Optometric examination of children: A literature review

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Pacific University
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Abstract
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Degree Type
Thesis

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OPTOMETRIC EXAMINATION OF CHILDREN;
A LITERATURE REVIEW

Submitted to
the Faculty of
Pacific University College of Optometry
as partial fulfillment of the requirements for the
Optometry Doctorate Degree

by
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March, 1982
ACKNOWLEDGEMENT

Thanks goes to Dr. Norm Stern whose suggestions formed the basis for the structure and format of this paper.
ABSTRACT

This work is an attempt to bring together in one source basic information and techniques for optometric examination of children. Test values expected for different age groups are presented first in each section. The emphasis is on findings that differ from those of adults. Because of this, proportionally more of the writing regards infants and young children as opposed to those above eight years of age. Following the expected findings are techniques offered in the literature that can be applied to children's testing. Because of the unreliable subjective responses, objective testing is emphasized. The review does not present all techniques in the literature, but attempts to provide basic practical data for a thorough examination of the young child. The areas considered are: visual acuity, refractive error, accommodation, oculomotor system, binocularity/fusion, color vision, visual perceptual motor, and ocular health.
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INTRODUCTION

This work is an attempt to bring together in one source basic information and techniques for children's examinations. The first part of each section presents and discusses expected test findings for children from birth to 12 years of age. The emphasis is on findings that differ from those of adults. Consequently, proportionally more information is presented for infants and young children than the older group. As many objective methods of testing are presented as possible because preadolescent children generally will not complain of visual discomfort and do not always respond reliably. The second part of each section is the presentation and discussion of techniques generally applied only to children and on variations of techniques used on adults that have been adapted to children.

It is expected children 8 to 9 years of age can respond to testing techniques used on adults though they may respond more slowly. It may also be necessary to provide greater differences between two choices, for example, in subjective refraction. It is generally recommended instructions be kept simple and given one at a time. It is best to avoid instructions that include concepts young children may not understand. A manual response, as pointing, is as simple as possible. Children will often respond slower verbally than manually. If verbal responses are required, questions that require yes or no answers are best
for young children. It may be easier to maintain the child's attention in a slightly darkened room. If the children are old enough to do so, their attention can be maintained during specific testing by having them read a printed test target. The examiner's imagination, creativity, and enthusiasm in testing will help to keep the child interested throughout the exam. Infants' attention is generally best when feeding.

A large number of children require ongoing vision care. The Orinda Vision Study found the proportion of children with vision problems increases by 1.6 percent per year. In ages 5 to 7, 18 percent had problems, increasing to 31 percent in ages 13 to 15. This large proportion of the young population could become an important part of any practice if the doctor provided child vision services.

It is hoped this work will give the basic information for the student or practitioner to provide quality children's care.
VISUAL ACUITY

Visual acuity relative to age has been examined by many researchers. There is agreement among most researchers to the extent that visual acuity can practically be measured in a child's examination. The greatest disagreement is in regard to infant acuity. Weymouth's findings are representative of average expected visual acuities for ages 0 to 12. These average visual acuities are drawn from his tables.

<table>
<thead>
<tr>
<th>Age</th>
<th>VA</th>
<th>Age</th>
<th>VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1 yrs</td>
<td>20/400</td>
<td>7</td>
<td>29/19</td>
</tr>
<tr>
<td>1</td>
<td>20/180</td>
<td>8</td>
<td>10/19+</td>
</tr>
<tr>
<td>2</td>
<td>20/80</td>
<td>9</td>
<td>20/18</td>
</tr>
<tr>
<td>3</td>
<td>20/28</td>
<td>10</td>
<td>20/18+</td>
</tr>
<tr>
<td>4</td>
<td>20/25</td>
<td>11</td>
<td>20/17</td>
</tr>
<tr>
<td>5</td>
<td>20/22</td>
<td>12</td>
<td>20/17</td>
</tr>
<tr>
<td>6</td>
<td>20/20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These are conservative figures compared to those of recent researchers who feel acuity is better than previously reported. The reported level of visual acuity infants are capable of varies greatly between examiners. Fantz gives the following breakdown for objective acuities.

<table>
<thead>
<tr>
<th>Age</th>
<th>VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 Months</td>
<td>20/400</td>
</tr>
<tr>
<td>1.5</td>
<td>20/400</td>
</tr>
</tbody>
</table>
Using objective evaluation of optokinetic nystagmus (OKN) to assess acuity shows newborns to have a visual acuity of 20/670. By two months of age, OKN reflexes show 20/100 and 20/80 by six months. Dayton et al, measuring OKN responses with electrooculography, demonstrated that infant acuity may be as good as 20/150. Premature infants have been shown to have a visual acuity of approximately 20/820, about one half that of full term infants tested in the same manner.

