

# Essay

## Visual Evaluation of the Infant

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### ABSTRACT

The developmental visual assessment of infants should include both qualitative and quantitative aspects. The quantitative components are based on static findings that can be compared to normative data and various developmental changes that occur over time. The qualitative aspects are not easily measured. These dynamic aspects should be observed as an ongoing process. This information can provide insights into how the infant is performing the particular task and what strategies they employ. These insights can be valuable when determining the unmet visual needs of the infant and to help in the development of therapy programs. While examining infants we should keep in mind the goal of the evaluation. Beyond doing a health evaluation, we should evaluate what can be done to provide the most appropriate plan to help the infant to develop to their potential. We should also be mindful that the experiences and world of an infant are much different than an adult. Their world begins at near and extends outward after birth. Early growth and development should allow the infant to go beyond their physical world of prehension and provide an opportunity to extend their visual world outward into the environment.

### KEY WORDS

infant development, infant vision, photorefraction, toddler

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### INTRODUCTION

*He who sees things grow from the beginning will have the finest view of them.*

Aristotle 384-322 B.C.

There has been increasing support for the early visual evaluation of infants before 6 months of age.<sup>1,2</sup> Advances in research and clinical tools provide an opportunity to easily and more accurately evaluate infants. The visual system of an infant is different than that of a toddler. The infant has only begun to experience their near space and have yet to explore outwardly as the toddler does. These differences warrant a view of infant visual evaluations with respect to what we are observing and testing and where in space we are actually observing and testing them from. This should be done from both a qualitative and quantitative basis. Several questions should be considered.

- 1-What are the developmental differences that you should consider between an infant and toddler examination?
- 2-How is the near world of an infant reflected in this evaluation?

The traditional visual evaluation evaluates whether a health problem is present.<sup>3,4</sup> This is a foundation which we can build upon and expand into the developmental vision care of infants. If we step beyond the concept of health issues and look at the child as a whole, we will begin to observe the importance of development to the visual process. This will lead to a better understanding of developmental conditions and appropriate treatment strategies. This article reviews the examination of infants with an emphasis on providing a framework for evaluation and assessment from a neuro-developmental perspective.

## Evaluating infants for their unmet visual needs

Integrating infants into the primary care practice has emphasized three evaluation and treatment components: 1. Can the baby see? 2. Are the eyes straight?, and 3. Are the eyes healthy?<sup>5</sup> These three questions are critical to any evaluation but if used in isolation they will limit our clinical decision making options. The main reason for evaluating infants should be to determine if they have unmet visual needs. An unmet need may be defined as anything that has not been addressed which could influence the development of vision and therefore affect the development of the infant as a whole. An example of an unmet visual need is an infant who is cross fixating and has not learned to abduct. This infant has inadvertently learned to cross fixate which can be reflected in the development of an esotropia. This interference influences the infant's ability to learn about space and time as they develop their visual world. These spatial and temporal characteristics are what the infant will use as a foundation for further development and learning. This may modify or restrict their ability to develop to their highest potential. Gesell<sup>6</sup> emphasized this when he stated, "One considers the over all organization of his visual equipment, and asks whether he has the ability to meet the normal visual tasks demanded by culture." The concept of infant eye care should include developmental vision care with an emphasis of its affect upon child development. This would include the evaluation of visual acuity/refractive issues, eye alignment and the health of the eyes. The critical addition to this examination sequence would be to also address visual and general infant development.

### What is different about an infant examination?

There are many distinct differences between the evaluation of an infant and toddler. Infants do not have control of their body and head that a toddler has. Control of the head and body are part of the foundation for directing action. The foundation of this control is adequate muscle tone which is based upon many factors including the reticular activating system and arousal level of the infant. Gesell<sup>6</sup> stated that, "Muscle tonus is a condition of tension which exists independently of voluntary effort, but which is a prerequisite for both reflex and voluntary movements. It is more than a condition, it is an active function—a mode of behavior." He also stated, "Tonus is essential for both static and dynamic posture. The early embryology of behavior consists, to a large extent, in the progressive organization of the tonus of the skeletal muscular system." These components of the body are a critical foundation for the development of vision and visual processing. Toddlers should have better visual skills than infants because they

have more experience with body control and how to move in space. The intimate relationship between vision and motor development suggests that you cannot fully understand the development of either without reference to the other.

When evaluating an infant it is important to keep in perspective where their visual space world is and how it is related to their development. The visual world of an infant develops from near (6 to 9") to far. In contrast, the toddler visual system has generally developed the ability to move freely inward and outward in space. This suggests that a routine distance refraction of an infant has little to do with their spatial reality. The distance refraction of a toddler whom has expanded their visual world outward should be interpreted differently than for an infant. When evaluating infants we should rely more on near retinoscopy which is performed within their spatial world. This can be done with the spot retinoscope and can incorporate observations over time and at different distances. As you probe along the z-axis of an infant, many different responses can be observed. These will be discussed later in the paper. This approach is different than obtaining a refractive measurement at one distance and time as is done with an autorefractor or photorefractor. As an adult, we rarely make a conscious note of our visual space as we freely move within our environment. To an infant, the exploration of space from near to far is perhaps one of the most important considerations required for development.

Another significant difference is the development of speech. A five year old can generally provide consistent verbal feedback during an evaluation. Infants cannot respond similarly and we must rely on more objective evaluation techniques. These observational skills can provide us with some of the most important pieces of information we glean from our visual examination<sup>7</sup> and should be considered as an essential part of the evaluation of infants.

In addition, infants exhibit a higher rate of change and experimentation than older children.<sup>8</sup> This is an important consideration while looking at the qualitative or quantitative findings during an infant evaluation. Quantitative information is important in that it allows us to know where the infant is with respect to a particular moment. We can compare this information over time to evaluate the developmental changes occurring within the infant. This information can be limiting because it is static in nature. The challenge is that many measurements are constantly changing and may be different from moment to moment. Evaluation using only quantitative information limits our assessment of an infant's development. Qualitative information is generally considered to be more dynamic than

quantitative information. How an infant does something or what process they go through can be more important in the assessment of visual development and unmet visual needs. Quantitative and qualitative information should be combined to accurately assess and understand visual development and how it affects the development of an infant.

