% CI, 0.79–0.99); the negative predictive value, 0.94 (95% CI, 0.78–0.99); and the overall accuracy, 0.95 (95% CI, 0.85–0.99).

CONCLUSIONS. This new 3D monitor–based test allows objective assessment of random-dot stereopsis in children older than 3 years. (*Invest Ophthalmol Vis Sci.* 2006;47:4842–4846) DOI: 10.1167/iovs.06-0238

Over the past 25 years, many psychophysical and electrophysiological stereotests have been developed for infants.^{1–7} Although the interest of the earlier investigations was predominantly to study the development of stereopsis, later, several studies focused on the measurement of sensory outcomes after the treatment of ophthalmopediatric disorders.^{8–11} Many testing procedures use the random-dot stereogram, because they convey no visual information other than random noise, if seen monocularly. However, if binocularly

fused, vivid depth perceptions occur. This lack of monocular cues makes this type of stereogram ideal for stereovision testing. In clinical routine, the most frequently used random-dot tests include the TNO test, the Lang I and II tests, and the Random-dot E test.¹² All these tests require verbal capabilities from the subject tested. Tests that can be used in preverbal children are the Infant Random Dot Stereoacuity Cards,⁵ the Preschool Randot Stereoacuity Test,¹³ random-dot stereogram-evoked potentials, and random-dot correlogram evoked potentials.^{6,14} All the tests designed for preverbal children require some type of dissociating glasses, and some of them allow only subjective testing. Easy-to-perform objective tests are necessary for screening of visual dysfunctions in children and for large-scale testing of the development of stereovision. We developed a new, 3D monitor–based random-dot test allowing natural viewing conditions with an objective assessment of stimulus recognition using infrared photo-oculography. In a previous pilot study including four older children, the testing procedure has been found to be usable in measuring a response to random-dot stimuli objectively in children.¹⁵ In this study, the new test was used in a larger number of children with normal and abnormal random-dot stereovision and compared to the ability to recognize the Lang I random-dot stereotest. In future, the plan is to test its usefulness for random-dot stereovision determination in infants.

METHODS

This research adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Kantonsspital St. Gallen. Informed consent was obtained for all children. Fifty-six children (mean age range, 2.9–8.7 years) were tested with the new method based on a random-dot stimulus presentation with an autostereoscopic monitor and a response measurement by infrared photo-oculography. This age group was chosen to allow comparison of the new test results with those of the Lang I random-dot stereotest. In younger children, the determination of the response with the Lang I test becomes unreliable, because lateral head movements are difficult to avoid and because they are not able to name the objects of the Lang I test. An additional reason to exclude children of less than 3 years was the possibly inaccurate squint diagnosis in that age group (e.g., differentiation between microstrabismus and orthotropia).

Patients

Eighteen normal children (mean age, 5.1 ± 1.1 years) and 8 children with anisometropic amblyopia (mean age, 4.9 ± 1.3 years), 14 with infantile essential esotropia (mean age, 5.3 ± 0.7 years), and 16 with microstrabismus (mean age, 5.2 ± 1.4 years) were recruited at the Department of Strabismology and Neuro-Ophthalmology of the Kantonsspital St. Gallen, Switzerland. After explanation of the type of study, relatives of the children who participated gave written informed consent for the new test. All patients underwent a complete orthoptic examination including the Hirschberg ocular alignment test, cover test, 4-prism-diopter base-out fusion test, ocular motility, and pupillary reaction. Visual acuity was usually measured with LH-Symbols in each eye. In older children, Landolt-rings were used. Binocular vision was tested with Bagolini striated glasses. Stereoscopic vision was determined with the Titmus-stereotest (fly, animal symbols, and rings) and

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the Lang I stereotest. The ophthalmic examination included a slit lamp examination of the anterior segment, a dilated fundus examination, and a determination of refraction under cycloplegic conditions. Normal children had a negative history of eye diseases, a symmetrical visual acuity of at least 20/30, and normal results in orthoptic and ophthalmic examinations. Spherical equivalents were between -0.5 D and $+1.5$ D, and astigmatisms were smaller than 1.25 D. Children with anisometropic amblyopia had an anisometropia of more than 2.5 D (spherical equivalent) and, at the time of diagnosis, a difference of visual acuity of more than 0.4 log units between the eyes. At the time of testing all were treated with occlusion therapy and had a visual acuity of >0.4 in the amblyopic eye. All children saw at least the Titmus-fly, and six of them had a positive Lang I stereotest. Children with infantile esotropia had history of early onset of strabismus (<6 month of life) and congenital signs (DVD and nystagmus latens). Binocular vision and stereovision was negative. Children with microstrabismus had primary microstrabismus with small-angle esodeviation (≤ 10 prism diopters), harmonious anomalous retinal correspondence, stereovision of at least Titmus-fly, and no congenital signs (DVD, nystagmus latens). All but two of them had negative Lang I stereovision.