A number of tests and techniques have been devised to test visual acuity in young children. The starting or stopping of optokinetic responses is one generally recommended for infants and very young children. OKN has been most often induced by passing vertical alternate black and white stripes, either mounted on a revolving drum or on a long strip of paper, before the eyes of the child. Schumann used the stopping, or hemming, of OKN to assess acuity. With OKN induced by a revolving drum, the acuity was based on the smallest size stationary object placed in the field that allowed for fixation to stop the nystagmus. Schumann did not consider this a true measure of visual acuity, but rather a recognition of a "minimum separable" angle. This technique, stopping OKN by introducing a fixation object
into the field, was found to have the best correlation to subjective acuity with older subjects.⁷ The correlation of speed of rotation of an OKN drum and subjective acuity is not good,³⁷ but Schumann feels an eight cycle per second change of black and white stripes elicits the maximum amplitude OKN response.⁵³ However, a range between 4 and 32 cycles per second is reported by others to be adequate.⁵²⁵³

Mohindra recommends modifying a standard equal width OKN drum to have varying width stripes to assess visual acuity. She feels the procedure of moving the standard drum further away is not practical because infants will not attend distant objects.⁴¹ (Gesell feels that at 16 weeks of age the far point of interest for the infant may be only three feet.¹⁹)

The use of a light to create a corneal light reflex has been suggested to increase the examiner's ability to see the nystagmus. Changes in the level of illumination in moderate amounts have little effect on the OKN response.⁵²

One advantage (or disadvantage) of OKN as a measure of visual acuity is that foveal fixation is not necessary. Whether the greatest effect on OKN occurs with foveal or peripheal retina stimulation is a point of debate.⁵² Which retinal area is stimulated would depend on the attention of the child and would be expected to produce a difference of response. Whether this is practically significant is not certain.
Optokinetic nystagmus is also affected by fatigue and will be slowed.\textsuperscript{52}

The use of lenses to correct refractive error results in a more rapid dampening of the nystagmus when a stationary object is introduced into the field.\textsuperscript{52}

With all the factors affecting OKN, its use to assess acuity is a gross measure and a negative result is not felt to be conclusive.

When the OKN testing is negative, an alternative is objective observation of fixation or pursuit motions. This technique is a measure of minimum detection and the angular subtense of the object will be much smaller than that for a minimum recognizable measure as is done with acuity charts.\textsuperscript{50} Small targets on wands or strings can be used with infants and small children. The contrast of the targets on the background is a factor, a black target on a white background being the most visible. It is reported newborns are capable of both steady and pursuit fixations,\textsuperscript{50} though others feel pursuits do not occur for some weeks.\textsuperscript{56} Practically, for observation, and based on the Gesell's premise that the infant builds visual space outward, it is best to perform this test at about one meter or less.\textsuperscript{19} Also possible is the use of edible cake decorations, items found in grocery stores. Targets of 1, 3 and 5 millimeters with varying hues from white to red are recommended. The white candy presented on a white tabletop is the most difficult to detect.\textsuperscript{15}
When lowered acuity is suspected in only one eye, the observation of behavior changes when monocular occlusion is performed can be used with small children and infants. The more severe the visual deprivation when occluded, the more pronounced would be the change.\(^{46,50}\)

When children are old enough to respond, acuity charts can be used. Gesell feels that basic forms such as a square, a circle and a triangle can be differentiated as early as 28 weeks\(^ {19}\) though the child would not be likely to respond until 18 to 24 months.

A shortened testing distance of ten feet is recommended instead of the customary 20 feet to better control the child's attention.\(^ {21}\)

Picture tests using size scaled pictures or outlines of familiar objects are easier than tests requiring orientation such as the tumbling E.\(^ {50}\) The New York Lighthouse Flash Card Vision Test may be useful for children age 2 to 3. The cards consist of progressively smaller pictures of a house, or umbrella, and an apple. The visual acuity is considered to be the smallest the child can identify correctly four times.\(^ {7,21}\) The Keystone Peek-A-Boo series is an adaptation for the telebinocular that uses picture cards to assess acuity.\(^ {21}\) (The series of cards also tests phoric posture, fusion, color vision and stereopsis.) A problem with picture charts is that unfamiliarity with the test objects may lead to an erroneously low acuity score.\(^ {7}\) A higher acuity score may result when the forms are repeated and scores generally are higher on acuity tests which require
form recognition versus Snellen acuity. H. F. Allen's picture charts are designed with black lines and white spaces in an attempt to more closely approximate Snellen testing. The charts are now in widespread use and consist of such items as a birthday cake, telephone, car and driver, and horse and rider.

A four year old can generally use a tumbling E as can a three year old with some home training. A single tumbling E may be less confusing to the child than a whole line presentation, although whole line testing is also recommended.

A child of age 5 to 6 should be able to respond to a standard Snellen acuity test through not as rapidly as an older child. A closer test distance, 10 feet, is still recommended.

Nearpoint testing should also be performed for all ages.