### **What are the important aspects of the infant's developing visual world?**

Vision and motor are often discussed as two separate processes. One can ask if it is possible to have vision without a motor component. Streff<sup>9</sup> has used the research of Gesell to support his statement that, "Vision is Motor." If we look at how the infant uses vision and motor we can expand our assessment into the processes of reach, grasp, manipulate and release. Most of us have observed young infants reaching for an object and grasping it with their hand. Also observed is the corresponding difficulty in initially releasing their grasp. These processes can provide information on how the infant can visually reach, grasp and release. Vision and motor are important to the development of infants as they grasp their physical world visually long before they grasp it manually.<sup>10</sup>

As an infant begins to understand their world, they do so through a process that is always relative to time and space.<sup>8</sup> We should include qualitative information that is collected through observation over time. The visual development of an infant should be evaluated with reference to general child development. Gesell<sup>10</sup> clearly supported this while describing the difference between eye and vision in his statement, "Vision is not a separate, isolated function; it is profoundly integrated with the total action system of the child—his posture, his manual skills and motor sets, intelligence and personality make-up." This may be even more important in those infants who are premature or developmentally delayed and for those placed into activities and demands that are not developmentally appropriate.

### **Schema and frameworks for evaluating infants**

Through each of our own didactic and clinical experiences, we are able to evaluate different levels of performance while observing a patient. Our observations change as the infant continues to grow and develop their skills and abilities. The following framework can be used to evaluate infants based upon the observations of visual and infant development. In order to develop this framework, we should begin with a definition of vision. One such definition is: "Vision is the deriving of meaning and directing of action within a spatial-temporal based world."<sup>11</sup> This definition relates to observations of performance and includes aspects of the sensorimotor

system as they are related to the dynamic and static processes noted. These sensorimotor aspects include:

- Tactual (information from touch)
- Motor (information from proprioception and kinesthesia)
- Vestibular (linear and angular information)
- Audition (information from hearing)
- Visual (information from the visual process)

These systems all have reciprocal relationships with each other. A clinical example is that a patient may report diplopia at near. If the patient touches the object of regard it may then be seen as one. An explanation for this phenomenon is that the arm has provided information on localization of the target through proprioception (joint and muscle information) and kinesthesia (location of body in space based upon movement). The patient has used the reciprocal relationship of vision with proprioception and kinesthesia to match the localization in physical space. A second factor is that when the hand is involved with a task the amount of attention placed upon task increases. A third factor is that the perceived target may be relatively larger and thus easier to fuse (i.e., the hand and bead together appear larger than the bead by itself). The auditory spatial world is also reciprocally linked. The auditory system is quite similar to vision because it also has parvocellular and magnocellular pathways that provide different aspects necessary for efficient processing of sensory input. The use of auditory localization is related to visual localization.

These sensorimotor systems provide considerable information other than stimulus and response. Traditionally the vestibular system has been recognized as providing information about linear and angular head movement but is also involved in attention and arousal. In addition it provides a stimulus for motor tone<sup>12</sup>. This tone can be described as high versus low, stable vs. variable and whether it is consistent enough to maintain posture.<sup>12,13</sup> The vestibular system is the first sensory system to become fully myelinated and is considered to be the basic foundational input for sensorimotor processing. The sensorimotor system provides information about body awareness based upon the ability to discriminate and isolate body parts. This motor information is related to associated movements and actions. These all have important contributions in the evaluation of an infant's orientation of body in space.

The knowledge of an infant's orientation is vital for visual development. The term orientation is used in relation to Kraskin's description of the three fundamental abilities needed to learn the construct of space and time (see Diagram 1).<sup>11,14</sup> The orientation of one's self requires you to be in balance with gravity. Balance can

have both static and dynamic components. Dynamic balance is classified as the infant in motion and static balance as the action of not moving.<sup>15</sup> An infant lying on their back may be considered to be in balance with gravity versus being in a supported sitting position from which they would otherwise fall over. In the supine position the infant is in a better position to compute space and learn about localization through their movement patterns. Early development from this position includes the control of their head against gravity. Furthermore, a mobile placed within grasp provides the infant with an opportunity to actively explore localization. This allows the infant to confirm what they have located through visual and manual localization. This ability to orientate and localize is the basis for further manipulation of the movement patterns of centering and identification. These abilities should not be discussed in isolation, but rather in relation to each other. A clinical example is that if the infant has not developed an appropriate awareness of orientation, they may not localize targets accurately or consistently. This can result in a mismatch of visual, vestibular and motor input. The visual confusion from these adaptations may further lead to the development of other visual conditions.

Gesell<sup>6,10</sup> spoke of the functional complex of the visual system as including three basic functional fields: skeletal, visceral and cortical. These are related to the conventional fixation-focus-fusion triad of vision. The skeletal component seeks and holds a visual image (fixation); the visceral component discriminates and defines the image; and the cortical unifies and interprets it. These functional skills develop jointly but not uniformly. These can be discussed in relation to two visual models. The optical model primarily would use the skeletal and would emphasize reach, grasp and release. The reach includes the ocular alignment to the target (vergence), the grasp would be the relative movement of optics for the distance (accommodation) and the release would be the change in fixation or attention. The developmental model includes the skeletal, visceral and cortical areas. This would allow for the reach, grasp, *manipulate* and release of the object of regard. Manipulation must first have attention and arousal as its basis. From this the infant uses their attitudes and actions to change their projection of or to physically handle the target of regard. By evaluating the infant from a developmental model one includes the use of the optical model. The key extension is into how the infant interacts and manipulates their developing visual

<b>Diagram 1</b>		
<b>Three Fundamental Abilities Needed to Learn the Construct of Space and Time</b>		
<b>Information Processing</b>	<b>Movement Patterns</b>	<b>Fundamental abilities</b>
Balance with gravity	Orientation	Freedom or basis to compute
Balance with task	Localization	Range to compute
Manipulation of the task	Centering/Identification	Facility to compute

world. This is where many visual adaptations may originate.