Autostereoscopic Display

The stimulus was presented on an autostereoscopic display (display 2018XLQ; DTI, Rochester, NY) which allows viewing of full-color 3D images without special eyeglasses at a rate of 60 frames per second. 3D images are generated similarly to 3D postcards. Vertical illuminated lines generated behind a liquid-crystal display result in all the odd columns of pixels being projected in the left eye and all the even ones in the right eye. The screen had 1280 columns and 1024 rows of pixels. Therefore, each stereoscopic image consisted of 640 columns and 1024 rows. A 3D image is only perceived at a certain distance. The best distance depends on the interpupillary distance of the observer and can be calculated trigonometrically (e.g., for an interpupillary distance of 66 mm the distance is 80.0 cm). The distance between the screen and the child's headrest was always optimized according to the interpupillary distance. The visualization is rather insensitive to vertical displacements of the observer. However, the viewing zone allows only small displacements (of approximately 2 cm) to the side and toward or away from the screen (approximately 6 cm). Displacements of >2 cm to the side also allows the subject to see the random-dot stimulus—however, in an uncrossed manner. Before starting and during each experiment, it was ensured that the head was optimally placed in the center of the headrest.

Random-Dot Stimulus

Random-dot circles with a diameter of 10 cm and a crossed disparity of 0.34° were generated in four different locations with the coordinates $+10$ cm/ $+10$ cm, $+10$ cm/ -10 cm, -10 cm/ $+10$ cm, -10 cm/ -10 cm. The size of the random dots was 5.5 mm. Because the display's image separation between the right and left eye of our screen is not complete, it would be possible to perceive the other eye's image very faintly. This inconvenience is unproblematic if the monitor is used only to show equally luminant images to both eyes to visualize 3D images. However, in our experimental setting, it may have allowed the random-dot stimulus to be seen monocularly. Therefore, a faint counterimage of the same intensity was generated, which neutralized the imperfection of the autostereoscopic screen. The stimulus randomly changed its position between the four possible locations. The stimulus was presented monocularly and binocularly to 10 cooperative children older than 6 years as well as to 10 adults. When asked, all were able to see the stimulus binocularly; however, in the monocular condition, none of them, even if the head was displaced, was able to see the stimulus. To ensure that the stimulus could not be seen with nonstereoscopic binocular cues, it was presented to five cooperative children older than 6 years and five adults, while prisms in front of the right eye induced different grades of diplopia. In each subject, we simulated

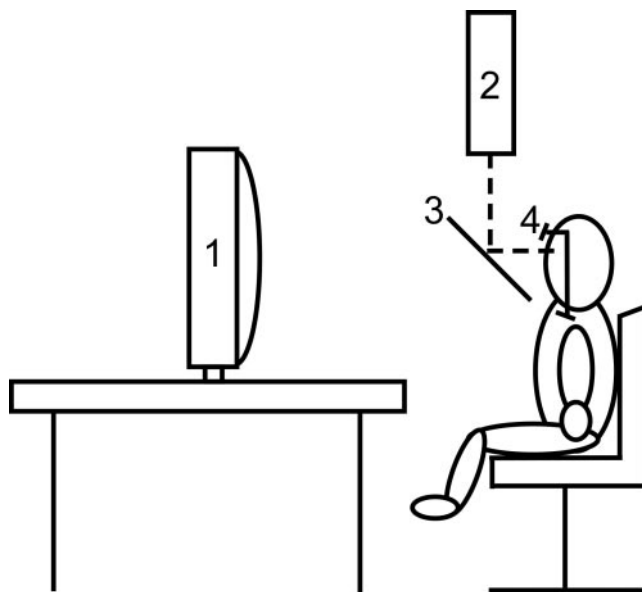


FIGURE 1. Experimental setting: 1, autostereoscopic monitor for stimulus presentation; 2, infrared illumination and infrared photo-oculography camera; 3, hot mirror; 4, chin and head rest.

right hypertropia, right hypotropia, esotropia, and exotropia of 2, 4, 6, 10, 14, and 20 prism diopters. Induced squint angles were verified with the simultaneous prism cover test. None of the subjects was able to see the stimulus under any of the conditions.