Acuity assessment potential has also been evaluated using the visual evoked potential. The results show better acuity than measured by other methods. The signal summation methods are very sensitive. There is debate as to whether the infant can use the information. Lewerenz reports the VEP to be abnormal until age 3 months.
REFRACTIVE ERROR

The mean refraction for full term newborns is approximately 2 diopters (D) of hyperopia.$^{7,32}$ The distribution of refractive errors is quite wide, up to $\pm$ 12 D$^7$, one standard deviation reported to be 2.73 D.$^{44}$ One fourth of the neonates are myopic at birth.$^{44}$ The population mean of hyperopia decreases both in amount and variance until school age where the average refractive error is 1.00 D less hyperopic than at birth. The standard deviation being approximately 1.60 D.$^{7,31}$ Data from Hirsch and Blum show the average refraction at school age to be slightly less, 1.00 D of hyperopia. They report very little high hyperopia and less than 1 percent myopia.$^7$ During the first six years of school there is a continued shift toward myopia.$^7,31$ The mean refraction during ages 5 to 14 changes more than the median indicating some individuals change much while others change very little.$^{32}$ Of these children, 75 percent change less than 0.5 D and 1.00 D, and only 5 percent change by more than 1.00 D.$^{31}$ In a later study, Coleman also found little to no myopia in grades K, 1 and 2 with an increase in myopia in grade 3.$^{12}$ This progression continues through the school years.$^5$

Myopia at birth is found more frequently in premature infants.$^7,51$ This "myopia of prematurity" was found to reduce dramatically in the first year of life.$^7$ Scharf et al.$^51$ in a seven year longitudinal study of the visual
status of premature infants, found there was a shift of those who were myopic toward hyperopia which continued up to age 8. Hyperopic premature infants followed the normal course toward less hyperopia. Emmetropes generally remained emmetropic with 56 percent of the premature myopes going to emmetropia. The remainder showed less myopia than at birth.\textsuperscript{51} Scharf et al also reported birth weight and family history of myopia did not appear to be factors related to the infant's myopia.\textsuperscript{51} However, Borish reports on a study linking very low birth weights to higher degrees of myopia.\textsuperscript{7} The myopia of prematurity is thought to be mostly lenticular in origin.\textsuperscript{51}

Hirsch summarizes the expected refractive changes for a child after age six as follows:\textsuperscript{30}

If the spherical refraction is between 1.25 D and 0.50 D of hyperopia there is a greater chance of becoming emmetropic. A child hyperopic by 1.50 D is likely to remain hyperopic and may even become more so. The child who is emmetropic to 0.50 D hyperopic at age six is likely to progress to myopia. This is particularly true when against the rule astigmatism is present. The myope at age six will remain so and will likely become more myopic. For the low hyperope, less than 0.50 D, there is the likelihood of a shift into myopia even into the late teens if there is a visually stressful environment.

The age of onset of myopia is related to the final amount present. If 1.00 D of myopia was noted between age 4 to 8, the final degree of myopia was likely to be twice the amount
if 1.00 D was reached between age 11 to 15, 4.75 D for the 4 to 8 age group versus 2.29 D for the 11 to 15 age group.  

Mohindra found clinically significant astigmatism in 45 percent of 276 infants between birth and 50 weeks of age. This she reports is five times that found in older children and ten times that found in adults. She feels this infantile astigmatism is reduced in the course of postnatal development. Hirsch reports only a small percentage of young children to have significant astigmatism. Only four to six percent having greater than 0.75 D, mostly with the rule.  

The technique for determination of refractive error would depend on the age of the child.  

Static retinoscopy has been used with infants. In order to avoid the near accommodative posture, Haynes et al found in awake infants it may be necessary to perform the retinoscopy on infants less than four months of age while they are sleeping. When the child is old enough to watch a cartoon, projection at 6 to 8 feet should give enough fixation time for retinoscopic evaluation with loose lenses. A large noisy object at the far end of the room can be used.  

Mohindra advocates the use of nearpoint retinoscopy in a dark room with the retinoscope for fixation to assess refractive error. Her rationale is that static retinoscopy
is not valid because of unsteady fixation and inaccurate accommodation responses in infants. The procedure is to perform retinoscopy monocularly at 50 centimeters in a dark room while observing that fixation is maintained on the retinoscope. She adds to the gross finding -1.50 D for the refractive error. She has found fixation and attention to be best while the infant is being fed.

Studies show an increased degree of myopia as measured by the ophthalmoscope lens when compared to the subjective refraction. Accommodation in the subject and/or the examiner is thought to be the cause. 7

Since a toric cornea generally accounts for the majority of cases of significant astigmatism, corneal measurement should give a clue as to the degree of astigmatism expected. 7 Keratometry readings average 50.50 D at birth compared to 43.00 D in the adult. 44 The infant can be held in front of a keratometer turned 90° off its normal position. This is felt to be the most difficult but most desirable method of measure. 20 A placido disc or illuminated keratoscope is a more gross measure of corneal astigmatism.