Another aspect of evaluating infants we should consider is from Robert Pepper<sup>16</sup> who describes the levels of visual performance in regards to meaningful movement. He asks five questions which form the foundation for his testing and training. One can easily apply these principles to the evaluation of infants:

1. Can I do it? (can you fixate a target)
2. How well can I do it? (do you lose localization easily)
3. How long can I do it? (can you maintain fixation long enough to learn something)
4. Can I accept change? (can you maintain fixation while transitioning between postures)
5. Can I problem solve? (if you lose fixation, can you figure out what to do to recover it)

These relate to the observations of the infant as they are interacting during your visual examination. They are not simply quantitative findings, but rather qualitative aspects from which you can base your observations of visual development. This is by no means an exhaustive or definitive list, but some simple concepts to consider in an evaluation.

### **Examination procedures**

The examination of infants is a very rewarding aspect of one's practice. A fundamental point is while examining infants we must keep in mind that what we are observing is an external representation of the internal world of the infant.<sup>17</sup> The observations we make of infants are based upon what they have already learned from previous experiences. It also includes our interpretation of how they may be responding and adapting to the demands of their current environment.

### **Case history**

The case history of the infant is one of the most important aspects of a visual evaluation. It can provide you with the information you need to formulate the sequence of your examination. One way to collect developmental data is to have the parents fill out a questionnaire prior to the evaluation. This can be mailed to the caregivers when the appointment is made and then brought to the examination. This questionnaire is only the beginning of the history as the parental responses should be further discussed and elaborated upon prior to examining the infant. The history should not end here as

during your examination, observations may lead to more questions. (Please see an example in Appendix A from *Infant Vision Shorts*.<sup>18</sup>)

The prenatal care and development of the infant and the mother's behaviors from conception onward can be critical to assessing and determining a proper guidance and treatment plan. If the mother was bed ridden it is more likely that the fetus will be born with a very low birth weight (<1500 g).<sup>19</sup> This may be for a variety of reasons including the lack of vestibular stimulation and long periods without arousal from normal movement. This can suggest a possible developmental delay as the child is born preterm. The diet and nutritional intake of the mother (during pregnancy and breast feeding) should be reviewed as it is critical for the infant to obtain the necessary nutrients for appropriate development. Alcohol and drug usage should also be noted as to their negative effects upon fetal and infant development.<sup>20</sup>

The birth process itself is a traumatic event. Natural child birth is usually considered to be the best approach for being born. Premature infants are often taken by caesarean section because of the concern of the ability of the immature infant to endure the trauma of going down the birth canal. There has been an increase in the number of caesarean births and this is often discussed in relation to the increased demands of schedules of both mother and doctor. A normal vaginal birth has several advantages. One of which is that the chest is compressed during birth and fluid is squeezed from the chest. In a caesarean the fluid must be suctioned out. Other advantages include faster recovery, shorter hospital stays and easier breastfeeding.

Cranial-sacral therapists and cranial osteopathic physicians often consider going down the birth canal as the first cranial-sacral treatment and suggest that a baby born by cesarean section be referred for assessment of their cranial rhythm.<sup>21</sup> Similarly, a long and extended labor with a corresponding head malformation may also suggest concerns with the normal cranial rhythm. The infant's heart and blood pressure findings during the birth process are helpful in evaluating cases of anoxia and the APGAR scores may give you an indication of how healthy the infant was at birth.

The postnatal history should include information on ear infections, use of antibiotics, immunization schedule, trauma, allergies, and breast vs. formula feeding as they can have an impact upon development of the infant. How the mother calms her infant may also have an effect upon visual development. In infants less than one year it is common that mothers rock their babies up and down regularly to help calm them. This vestibular movement may be one of the reasons why very little vertical strabismus is noted in young infants. The rocking may

provide a balanced input of vestibular induced tone to the extraocular muscles involved with the vertical control of alignment.<sup>22</sup>

### **General considerations of the infant evaluation**

There are many aspects to consider while evaluating an infant versus older children. The development of the visual system is quite different between a 3-4 week newborn and a 12 month old. In the first year of life three major changes should be considered:<sup>8</sup>

- 1- Newborns generally are not visually alert. Around 3 months there appears to be a major increase in visual alertness.
- 2- Improvement in accuracy of reach, grasp and manipulation with hands at about 4 months coincides with the onset of stereopsis.
- 3- The onset of crawling and walking provides experiences with objects outside of the normal hand reach. This creates a need to see beyond arms length and further extends their space world outward.

The appropriate time to examine an infant is when they are awake and alert.<sup>23</sup> The timing of the evaluation is critical and generally should not be scheduled during the infant's normal naptime. If you examine an infant and are told that their eye turns in when tired, it may be beneficial to see them just before naptime or at the end of a long day. This may give you a better opportunity to confirm the visual findings and make appropriate clinical decisions. The time of day may even be more critical in the case of developmentally delayed or medically unstable children who may only have brief times of arousal throughout the day. The previous events of the day can also lead to further scheduling considerations. An example would be having vaccinations in the morning or a sleep pattern change secondary to unforeseen circumstances. These are factors that could change the outcome of a visual evaluation.

It is important to listen to parents as they are the main caretakers and generally know their child better than anyone else. If a parent states they have seen an eye turn in and you can't elicit one, respect their comments until a more definitive determination can be made. An example would be the observation of epicanthal folds that would lead to a diagnosis of pseudoesotropia. You may still not have a basis for their observations if an intermittent esotropic infant happens to come in on a day in which they are fully alert and are doing well. If an examination is incomplete or if concerns are still present following the initial assessment, it may be necessary to have the infant return for further evaluation.

### **Motor evaluation**

This topic is included because it can be vital to the evaluation of an infant's visual development.