Eye Movement Recordings

An extensive description of the experimental setting of the infrared photo-oculography system has been published previously.¹⁶⁻¹⁹ The stimulus generator and recording system were provided by Metrovision (Perenchies, France).

The children were seated on the lap of the mother or alone, with their heads stabilized by a chin and front rest (Fig. 1). The monitor for stimulus presentation was placed in a frontoparallel position, and the distance from the eyes was calculated according to the instructions of the 3D monitor provider. Eye position was determined by measuring the position of the corneal reflex with respect to the center of the pupil. Eye movements were recorded under binocular viewing conditions from the fixating eye. In orthotropic children, recording was performed from the right eye. In children with strabismus, the fixating eye was recorded. An infrared illumination of the eye (880 nm) was used to produce the corneal reflex and the pupil image. The system operated with a sampling rate of 30 Hz and achieved a resolution of 10 arc min.^{17,18} Illumination source and camera were installed above the child's head. A hot mirror (dichroic filter separating visible light and infrared light) was used to illuminate the eye and to record the reflexes with the camera. Calibration was defined by the geometry of the anterior chamber¹⁸ and was estimated from biometry data of 20 eyes of subjects aged between 3 and 7 years. Optimal alignment during recording was achieved looking at an image of the child's eye on a computer screen. If necessary, the head position of the child was adjusted during the recording period.

Calibration. Correction factors were derived from repeated presentations to 20 children of a horizontal and vertical step ramp stimulus with the following x/y -axis: horizontal step ramp $0^\circ/-10^\circ$, $0^\circ/0^\circ$, $0^\circ/+10^\circ$ and vertical step ramp $-10^\circ/0^\circ$, $0^\circ/0^\circ$, $+10^\circ/0^\circ$.¹⁸

Recorded Data. Recording supplied the running time in seconds and the x - and y -coordinates of the eye's position in degrees at a frequency of 30 Hz. The duration of recording of the stimulus response was always identical and was 38 seconds. Each child was measured only once, resulting in 1140 lines in the data file. The algorithm for data

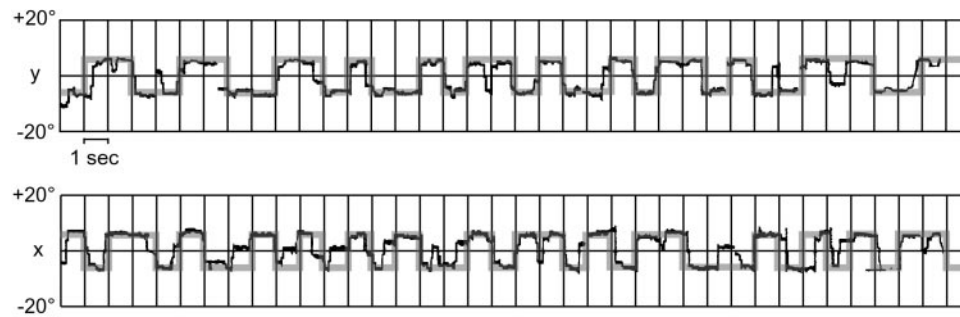


FIGURE 2. Eye movement recording of a normal, 5-year-old child. The ordinate labeled x corresponds to the horizontal eye positions (degrees), the ordinate labeled y to the vertical ones, both plotted against time (seconds). Negative values, to the left or below the center; positive values, to the right or above the center. *Black trace:* the eye positions; *gray trace:* positions of the stimulus. There was an excellent correspondence of eye positions on both axes with the stimulus position. Therefore, the stimulus was recognized during nearly the entire recording period.

analysis to extrapolate missing values due to blinking and to exclude outliers using the robust mean and SD has been described in detail previously.¹⁶ Briefly, loss by blinking was determined in normal subjects and found to be three measurements (0.1 second). Therefore, gaps of up to three data points were extrapolated for the x - and y -coordinates. Outliers were detected and eliminated using the robust mean and SD. The amount of data representing nonoptimal pursuit was considerable. For example, ideal optimal horizontal pursuit would consist of y -coordinates of only 0° . To determine which y -values (x -values) can be used for analysis of horizontal (vertical) eye movements, outliers were calculated by means of the median absolute deviation, a method from robust statistics. The robust mean \bar{y} is given by the median of all values

$$y_i, i = 1, 2, \dots, n: \bar{y} = \text{median } y_i$$

and the robust SD is determined by

$$\sigma = 1.4826 \cdot \text{median } |y_i - \bar{y}|$$

Then, we retained only those y_i with $|y_i - \bar{y}| \leq \sigma$ for further consideration. In a similar manner x -values were filtered to determine those useful for analysis of vertical eye movements. For further details, we suggest reading our methodological article about the algorithm for data analysis from photo-oculography.¹⁶