The reflected rings are evaluated for toxicity indicating astigmatism, the longest axis of the ellipse being the flattest meridian of the cornea. 20

Nearpoint retinoscopy in the form of bell retinoscopy and monocular estimation method have been suggested to
evaluate a cylindrical component to the refractive error.\textsuperscript{4,21} They have also been recommended to check for anisometropia.\textsuperscript{4,21}

If the child is old enough, an automatic refractor may be used. Barnes and Anderson\textsuperscript{3} found a high correlation for sphere and cylinder powers with an automatic refractor compared to a practitioner's subjective to best visual acuity. However, the cylindrical axis measure was not reliable.

An estimation of the refractive error can be made based on the visual acuity. The following abridged table after Borish is offered for gross estimates of refractive error.\textsuperscript{7}

\begin{center}
\begin{tabular}{|c|c|c|}
\hline
Diopters & Simple myopia or absolute hyperopia & With the rule astigmatism\textsuperscript{a} \\
\hline
0.50 & 20/30 & -- \\
0.75 & 20/40 & -- \\
1.00 & 20/50 & 20/30 \\
1.50 & 20/100 & 20/40 \\
2.00 & 20/150 & 20/50 \\
2.50 & 20/200 & 20/70 \\
3.50 & 20/300 & 20/125\textsuperscript{b} \\
4.50 & 20/400 & 20/200\textsuperscript{b} \\
\hline
\end{tabular}
\end{center}

\textsuperscript{a} Against the rule astigmatism would affect acuity to a slightly greater degree and oblique axis to an even greater degree.

\textsuperscript{b} Extrapolated from data.

In refracting the child, it may be easier to have the child read successively smaller lines of print as lenses are changed than to compare the difference in clarity of two choices.\textsuperscript{21} For the astigmatic correction, a moderate cylinder amount can be rotated to the two principle meridians to see if the child notices a difference.\textsuperscript{7}
The use of a cycloplegic in refraction depends on the examiner and examinee and a slightly more hyperopic or less myopic refraction will occur\(^7\) (though the reverse can occur\(^7\)).

Mohindra questions the use of cycloplegic agents on infants because of the side effects on the visual system, the underdeveloped state of the vision system, and the lack of evidence for significant differences between cycloplegic versus non cycloplegic refraction.\(^41\) She also feels cycloplegic retinoscopy has the potential of error because of oblique axis measure and glare from a dilated pupil reducing reflex dampening.\(^42\) Ingram and Barr compared findings from a study using cyclopentalate for cycloplegia to one using atropine. On the one year old subjects the results were similar while the cyclopentalate was safer. They felt that before three months of age, atropine may well be absolutely contra indicated.\(^36\)
ACCOMODATION

The amplitude of accommodation and facility of accommodation have an effect on each other's findings and both should be considered in the child's exam. The extent to which each examiner specifically tests performance in area should depend on his or her ability to draw as much information as possible from a single test.

Haynes et al.\textsuperscript{25} using retinoscopic evaluation found newborns had accommodation locked at approximately 19 centimeters while awake. By the time the infants had reached four months of age the accommodative system was similar to an adult's.\textsuperscript{25} Wold studied accommodative amplitude for 125 school children age 6 to 10.\textsuperscript{62} Accommodation was measured in a number of ways (see accompanying table).

Since the limits of accommodation for all ages were within \(\pm 1.00\) D of the average for all ages, the figures below could practically be considered to apply to all ages 6 through 10. The averages in the following table are rounded to the nearest diopter and the standard deviations are approximate.

Accommodative Response age 6-10 After Wold.\textsuperscript{62}

<table>
<thead>
<tr>
<th>Monocular Tests</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concave Sphere to blur</td>
<td>13.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Letter target to blur</td>
<td>18.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Retinoscopy\textsuperscript{a}</td>
<td>16.00</td>
<td>1.50</td>
</tr>
<tr>
<td>Optometer</td>
<td>13.00</td>
<td>2.50</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Minus 4D to 6D lenses were used in a trial frame in order to keep the target out approximately 10 cm. and a switch from a slight
with retinoscopic motion to a strong with motion was considered the retinoscopy push up amplitude.

Duane found binocular accommodation limits slightly greater than monocular but not more than 1.00 D. Donders found similar amplitudes at age 10 with a reduction to 12 D at age 15 and to 10 D at age 20.

Greenspan feels accommodative amplitude need not be checked as a rule rather that the positive relative accommodation and negative relative accommodation be checked and both should equal approximately 2.00 D.

Hoffman and Rouse feel a difference of accommodative amplitude greater than 0.50 D between the two eyes is indicative of accommodative problems. Borish lists a number of studies that report monocular accommodation to be within 0.50 D of the fellow eye. In amblyopia, unequal accommodative limits persist even though visual acuity is regained.