Developmental milestones are often used to determine where the infant is relative to their developmental timeline. It is important to keep in mind that the sequence of motor development is likely more important than where they are on the timeline. When one speaks of the sequence they are generally looking at the infant more holistically and thus each aspect is relative to the other. This is an important concept in respect to the development of reciprocal interweaving as described by Gesell.<sup>6</sup>



Figure 1. Head control at 2.5 months, note head lag.



Figure 2. Head control at 10 months is well developed and sustained

Likewise, if one speaks of where the infant is along the developmental timeline, it is only relative to what is normal for that skill. This does not allow for the opportunity to observe it relative to other skills and the development of reciprocal interweaving. Another critical observation is how they perform these milestones and the relationship to the needs and demands that are placed upon the visual system. The basic milestones can be further evaluated by observing the quality of how they transition from one posture to another. An example would be how they transition from prone to sitting. Is the transition smooth, do they need more work at it or can they transition at all? A useful tool for helping parents to become better observers of motor development is “My Motor Baby” by Olsen- Puttkammer (see Resources). It covers birth to 18 months and can be filled out and updated for follow-up visits. The following list includes the primary motor milestones used to evaluate the development (for normative data see Appendix B):

1. Positional or Static Posture

- Prone
- Supine
- Sidelying (aided/unaided)
- Quadruped (aided/unaided)
- Sitting (aided/unaided)
- Standing (aided/unaided)

2. Locomotion or Dynamic Posture

- Rolling
- Crawling
- Creeping
- Sitting
- Pull to Stand and Cruising
- Walking

3. Reaching

- Reach, Grasp, Manipulate and Release (random to voluntary, unilateral to bilateral)

During an infant evaluation it is important to observe the head and trunk as related to visual control. This can lead to postural positioning that is developmentally

appropriate and also recommendations for developmental guidance. Infants are commonly held or positioned by their caregiver while being examined. It can be beneficial to observe and examine the infant on the floor versus being held by their parent. The visual performance of an infant may be different in a supported vs. unsupported position. If an infant is putting effort into maintaining balance, an esotropia may be revealed that otherwise may not be noticed. Difficulty in transitioning from one posture to another may also be reflected in differences during retinoscopy. If there are developmental issues a wheelchair or other supporting device may be part of the infant’s daily life. It may also be beneficial to observe and evaluate the infant using them.

Another consideration is the principle of lower development which may lead you to other probes. An example would be an infant who has just learned to sit in a straight leg position. The infant may be sitting with their legs out and when they try to reach for a target they may not be able to hold their posture. They will often go from the straight leg position into a “W” sitting position in which their knees are forward and feet positioned backward. This lower level position is not one that should be allowed to develop as it requires less trunk tone to hold the body upright and can lead to other developmental issues. Generally the use of this position is short lived while the infant is expanding their operational range. Once the infant learns to reach from the “W” sitting position, they generally continue development by integrating reaching into the straight leg position. This principle can be applied while observing the development of many aspects of motor and vision.

There are some indications that newborns can crudely direct their hands toward targets of interest, but these movements are not sufficiently reliable for measuring a response. It is suggested that by 4 months infants can visually direct their arm movements. These movements are initially made with a number of smaller

corrective steps. Generally by 18 months the reach is consistently made in a single, ballistic action. The reach can also be evaluated with the aspects of grasp, manipulate and release.<sup>8</sup> Retinoscopy can be done simultaneously which will allow you to further evaluate how the child is performing. While reaching, changes in retinoscopic patterns, brightness and color may be observed with the spot retinoscope.

If there is difficulty in any of the areas of motor development an appropriate referral should be considered to a sensory integration or NDT (Bobath Neuro- developmental Treatment) trained occupational or physical therapist. Another consideration of this evaluation is for the optometrist to evaluate the primitive reflexes. These reflexes are critically important in the development of the interrelationships of the brainstem, cortex and cerebellum. Reflexes have an impact on the development of all systems and the integration of senses.<sup>24</sup> These reflexes can have a profound effect upon the development of visual-motor, ocular-motor, accommodation, visual memory and crossing the midline. (Further information about these reflexes can be found in a DVD that is available from Dr. Sam Berne.<sup>25</sup>)

### **Ocular motilities**

The testing of ocular motilities is critical to evaluating an infant. It not only provides information regarding the integrity of the visual pathways but can also provide indications of how visual development is proceeding. Fixation (position maintenance) is sometimes considered a special type of pursuit. It is more than the inhibition of movement and thus should be considered an eye movement itself.<sup>26</sup> Pursuits, saccades, optokinetic nystagmus and the vestibular ocular reflex are the other important eye movements that should be evaluated in infants. The target demands should be appropriate for the infant as different responses may occur with larger (face) versus smaller (bead) targets. The time allowed for response is also an important consideration in newborns. It is common to observe a significant time delay in response to stimuli as compared to a toddler. Another important consideration of testing is that visual fields in the newborn are relatively small and develop outward with age. This can affect the evaluation of pursuit and saccadic eye movements. Differences should also be noted between monocular and binocular abilities. Postural and motor control should always be observed during the ocular motor evaluation. This is important because infants are beginning to learn to differentiate head and eye movements from the rest of the body.

Fixation is evaluated as to whether it is central, steady and/or nystagmoid. It is also beneficial to know how long an infant can hold fixation and how well they refixate onto targets after they have lost them. Fixations can also be different when infants are in different body postures, especially if support against gravity is needed. Another consideration is that infants are often moved through space. With any linear or angular head movement we can evaluate the quality of fixation and the time to refixate a target. This is helpful in evaluating visual development as fixation during the first year develops primarily from a motor to a sensory response.<sup>27</sup> This is secondary to changes occurring in the vestibular ocular reflex and the maturation of the fovea.

Infants generally demonstrate some pursuit movements by about 2 months of age.<sup>28</sup> Movements earlier than this are generally more saccadic like. However, some controversy exists as the lack of pursuits earlier could be dependent upon factors such as the stimulus movement chosen and the attentional or sensory factors regarding target visibility.<sup>29,30</sup> The range of movement should be evaluated because a common finding of infantile esotropia is decreased abduction. This can lead into the development of a cross fixation pattern as the infant learns to substitute this for the inability to abduct. Any abduction deficit noted should be tested with a doll's eye movement to determine if a true abduction deficit is present or only a volitional one. This is important to note as it can be a key factor in the diagnosis and treatment of infantile esotropia.