Analysis of the Curves

Two plots displayed the ocular response graphically: time against x -coordinate and time against y -coordinate. The following coordinate system was used: x -coordinate corresponds to horizontal and the y -coordinate to vertical eye movements, negative values correspond to displacements to the left, or inferior to the center, positive values to the right, or superior to the center. On each child's curve, a line plotted with identical coordinates of the expected eye movements if all stimulus positions were followed was superimposed. One of the authors (AB) determined in a masked manner, without knowledge of the diagnosis and stereoscopic functions, which saccade ends corresponded to presented stimulus positions. A positive response was assumed if during the whole recording period two or more consecutive saccades corresponded to the stimulus coordinates. Therefore, if the stimulus was seen and followed with the eyes, an attention time of 4 seconds was sufficient to prove the presence of random-dot stereopsis. If during the 38 seconds of recording time no correspondence or only a correspondence of one stimulus position was seen, a negative response was assumed. In this study, to allow a masked study design, the analysis of all the children's curves was performed after all children had been measured. In clinical use, the determination can be per-

formed immediately at the end of the 38-second recording. A determination takes approximately 10 seconds.

Lang I Stereotest

The results were compared to the ability to recognize the Lang I stereotest. We assumed the Lang I stereotest as the gold standard. The children had to name at least one of the three figures shown on the card correctly. In addition to that, the figures had to stand out, to minimize the risk that the card had been recognized monocularly. During stimulus presentation the card was held still and the child was allowed no head movement. The positive and negative predictive values and the accuracy of the new test were calculated, including the 95% confidence intervals (CIs) based on the binomial distribution.

RESULTS

Figure 2 shows the eye movement recording of a normal, 5 years old child with very good cooperation. The ordinate labeled x shows the horizontal eye positions, the ordinate labeled y is the vertical positions against time. The black line corresponds to the eye positions, the gray one to the position of the stimulus. There was a close correlation between the eye positions in both axes and the stimulus position, showing that the stimulus was seen during nearly the entire recording period.

Figure 3 shows a plot of the x -coordinate versus the y -coordinate of eye movement recordings in two children. The left side shows one 5-year-old child with positive response and good cooperation and the right side a 3.5-year-old patient with congenital infantile esotropia with negative response. Because of the omission of the time axis, this type of plot does not help to answer definitively whether the stimuli have been seen. However, it can be used for a quick orientation. Usually, a concentration of fixation in the four locations in which the stimulus is presented correlates with a positive response. However, to confirm such a hypothesis, the plot type shown in Figure 2 has to be analyzed.

Table 1 shows five two \times two tables with the results of testing random-dot stereovision with the Lang I test and with the 3D monitor. The top four tables show the results in the four categories of diagnosis included in our study: microstrabismus, congenital infantile esotropia, anisometropic amblyopia, and normal subjects. The bottom table summarizes the results in all children and was used to calculate the sensitivity, specificity, positive, and negative predictive values and overall accuracy of the new test. Twenty-four of 26 Lang I-positive children showed positive responses with the new 3D test.

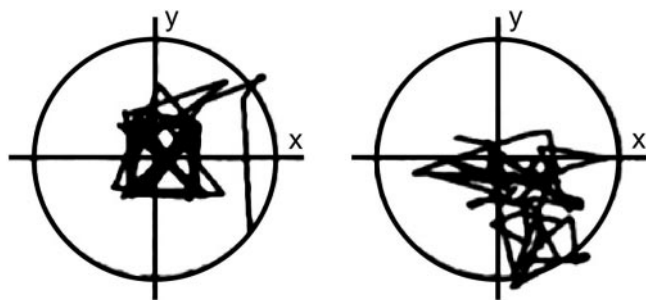


FIGURE 3. An x - y plot for two children, summarizing the whole recording period. *Left*: a 5-year-old child with positive response and good cooperation; *right*: a 3.5-year-old child with congenital infantile esotropia with negative response. Omission of the time axis in this type of plot does not indicate definitively whether the stimuli have been seen. However, this type of plot can be used for a quick orientation. Usually, a concentration of fixation in the four locations in which the stimulus is presented and the saccades between them correlate with a positive response. To confirm such a hypothesis, plots against time, such as the one shown in Figure 2 are necessary.