According to Haynes work as previously mentioned, accommodative facility is good by age four months. Gesell reports at 30 weeks of age a "cyclic" accommodative response was found to nearpoint tasks. Both "with" motion of the retinoscopic reflex indicating too much accommodation, and "against" motion indicating too little accommodation are part of the cycle.

Haynes evaluated facility as measured by a near/far rock. He used 20/80 letters at 20 feet and 20/25 letters
at 16 inches, with an oral response. The findings for grades one through six are as follows:

Near/Far Accommodative Rock

<table>
<thead>
<tr>
<th>Grade</th>
<th>Mean cycles per min.</th>
<th>Standard Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>4.39</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>4.60</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>5.04</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>5.02</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>5.11</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>5.88</td>
</tr>
</tbody>
</table>

Hoffman and Rouse do not give an age break down for the + 2.00 D flipper test but state that less than 12 cycles per minute at 16 inches with 20/30 letters is indicative of accommodative problems. Haynes reports the mean number of accommodative lense rocks to be 21 cycles per minute (No ages given.) Subjective responses are felt to be important in evaluating the number of flips and a suppression check is needed with accommodative rocks.

Near retinoscopy, bell retinoscopy, and the monocular estimation method (MEM) have been used to test accommodative posture and facility.

Gesell lists near retinoscopy findings through lenses while viewing an acuity target. The value for age 2 through 5 years of age was found to be a 0.50 D to 1.00 D lag of accommodation. The lag of accommodation for a nearpoint target as measured by MEM should be 0.75 D or less. The MEM is performed by the examiner estimating the lag of accommodation and then inserting a loose lens to confirm the estimation. Haynes gives consideration to the demand
of the target when using MEM. With just a white card for a target, the lag at 16 inches is 1.00 D, usually agreeing with the binocular cross cylinder finding and in any case never being more plus than the cross cylinder. With a 20/100 letter, the posture moves in to where the lag is 0.62 D. Haynes finds that in patients with low accommodative facility or accommodative insufficiency, the posture of the accommodation does not change much when initially viewing a different target. The posture of accommodation remains out 1.00 D to 1.75 D beyond the plane of the card with transient motions in to obtain meaning. Care must be taken to observe the central pupil reflex and not peripheal changes. Haynes feels that in cases with disturbed convergence, performance such as receded near-point of convergence or low ductions, the MEM will appear normal.

Apell describes the use of bell retinoscopy. Performing retinoscopy from one meter he uses a steel ball for fixation and moves it in toward the patient. Apell finds "with" motion reduces to "against" 17 to 14 inches from the patient. Moving away, "against" motion reduces to "with" motion at 15 to 18 inches. He feels accommodative flexibility is indicated if the distance of change is the same when +.50 lenses are used. If the changes occur two inches further out, the system is thought to be "rigid". If "with" motion is noted inside of 14 inches, the patient
probably is not binocular and should be asked how many targets there are. Apell feels pupil size is important and should be noted if it is greater than 7 mm or less than 5 mm.

Monocular and binocular cross cylinders are also used to evaluate accommodative performance. The binocular cross cylinder finding with a low acuity demand target should be approximately 1.00 D more plus than the subjective refraction and monocular values an additional + .25 D over the binocular.

The symptomology associated with accommodative dysfunction is important because it can alert the examiner to the possibility of problems. Symptoms of accommodative problems might include excessive rubbing of eyes, asthenopia with near work, irregular working distance, periodic far blur, or inability to sustain nearpoint work.

Pupillary constriction is generally regarded as an indication of accommodation. However, Burian and Von Noorden cite two studies as evidence that pupillary response is related to convergence innervation and not accommodation. Alpern's work indicates that pupil size continues to decrease with push up accommodative demand though the amplitude of accommodation had been reached.
OCULOMOTOR SYSTEM

The ability to fixate and follow with close correspondence of both eyes is well established in the first few weeks of life.\textsuperscript{23,50} The infant should show sustained interest in near objects at one month with convergence by two months.\textsuperscript{19} At three months, eye movements will begin to be coordinated with head movement.\textsuperscript{19} At ten months, the eyes should sweep 180\textdegree\ easily\textsuperscript{19} and ocular motility and tracking should be smooth by one year.\textsuperscript{6} Gesell\textsuperscript{19} outlines a progression of improvement of fixation and pursuit from short periods of limited motility at age five to longer and more intent fixation at age seven. Gesell finds binocular performance better than monocular, becoming more equal at age eight. Also, at age eight there is some tensing of the head and neck with an improvement in pursuit fixations.\textsuperscript{19}

The ocular motor system performance is felt to develop in correspondence with other visual and visual perceptual performance.\textsuperscript{33,19}

Objective observation is the standard in testing ocular motility. A larger acuity target, 20/80, is recommended for testing oculomotor skills.\textsuperscript{33} When performing saccade tests, the distance from the child and between the targets should approximate the requirements of reading, 16 inches distant and 8 to 10 inches separated.\textsuperscript{21,33} Greenspan considers slight undershooting in saccades to
be normal but double undershooting (two or more moves to gain fixation) or overshooting to be potentially abnormal.\textsuperscript{21}