Saccades are movements between two objects and can be affected by many factors. The ability of the infant to develop adult like saccades generally occurs during the first two months and can be evaluated by assessing accuracy and latency. Infants are considerably less accurate with their initial saccades as they tend to undershoot.<sup>31</sup> This is generally followed by a series of shorter saccades. Each shorter saccade places the infant's eyes closer to the target as they develop accuracy. Toddlers on the other hand generally make a more accurate saccade followed by a small corrective one if needed. The saccadic latency of infants is also slow in comparison to older children and therefore one must allow for more response time during testing.

The vestibuloocular reflex (VOR) appears to play several important roles in the infant. The motor component is a major contributor to keeping the eyes aligned early in development and the monocular suppression of the VOR is an indicator of binocular development. The VOR is important because it decreases the image blur secondary to any head movement. The compensatory eye movement is opposite in direction to the head so that the image is partially stabilized. The



Figure 3. OKN at 2.5 months. Nasal to temporal emerging, temporal to nasal was already well established.

VOR has a gain of 1.0 from birth to 4 months and does not reach an adult-like status of 0.6 until about 5 years of age. Rethy has suggested that the motor system keeps the infants eyes aligned as the sensory system develops.<sup>27</sup> This is probably done early by the VOR and the gain of 1.0 corresponds to the motor component necessary to align both eyes on a reflex basis secondary to any head movement. As the VOR gain lessens with age, the sensory system must intercede and modulate information so that alignment can be maintained. The monocular VOR suppression usually appears at about 3-6 months and is firmly established by 6-9 months.<sup>32</sup> This corresponds to the time onset of stereo and binocular development. Flynn found that early onset strabismics(2-12 months) demonstrate an inability to suppress the VOR.<sup>32</sup> This may be used as a supplemental test to evaluate the quality of early binocular development. When testing young infants a mirror can be used to directly assess the ability to suppress the VOR.

Optokinetic nystagmus(OKN) testing with infants has traditionally been used as an indirect way of assessing visual acuity. This testing may be more important when considering the development of binocularity and strabismus in infants. Tychsen has suggested that motion differences play a critical role in the development of infantile esotropia<sup>33</sup> (see Diagram 2). The temporal to nasal monocular OKN is normally elicited at birth. The nasal to temporal OKN is usually first elicited at about 2-3 months of age but is still asymmetric versus temporal to nasal. Symmetry doesn't usually become established until about 9 months. OKN development is related to the window of binocular and stereo development from 3-5 months. The biased development of OKN motion in the temporal to nasal direction can lead to the manifestation of ocular motor findings that typify infantile strabismus.<sup>31</sup> An infant with a none to weak OKN response in the nasal to temporal

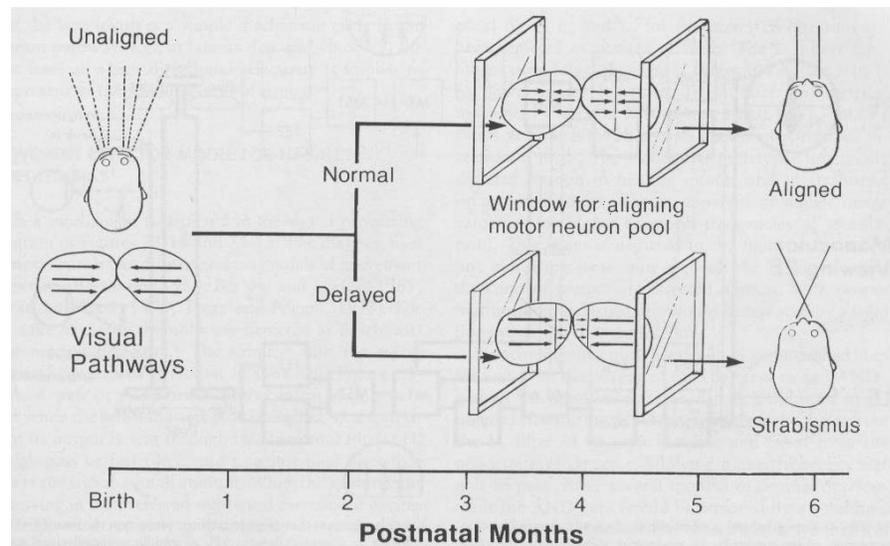


Diagram 2. Development of monocular OKN and stereopsis. Reprinted with permission of author.<sup>33</sup>

direction should be watched carefully. They would likely benefit from an appropriate visual guidance program with the goal being to improve the balance of motion asymmetry and to prevent the esotropia from becoming established. This temporal to nasal balance may also be intimately related to an abduction deficit and a cross fixation pattern.

### Visual acuity

One of the most common questions asked by parents is, "Does my baby see?" The answer to this question is influenced by a number of factors including: optical properties, changes in accommodation, differentiation of the retina and visual pathways, myelination and increased cortical connections.<sup>8</sup> Visual acuity should be assessed to determine that normal and symmetrical development is occurring. Four methods include the use of fix-follow-maintain with a transilluminator or toy, optokinetic nystagmus, preferential looking and electrodiagnostic testing. With the onset of new tests, preferential techniques may provide some of the best diagnostic information with an economical cost factor.

The use of a transilluminator and/or toy to investigate differences in visual acuity of infants should be used with caution, especially in isolation. It has been suggested that fix-follow-maintain<sup>34</sup> and resistance to occlusion<sup>35</sup> are not strong tests when used in isolation to evaluate the interocular differences in visual acuity. When used with retinoscopy and other functional testing procedures they can still be a valuable probe.