Therefore, the sensitivity of the new test was 92.3%. Twenty-nine of 30 Lang I-negative children had negative 3D stimulus responses, which yields a specificity of 96.7%. The positive predictive value of the new test was 0.96 (95% CI, 0.79–0.99); the negative predictive value, 0.94 (95% CI, 0.78–0.99); and the overall accuracy, 0.95 (95% CI, 0.85–0.99).

DISCUSSION

In this study, we present the results obtained in 56 children with a new, simple 3D monitor-based random-dot test developed by our laboratory. The new test has been found to be potentially useful in a pilot study including four children.¹⁵ The use of a 3D monitor allows natural viewing conditions and avoids using dissociating glasses. The stimulus recognition is objectively assessed using infrared photo-oculography. The time necessary to record a response is 38 seconds. Analysis of the curves takes approximately 10 seconds. Correct placement of the child before starting the recording may take several minutes, especially in younger children. Unnoticed lateral head displacement can result in a false-negative response or in a positive response—however, to an uncrossed stimulus of the same disparity. Usually, displacements are easily noticed because the oculographic camera loses the image of the recorded eye. Previous techniques such as Infant Random Dot Stereoacuity Cards,⁵ the Preschool Randot Stereoacuity Test,¹³ random-dot stereogram, and correlogram-evoked potentials also represent objective testing procedures with no need of verbal interaction. However, they require some type of image dissociation.^{6,14} Our new examination technique was tested in 56 children with normal and abnormal random-dot stereovision and compared with the ability to recognize the Lang I random-dot stereotest. Because the Lang I test is nonreliable in children younger than 3 years, only children older than that were included in the study. We included four different categories of children: those with microstrabismus, who usually do not pass random-dot stereoscopic tests, while recognizing other stereotests, at least if gross disparities are used; children with congenital infantile esotropia, who usually do not pass any stereotest; anisometric amblyopes, who typically pass random-dot stereotests; and normal subjects. We found high values for the new test for sensitivity, specificity, and positive and negative predictive values, if all children were grouped together. Because of the small number of children included in each subgroup, a statistical analysis of each subgroup does not

make sense. Looking at each subgroup separately shows that the correspondence of both tests seems to be good also for each diagnosis. Because the testing of the new method in 10 cooperative children and 10 adults revealed that monocularly, the stimulus could never be perceived, even if head displacements were allowed, our test might even be better than the Lang I stereotest. In our analysis, we remained conservative and assumed the Lang I stereotest to be the gold standard for random-dot stereovision testing. However, in our own experience and the experience of Joseph Lang (personal communication, December 2002) some random-dot-negative children rarely recognize the figures of the Lang I stereotest, even though card and subject remain still. Some subjects are also able to recognize the objects monocularly. The question of whether our test is superior to the Lang I stereotest cannot be answered by our study, because it requires using the test in a much larger number of subjects.

For routine clinical use, the new test will not replace the most frequently used random-dot tests such as the TNO test, the Lang I and II tests, and the Random-dot E test.¹² Although all these tests require verbal capabilities from the subject tested and do not allow objective measurement, they remain cheaper and easier to be applied in comparison to our 3D monitor-based test. In this study, we did not compare our new test to tests such as the Infant Random Dot Stereoacuity Cards,⁵ the Preschool Randot Stereoacuity Test,¹³ random-dot stereogram-evoked potentials, and random-dot correlogram-evoked potentials.^{6,14} Lateral head movement insensibility could be decreased with the use of 3D monitors, by adapting their image projection in relation to the head position. Although already available, the actual head-tracking mechanisms do not allow faster head movements like the ones usually occurring in children.