When the child is old enough to read, the case history may be significant. Difficulties such as skipping lines, rereading lines, lack of comprehension when reading, or a short attention span manifest when reading are potentially related to poor ocular motilities.\textsuperscript{21,33}

For quantitative evaluation of saccades, the Pierce Saccade or King-Devick Saccade Test could be used. Both tests are age normed with standard deviations and use two columns of letters the patient alternates between. The Pierce Saccade has regular spacing between each pair of letters while the King-Devick has random spacing between the two columns.\textsuperscript{33} The Eye Trac can also be used and gives a tracing the examiner can analyze.\textsuperscript{33}

For a quantitative evaluation of pursuits, the Groffman visual tracing and Michigan Visual Tracing are timed tests resulting in a score to compare to norms based on the correctness of response and time required for different ages.\textsuperscript{21}

Monocular fixation is measured by angle kappa, the angle between the visual axis and pupillary axis of the eye. The monocular light reflex is usually nasal on the cornea reflecting a positive angle kappa.\textsuperscript{20}

Monocular fixation can also be measured using entoptic phenomenon, the Haidinger brush, and Maxwell spot.\textsuperscript{7} An ophthalmoscope with a grid target can also be used to check
monocular fixation. The other eye needs to be occluded. The literature reflects a greater interest in qualitative assessment and symptomology than in quantifying the test results of ocular motor performance.
BINOCULARITY/FUSION

The first step in evaluating binocularity is general observation.\textsuperscript{55} Unusual head position or tilt may indicate fusional stress, as may behavioral responses to nearpoint testing.\textsuperscript{33} However, as previously noted, children are very adaptable and may not exhibit any signs of visual stress.\textsuperscript{7}

Concomitant eye movements are present in newborns\textsuperscript{50,23} but convergence may not be present until after two months.\textsuperscript{19} Roberts\textsuperscript{47} reports the prevalence of all tropias in the U.S. to be 3.7 percent, of which 1.2 percent esotropes and 2.1 percent exotropic. For age one to three years, the prevalence is 1.9 percent, most being esotropes (1.3 percent) and an equal split between exotropes and other (0.3 percent). According to Roberts, exotropia generally occurs after age four.

Techniques of testing for determination of the type and degree of strabismus is beyond the scope of this paper.

Based on the observation of preferential viewing of random dot stereograms, stereo vision may be present as early as one month of age.\textsuperscript{44,13} Fantz using a similar technique reports stereopsis may be present at birth.\textsuperscript{50} Infants 3½ months old have been reported to have 45 arc minutes of stereopsis as measured by random dot stereograms.\textsuperscript{54} Gesell, using behavioral observations, does not expect stereopsis until four months of age.\textsuperscript{19} Stereopsis
at the 100 percent level as measured by the Keystone Telebinocular test for Stereopsis (DB 6D) should be present by age eight.\textsuperscript{19}

Monocular corneal light reflexes should be done before binocular to look for irregularities of monocular fixation. Monocular fixation can be evaluated by estimating angle Kappa, the angle between the pupillary axis and visual axis of the eye. A slight positive angle kappa, reflex nasal to pupil axis, is normal.\textsuperscript{22,20} On older children who can follow instructions, a measuring ophthalmoscope can be used to check fixation.\textsuperscript{7}

The Hirschberg corneal light reflex is widely used to evaluate binocularity. A light is moved toward the patient on the midline and a symmetrical position of the corneal light reflexes is indicative of binocularity.\textsuperscript{7} The Hirschberg light reflex is a gross test and requires the child fixate the light.\textsuperscript{57} However, the test is quick and requires no occlusion. Griffin feels it to be valid only for nearpoint testing and that the sensitivity of the Hirschberg test is 5.5 which is less than the cover test.\textsuperscript{22} Strangler et al states the Hirschberg test may miss deviations up to 7 degrees and may not show strabismus until accommodation is in play.\textsuperscript{56} The unilateral cover test is monocular occlusion with observation of the opposite eye for refixation.\textsuperscript{9} Romano and Von Noorden feel that even an experienced examiner cannot detect a deviation of less
than two prism diopters using the cover test. The use of a lateral base prism of sufficient power to cause a refixation that can be seen by the examiner, can be used to test for fusion.