The optokinetic drum has been used to assess visual acuity but is subject to errors because adult OKN is related more to the cortical pathways whereas early infant OKN appears to be generated primarily by the indirect subcortical pathway.<sup>36</sup> Interpretation is

additionally complicated as the development of OKN is dependent upon the maturation of other visual functions (ie-visual acuity, contrast sensitivity, velocity sensitivity, direction of selectivity of target motion and the development of the visual field). With these considerations, the validity of the OKN to evaluate visual acuity in birth to 6-7 month old infants may be questionable.

Forced choice preferential looking techniques have become more commercially available and this may further support their use as the standard for assessment of infant visual acuity. The most common test is the Teller Acuity Cards which have been widely researched and norms have been published.<sup>37,38</sup> Teller II cards have become commercially available and are an improvement over the initial cards because they are printed digitally and are laminated to increase durability. There are also several other infant visual acuity/contrast sensitivity tests commercially available including: Face Dot Paddles, Patti Stripes Square Wave Grating Paddles and Cardiff Cards (see Resources). An advantage of the Teller cards is that your face (an excellent high interest target for infants) is eliminated as you look through the peep hole. The other paddles/cards mentioned here allow your face to be exposed and this can interfere with testing.



Figure 4. Teller acuity cards at 2.5 months.

larger university facilities where infant research is being done. The VEP is measured as an electrical signal that is generated in the occipital region of the cortex following the presentation of a visual stimulation. It is measured with reference to amplitude and latency of response and can be helpful in evaluating certain visual conditions including amblyopia.

### Retinoscopy and refractive status

The discussion of refracting infants should include a number of important considerations. Initially one must reconcile that this is not a stable finding and thus the term 'status' may be more appropriate versus 'error.' It is also dependent upon a number of factors. They include the

methods and conditions used (including cycloplegia vs. non-cycloplegia), the attentional level of the infant, the postural needs and positioning of the infant, the type of retinoscope used, the ability of the infant to accommodate and/or to project into space, and many others. From a developmental perspective we should not be overly concerned about the specific quantitative number found that neutralizes the retinoscopic reflex. Our concern should be what retinoscopy may indicate regarding any unmet visual needs that can be addressed with the use of guidance, lenses and/or therapy. The chief concern for an otherwise healthy infant is whether or not they can extend their localized visual contact outward and increase their quality of contact.

There are many different ways to evaluate the refractive status of infants with advantages and disadvantages to each. The appropriate technique and application of concepts depends upon what you are trying to determine. The traditional method to rule out significant anisometropia and/or ametropia is to guide them to look at far point so that their attention is being extended outward while being scoped as an adult. A consideration should be made as to whether this is relevant to the young infant's visual world that is generally considered to be inside of 20 inches. An assumption when using this data is that infants and adults maintain the same visual world and have had the same visual experiences. A critical difference is that adults have gone out and experienced the world and freely move in and outwardly in space. In contrast, the infant may not be able crawl out to the toy across the room for another month or two and thus have no physical confirmation regarding what the physical distance really is. The infant's world beyond their reach may be considered as only virtual. Thus the measurement of a distance refraction may not be comparable to that of an adult.

A second method is known as the Mohindra technique.<sup>39</sup> It is done monocularly at 50 cm with the assumption that the eye reverts to a resting state of refraction in the dark, often slightly myopic. A  $-0.75$  to  $-1.25$  is added to the measured amount to determine the refractive status which generally matches well to a cycloplegic refraction. One concern is that during the Mohindra technique the infant is not looking at a real world as done under normal lighting conditions. The advantage of this technique is that the reduced lighting removes visual distractions and no cycloplegia drops are needed.

The third method is known as photorefractometry and requires little expertise to administer. Photorefractometry can detect as little as  $.50$  diopters of ametropia and can provide you with a permanent record.<sup>40</sup> The procedure

does not have the ability to observe qualitative information over time so you cannot determine how long the infant makes visual contact or with what quality. There is a further concern because most of the working distances of these instruments are outside the experienced visual world of the younger infant. The main benefit is that it can readily be used as a screening tool.

The fourth method emphasized by Streff is to use a spot retinoscope and observe the infant while scoping at several different distances with lenses as probes. The spot provides several advantages over a streak. It is much easier to observe the simultaneous processing versus scoping different meridians in a sequential manner over time. In addition, the qualitative aspects can be observed such as symmetry, brightness, color and the ability to reach, grasp, manipulate and release. The use of several working distances helps to evaluate where they are and how they deal with different distances in their visual world. If only one distance was used as in the Mohindra technique, you can ask how retinoscopy at this single distance might relate to the rest of the infants world. Similarly if you only had the distance refraction of an adult, would that give you any idea how they were doing at near? Having two pieces of information (scoping from different distances) allows one to determine how the two findings relate to each other and thus how the infant is dealing with space along the z-axis. This technique can be further extended to scoping under different postural demands. The following picture demonstrates what was found under crawling and creeping conditions. His retinoscopy revealed symmetrical brightness while sitting in his mothers lap, however they were asymmetric with the left dimmed when scoped while trying to crawl on all fours.

The prevalence of refractive error in young children is approximately 15-30% and often shows large fluctuations.<sup>23</sup> As you examine an infant the primary finding is variability. The infant may demonstrate myopia, then hyperopia and even astigmatism. At birth the average refraction found is around two diopters of hyperopia with mild astigmatism. Generally these findings will reduce as they approach the age of three. This is another good reason for the use of the term refractive status versus refractive error. There are many possible reasons for the refractive fluctuations. During the first 3 months head control is generally not developed and often researchers must hold the infants eyes open to be evaluated. Secondly, accommodation is still developing. The refractive measurement in adults is



*Figure 5. While crawling at 10 months, the left hand was held under his chest. This suggests that reciprocal interweaving is incomplete or underdeveloped.*



*Figure 6. Scoping while crawling at 10 months. The left eye is dim compared to the right. At 12 months he started incorporating his left hand and the retinoscopy simultaneously brightened..*

usually considered a static finding, however in infants it is as dynamic as their ability to learn how to move in and outward in space.