In conclusion, our new examination technique allows an objective assessment of random-dot stereopsis in children older than 3 years. Future studies will assess whether the method is useful for screening children for visual abnormalities and whether the results can be compared to other random-dot stereotests. If applicable to preverbal children, it may also permit the study of the development of stereovision under

TABLE 1. Two-by-Two Tables for Testing Random-Dot Stereovision

	FCT	
	+	–
Microstrabismus ($n = 16$)		
Lang I		
+	2	0
–	0	14
Congenital infantile esotropia ($n = 14$)		
Lang I		
+	0	0
–	1	13
Anisometric amblyopia ($n = 8$)		
Lang I		
+	5	1
–	0	2
Normals ($n = 18$)		
Lang I		
+	17	1
–	0	0
All subjects ($n = 56$)		
Lang I		
+	24	2
–	1	29

Testing was performed with the Lang I test and the 3D monitor for subject groups, as shown.

natural conditions. The new test may also be useful for the objective measurement of the sensory outcome after the treatment of ophthalmopediatric disorders. An ongoing study in an identical experimental setting using an infant car seat; a tilted, frontoparallel 3D monitor; and an infrared photo-oculography camera located over the infant's head capturing the eye movements over a hot-mirror directly in front of the monitor, will determine the earliest age on which the new testing procedure can be used.

References

- Atkinson J, Braddick O. Stereoscopic discrimination in infants. *Perception*. 1976;5:29-38.
- Birch E, Petrig B. FPL and VEP measures of fusion, stereopsis and stereoacuity in normal infants. *Vision Res*. 1996;36:1321-1327.
- Birch EE, Gwiazda J, Held R. Stereoacuity development for crossed and uncrossed disparities in human infants. *Vision Res*. 1982;22:507-513.
- Birch EE, Shimojo S, Held R. Preferential-looking assessment of fusion and stereopsis in infants aged 1-6 months. *Invest Ophthalmol Vis Sci*. 1985;26:366-370.
- Birch EE, Salomao S. Infant random dot stereoacuity cards. *J Pediatr Ophthalmol Strabismus*. 1998;35:86-90.
- Petrig B, Julesz B, Kropfl W, et al. Development of stereopsis and cortical binocularity in human infants: electrophysiological evidence. *Science*. 1981;213:1402-1405.
- Held R, Birch E, Gwiazda J. Stereoacuity of human infants. *Proc Natl Acad Sci USA*. 1980;77:5572-5574.
- Eizenman M, Westall CA, Geer I, et al. Electrophysiological evidence of cortical fusion in children with early-onset esotropia. *Invest Ophthalmol Vis Sci*. 1999;40:354-362.
- Mulvihill A, MacCann A, Flitcroft I, O'Keefe M. Outcome in refractive accommodative esotropia. *Br J Ophthalmol*. 2000;84:746-769.
- Shirabe H, Mori Y, Dogru M, Yamamoto M. Early surgery for infantile esotropia. *Br J Ophthalmol*. 2000;84:536-538.
- Simonsz HJ, Kolling GH, Unnebrink K. Final Report of the Early vs. Late Infantile Strabismus Surgery Study (ELISSS): a controlled, prospective, multicenter study. *Strabismus*. 2005;13:169-199.
- Noorden GK, Campos EC. Binocular vision and ocular motility. Examination of the patient. V. Depth perception. St. Louis: Mosby; 2002:298-307.
- Fawcett SL. An evaluation of the agreement between contour-based circles and random-dot-based near stereoacuity tests. *J AAPOS*. 2005;9:572-578.
- Julesz B, Kropfl W, Petrig B. Large evoked potentials to dynamic random-dot correlograms and stereograms permit quick determination of stereopsis. *Proc Natl Acad Sci USA*. 1980;77:2348-2351.
- Breyer A, Jiang X, Rutsche A, Mojon DS. A new objective test for random-dot stereopsis in preverbal children (in German). *Klin Monatsbl Augenheilkd*. 2003;220:96-98.
- Ruetsche A, Baumann A, Jiang X, Mojon DS. Automated analysis of eye tracking movements. *Ophthalmologica*. 2003;217:320-324.
- Buquet C, Charlier JR. Quantitative assessment of the static properties of the oculomotor system with the photo-oculographic technique. *Med Biol Eng Comput*. 1994;32:197-204.
- Charlier J, Buquet C, Desmidt A, Querleu D. Application de la technique photo-oculographique à l'étude de la poursuite visuelle au cours des premiers mois de la vie. *Bull Soc Ophthalmol Fr*. 1993;11:973-978.
- Vital-Durand F, Atkinson J, Braddick OJ. Evaluation of sensory visual development based on measures of oculomotor responses. In: Buquet C, Charlier JR, eds. *Infant Vision*. New York: Oxford University Press; 1996:291-306.