Gross suppression can be checked by inducing diplopia with vertical prism or by questioning the child about physiologic diplopia. The child needs to be old enough to understand what double vision is. The stereo fly is a gross test for stereopsis. An advantage of the stereo fly is that a young child will often make an overt reaction to the three dimensional fly. An estimation of the amount of stereopsis can be made based on where the child reaches to touch the wings. The Wirt Circles can be used to quantify the amount of stereopsis. Hoffman and Rouse prefer stereo tests that have no monocular cues, such as Randot. Since they are simple geometric forms, they may be used on children as young as two years. With these polaroid targets, the perception of depth can be reversed by putting the polaroid glasses on upside down. For the most accurate measure, it is important when using the polaroid tests that the eyes be level in the horizontal and the target not be tipped distant or sideways relative to the patient. It is recommended the stereo tests be performed at the proper distance. If they are used at a different distance, the degree of stereopsis should be recalculated.
The red lens test uses a red translucent lens before one eye while viewing a small light source. The child is asked how many lights there are and what color the lights are. One pink light indicates fusion. (Color naming may be poor in children under age six.) If fixation is not on the light, two lights may be reported. Because of this, the red lens test requires careful observation by the examiner. Red green glasses can be used in a manner similar to the red lens. Establishing a naming scheme for the colors can help.

The Worth-4-dot test can be used to check for suppression and fusion. This does require the child to count the number of lights and therefore may not be suitable for young children. In addition, the Worth-4-dot is thought to miss subtle suppressions.

Keystone Peekaboo series for the telebinocular can be used for children under six years of age to test for fusion, stereopsis, and vertical and lateral phorias. Other Keystone cards can be used with four to seven year olds, but more accurate measures can be made after that age with instruments as long as the instructions and questions are kept simple.

By school age, the nearpoint of convergence should be two inches and the vergence movements should be smooth both in and out from the working distance to 20 feet. Using flipper prisms with 4BI/8BO for distance and 8BO for distance and 8BO.
BI/12° BO at near with a 20/30 line, eight to ten cycles per minute are expected.33

After age eight, more accurate measures of fusion can be made using standard testing.
COLOR VISION

Color vision is normal in 99 percent of females and 92 percent of the males. True protanopia occurs in only 1 percent of the males, which is the same as true deuteranopia. One in ten thousand is a true achromat, females occurring as frequently as males.27 The remainder of color defectives are varying degrees of color anomaly. Congenital color defects are almost always bilateral.50 Early testing of color vision, particularly males, is important in order to properly counsel the parents.

Simple naming of colors is not adequate because young children do not accurately name colors and older children learn ways to guess color.7,27,57

Children can be tested for color vision at an early age. HRR pseudoisochromatic plates that did not require reading skills were used with nursery school children. When the geometric forms (circle, triangle and cross) were used and the child had a printed sheet with the forms to match by pointing, the failure rate dropped to where only a few color blinds were found.57

The selection of color crayons to match one selected by the examiner could be used to test for color blindness. If the crayons provided by the examiner were close to the confusion colors of the different anomalies, a mixed assortment of colors would occur with the color deficient.27
The Dvorine pseudoisochromatic plates are judged to be better than the Ishihara plates because the Ishihara results in some misclassification. The HRR plates are no longer available.

The Farnsworth D-15 color test is understood by older children and they enjoy the task.

It is important for accurate testing that the color temperature of the light source be 6500°K for all color testing.
VISUAL PERCEPTUAL MOTOR

Gesell feels periodic visual examinations during the school years should have more emphasis on the appraisal of the developmental factors which relate to visual acuity. Porter and Binder cite numerous references by developmental specialists implicating visual motor deficiencies as a possible cause for academic underachievement.

The extent to which the optometrist deals with perceptual and developmental difficulties should depend on his or her capabilities and interest. However, children, particularly those in school, will be referred by educators, counselors and/or parents who wish to know if visual deficits are the cause of poor performance in academics or other activities. Even if the optometrist does not wish to provide therapy for visual perceptual or visual motor problems, he or she should be capable of recognizing visually related developmental problems for proper referral to a practitioner who does.

This section is not intended to prepare the reader to do developmental testing, but to make him or her aware of the areas of testing and some of the tests a developmental optometrist might use. For the reader who wishes to pursue developmental optometry further, additional references are listed at the end of this section.

Greenspan feels research has not confirmed the practicality or validity of any screening method for a broad
spectrum of specific perceptual skills. He recommends a careful analysis of signs and symptoms with an inquiry into school performance. Perceptual motor testing is not felt to be necessary on children over 12 years of age unless the history warrants it.

Hoffman and Rouse list over 50 symptoms they feel are related to different areas of perceptual motor deficiencies. Following is a sampling of these behaviors for each area Hoffman and Rouse list.

Gross motor and bilateral integration
1. lack of coordination and balance
2. difficulty with rhythmic activities
3. can't sit still

Directionality
1. difficulty learning left and right
2. reverses letters and words

Form perception
1. difficulty determining what is significant in visual tasks
2. difficulty completing work

Visual closure
1. ignores details when doing visual tasks
2. cannot put several parts of task together

Visual sequencing
1. difficulty getting organized
2. poor spelling skills

Visualization
1. difficulty visualizing what is read
2. poor comprehension
3. tends to whisper to himself when reading
4. tends to avoid new situations
Visual motor integration

1. sloppy writing or drawing skills
2. excessive erasures when doing written work
3. can respond orally but cannot get answers on paper

Auditory perceptual discrimination and attention

1. doesn't recall verbally presented materials
2. difficulty relating symbols to their sounds
3. poor spelling

These are not intended to be a complete list of symptoms, but only to serve as an example of suspect symptoms.