It is usually not necessary to perform cycloplegic retinoscopy on most infants if good results are obtained with either near or distance retinoscopy.<sup>20,37</sup> If you are unable to obtain a good result and want to cycloplege the infant you can consider using Tropicamide instead of cyclopentolate.<sup>41-43</sup> Anytime the use of cycloplegics is considered one should be judicious in their application. They should be used with caution in infants under 3 months of age. Infants with blond hair or blue eyes may be especially sensitive to the side effects of cycloplegia. Other medical issues may affect the use of cycloplegics including infants with brain damage, Down's syndrome and spastic paralysis. Another specific concern may be the medically fragile infant as cycloplegics and tropicamide include side effects such as tachycardia, dryness and flushing of the skin, ataxia, slurred speech, confusion, hallucinations and constipation.

#### **Qualitative aspects of retinoscopy**

One can look at retinoscopy outside the scope of measuring the refractive status and reflect on the ability of the infant to derive meaning and direct action. This can be done by evaluating the qualitative aspects of retinoscopy. It is most easily done using a spot retinoscope. The four main considerations are symmetry, motion, brightness and color. They can also be evaluated as to the distribution of light including central vs. peripheral and other meridional differences. These can all change as the infant reaches, grasps, manipulates and releases within their visual world.

Motion is usually observed as we move our beam across the pupil area. It is recommended that you first observe the reflex for a moment instead of immediately running your beam across the pupil while attempting to

neutralize the movement. This allows you to simultaneously observe changes in pattern, brightness and color. An emphasis should be placed upon equality of the two eyes and the differences in light distribution. As you start moving the beam across the pupil an advantage of the spot retinoscope is that you can simultaneously observe all meridians without having to rotate a streak. With a streak scope you may miss the variable meridional differences as you are rotating the sleeve. The infant is often seen with varying degrees of astigmatism both axis 90 and then axis 180 and vice versa. In general, minus axis 180 is observed when the infant is concerned with flat surfaces and horizontal play. When engaged in vertical play such as stacking blocks or scanning up and down minus axis 90 is found<sup>44</sup>. This has also been suggested to be part of the development of accommodation and why infants may demonstrate early changes in astigmatism. As the infant is moving up and down in their visual space the accommodative convergence mechanisms continue to develop more freedom of movement therefore providing the opportunity to move inward and outward in space.

Brightness should be observed as it is a strong indicator regarding the level of contact that the infant is making. In relatively more hyperopic conditions the reflex is brighter centrally with little in the periphery. Under myopic shifts in refraction the periphery becomes brighter with decreased central brightness and motion. If the brightness disappears it may be an indicator of losing contact with the object of regard or possibly adapting toward amblyopia.

The color of the reflex is another factor to observe.<sup>6</sup> Dull gray can be a shift toward early amblyopia. A dull red is considered to be low recognition or awareness. Bright pink means a higher recognition but may still be off from a spatial aspect. A dull pink is the first indication of good spatial judgment. White pink is a better quality, but still with some minute periodic refractory shifts. A white reflex indicates that we now have quality and consistency. It is interesting to observe the infant as they begin to fall asleep. Under this condition the reflex tends to dull and increase with motion. When observing motion, brightness and color you can also relate your observations to the reach, grasp, manipulate and release of objects both manually and ocularly.

Another consideration of retinoscopy is that there are four stages in the development of ocular fixation that can be observed with the retinoscope<sup>45</sup>. Stage one consists of random limited brightness of one eye or the other. Stage



Figure 7. Retinoscopy at 4 weeks while held by mother. Good alternating of brightness.



Figure 8. Retinoscopy at 4 weeks while sidelying. The alternating of brightness was asymmetrical and this may be due to postural instability.

two consists of a definite right or left stage in which one eye will be bright with the other dim. The infant may use their right eye when visually reaching to their right and vice versa. During this period some of the earliest eye hand combinations are observed with the retinoscope. Stage three consists of some overlapping or intermittent bilateral moments of processing. This can be described as the right and left stage and there may be an increase in head movement. The infant may seem to use a more directed head shift to assist an eye to get into the teaming act with the other. Stage four is considered the bilateral or bi-ocular stage. This is described as the right-left stage because they have learned to put the two eyes together into action as a unit. Anything less than stage four at 8 months may be an indicator of a lag of bilateral and binocular processing. Observing the qualitative aspects of retinoscopy can be useful in determining the ability to derive meaning and direct action. This is probably more important to the developing infant than the quantitative measurement of the refractive status.

### Accommodation

The development of accommodation should be included while discussing the refractive status of infants. Haynes<sup>46</sup> and Haynes, White and Held<sup>47</sup> found that the reflex for near begins to shift within the first weeks of life. It is commonly observed that an early infant's visual contact range is from 6 to 9 inches corresponding to the distance of their mother's face. By the age of 16 weeks researchers had found that the infants were able to move outward to 25 inches. This has led to the statement that infants can accurately accommodate by this age. Another explanation is that this is a relative change in the projection of space. Infants may initially be able to see things as if projected from a different distance (observed as smaller or larger). More recent literature suggests that accommodation continues to develop in accuracy up to 6 months.<sup>48</sup>

It is apparent that accommodation or relative accommodation is present during the first year of life and

that accommodation should be evaluated during an infant examination. This can be done with a retinoscope and lenses and/or by observing changes while shifting your working distance. The onset of accommodative esotropia is usually not present until about 2-3 years of life but the evaluation of an accommodative component in infant esotropes should always be considered.<sup>49</sup>