A discussion of the relationships of these symptoms to the deficient areas is beyond the scope of this paper. Further, the relationships are a subject of controversy and will remain so until additional carefully designed research is done. The same holds for the relationship of testing results and performance in general.

A developmental optometrist might use any number of tests in a thorough evaluation. The skill areas to be tested for are generally agreed upon by different authors. A variety of methods of assessment can be applied to each area. The choice of which test to apply depends on the preferences of the examiner. Examples for each area are drawn from a number of sources.

(References: 17, 21, 33, 35, 44, 45, 49, 55, 59, 63, 64, 65.)

1. Visual perceptual
   A. Form discrimination
      1. ability to discriminate between similar shapes.
II. Visual - Perceptual - Motor

A. Gross Motor
1. Balancing tasks - both static and dynamic balance tests with and without visual input. Visual input may be altered through the use of lenses and/or prisms. Laterality is a consideration.
2. Purdue Perceptual Motor Survey.

B. Fine Motor
1. Pencil and Paper tasks - consideration is given to crossing the midline, vertical and horizontal relationships and size relationship.
2. Puzzle tasks - formboards, parquentry blocks, and key pegboards.
3. Winterhaven Perceptual Copy Form - six basic forms to be copied. Point scored for ages 6 years to 8 years 6 months.
4. Beery Developmental Test of Visual Motor Integration - copy task normed for age 3 to 16 years.
5. Bender Visual Motor Gestalt Test - copy task normed for age 5 to 13 years.

There are a number of other tests, formal and informal, that can be used to evaluate the visual components of performance. Tests are also used to identify other problem areas, such as auditory.\textsuperscript{33,49} Integration of different skills is an important theme throughout developmental writings.

An optometrist has the options of assuming clinical management of these cases. However, a thorough understanding of developmental optometry is needed which may require considerable time and efforts to acquire.

Additional readings in developmental vision:


OCULAR HEALTH

The role of optometry with regard to the child's health, ocular or general, is primary care/pathology detection with referral to the appropriate practitioner.

Case history with family health history is important. Approximate correlation between physical size and age should be noted.

Observation of the skull and face should be made for asymmetry.

The orbits should be near circular and equal. The lids and adnexa should also be symmetric. The palpebral apertures should be equally open and should close together. The involuntary blink reflex should be present at birth or soon after. The orbital lines and lids should be palpated. Open puncta should be noted. Tear duct formation may be delayed two weeks after birth. If the tear ducts are not developed within three months, the child should be referred. The cilia of the eyelid should be examined for number and direction. The size of the eye in the orbit should be noted. The eye is one half adult size at birth and is near full size by age four.

The sclera will appear slightly blue due to thinness. The cornea should be examined for size and clarity. Any clouding of the cornea is serious and requires immediate evaluation. The cornea is 10 mm in diameter at birth and reaches adult size by two to three years of age.
Corneal luster is indicative of a properly functioning lacrimal system. Reflux tearing is not present until several weeks of age. The iris has little or no pigment on the anterior surface at birth and appears blue to slate. It will take about two years for eye color to establish.

The pupil in the newborn is slightly nasal and below the center of the cornea. Unequal size pupils are found in 20 percent of the population and anisocoria greater than 2 mm is not uncommon. Newborns will react to light by blinking or jerking. Pupillary responses should be present but may be sluggish. The newborn's pupils may be miotic relative to older children. Non reactive pupils or white pupils are serious. Remnants of the tunica vasculosa lentis may remain and be visible in the pupil, particularly in premature infants. The lens itself will be more spherical in the infant.

Both direct and indirect ophthalmoscopy are possible. The optic disc will appear pale or gray and resemble optic atrophy. The disc color should be the same as an adult by age two. The primitive hyaloid system may not absorb completely by birth and project out from the disc. The macular area in the newborn may appear slightly elevated and flattens by three to four months at which time the foveal reflex will appear. The peripheral retina will appear gray and even white at the far periphery and becomes more colored as pigment is deposited. Retinal hemorrhages
occur in 15 percent of newborns and clear completely in two to three weeks.\textsuperscript{66}

In the event dilation is necessary, 0.5 percent to 1.0 percent tropicamide with 2.5 percent phenylephrine is recommended.\textsuperscript{67} Atropine, cyclogel and 10 percent phenylephrine have all produced serious side effects and are contraindicated.\textsuperscript{67}

Fields testing can be done by confrontation when the child is old enough. Having a child tell whether a fixated or peripheal object is moved will serve for confrontation.\textsuperscript{57} The Harrington Flocks tachistoscopic test may be used on older children, but the flash speed may be too fast.\textsuperscript{57}
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