### **Binocularity and stereopsis**

Binocular fixation can be termed the union of sensory and motor inputs. Rethy<sup>27</sup> pointed out that early alignment of the infant was mainly motor driven and became less so as the sensory system developed. The early alignment of infants can be considered uncoordinated with coordination developing during the first year. This is one reason why many infants seen during the first months of life demonstrate periods of misalignment. A common controversy occurs when we ask if infantile esotropes are esotropic at birth or do they develop esotropia. Several studies have found that infants tend to be exotropic and orthotropic at birth.<sup>50,51</sup> Very few were actually seen to demonstrate esotropia at birth. These early esotropic cases actually recovered binocularity and the only cases that developed into infantile esotropia were initially exotropic at birth. The finding that esotropia develops and is not present at birth has been used to classify these cases as infantile esotropia versus congenital esotropia. This suggests that the visual system of the newborn tends to be developmentally incomplete. The reason for the development of the esotropia is beyond the scope of this paper, however many possible factors can interplay. One important consideration is the infant's arousal state which varies considerably throughout the day. When it is low they tend to hold their normal resting state similarly to that of our neurophysiological rest point during sleep (disengaged and outward). As the infant develops they appear to increase the amount of time in a higher arousal state and become more actively engaged in their visual world. The development of this engagement may be considered with reference to reach, grasp and release. An infant does not have the smooth and accurate control of an adult. The initial learning of reach and grasp for a target is done in an all or none fashion and without gradation of movement. If the grasp is locked too long, the difficulty of release may lead to an intermittent eye turn. This eye turn may eventually become more habitually present and the establishment esotropia has begun.

The classification of infantile strabismus includes direction or type (eso, exo, hyper and cyclo), laterality (unilateral or bilateral), magnitude, comitancy and the state of fusion or frequency (manifest, intermittent, latent, percentage of time strabismic). Further

questioning should be made as to the development of the strabismus. How did it develop, what were the time frames, under what conditions did it initially present, did it ever seem to be intermittent and was there anything they initially did that seemed to make it go away.

An evaluation should include both motor and sensory components. The motor component can be evaluated using the Hirschberg Test or Krimsky Test. Most adults will demonstrate a small positive angle kappa but infants will commonly demonstrate a negative angle kappa. This negative angle kappa tends to simulate an esotropia but can also hide an exotropia. One drawback of this test is that it is not sensitive enough to pick up large phorias or a small angle tropia.<sup>52</sup> A cover test using your thumb is generally adequate to observe the phorias and/or small angle tropia. It is common to use fixation targets such as smaller toys with both auditory and visual interest. You can also use one of the most interesting targets for an infant which is your own face. If you observe the infant with multiple size targets, you may obtain some insight on how size of the field affects the infant's visual abilities. Convergence should be evaluated and it begins commonly around 3 months of age.<sup>53</sup> It should be noted that this motor development precedes the shifting of visual attention (i.e., from near to far) which appears around 6 months. In contrast, the shifting of attention laterally begins in the first few months of life.<sup>8</sup>

Coarse stereopsis of about 30-60 minutes has been seen as early as two months, but most infants show an abrupt onset of stereopsis at 3-5 months of age.<sup>54</sup> The use of Polaroid glasses with stereopsis testing can be a challenge with infants. The advent of the Stereo Smile Test<sup>55</sup> has been useful but also requires glasses. A stereo test that does not require polaroid glasses is the Lang Stereo Test.

### **Visual fields**

The peripheral vision of infants should be evaluated for

several reasons. First, many of the visual acuity tests are based on a preferential looking paradigm in which infants detect eccentrically located stimuli. Another concern is the development of the parvocellular and magnocellular pathways and their influence on the development of strabismus. It would be important to



*Figure 9. Positive Lang stereo response with reach at 10 months.*

know that the performance on preferential looking was due to an underdeveloped visual field versus poor visual acuity. The smaller visual field could also place an infant at a higher risk for the development of strabismus. The visual fields of infants have been studied using both static and kinetic behavioral perimetry. The mean binocular hemifield of a newborn has been found to be 17-34 degrees, a 3 month old 40-50 degrees and at 12-24 months becomes adult-like using 6 degree targets. The visual world of an infant is developed and likewise the ability to deal with stress is also learned. Shipman stated, "Stress causes a constriction of the perceptual fields so the person observes less, sees less, remembers less, learns less and becomes generally less efficient."<sup>56</sup> Psychological stress can also predispose, precipitate or perpetuate strabismus and amblyopia.<sup>57</sup> Thus the relationship of visual fields, stress and strabismus may play an important factor in the early development of infantile esotropia. This is an important factor because the visual fields of infants provide feedback for alignment and are relatively small in comparison to toddlers.

### Ocular health

A comprehensive ocular and visual health evaluation should be performed upon all infants. This should include evaluation of the anterior and posterior segments. Anterior segment evaluations can be done with a Burton lamp, hand held slit lamp or a bluminator. It is generally considered important to complete a dilated fundus examination on all children at their first examination.<sup>20</sup> With infants this must be evaluated as to the possible side effects and cost benefit ratio. Tonometry may be done with a handheld Goldmann, portable non-contact tonometer or Tonopen.

### Summary

This article is an overview of some of the quantitative and qualitative factors that should be addressed in a developmental visual evaluation of the infant. It includes representative tests from each area evaluated and each individual Optometrist must determine what tests and special techniques to use while examining an infant. If one examines an infant using only quantitative information, you may be missing observations that could otherwise lead you to the unmet visual needs of the infant. The qualitative information is generally based on a holistic evaluation of the infant's visual development. This will also provide you with a framework and schema that can help you put together a guidance and treatment plan for the benefit of the infant. With this in mind we can provide excellence in the developmental visual care of infants if we:

1. Care more than others think is wise.

2. Demonstrate patience more than others think is practical.
3. Expect more than others think is possible.

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## APPENDIX A-Infant History

### DEVELOPMENTAL HISTORY OF INFANT

#### Considerations of Mother:

Pregnancy: Full Term  Premature  Comment \_\_\_\_\_  
 Was Mother: Active  Quiet  Require Bed Rest  Other \_\_\_\_\_  
 Health: High Blood Pressure  Diabetes  Other \_\_\_\_\_  
 Medications: Prenatal  Postnatal  Comments \_\_\_\_\_  
 Did Mother Use: Alcohol  Smoke  Illicit Drug  Comments \_\_\_\_\_  
 Prenatal Nutrition: Adequate  Limited  Prenatal Vitamins   
 Comments \_\_\_\_\_

#### Birth:

Type: Forceps  Breech  Caesarean  Natural  Other \_\_\_\_\_  
 Did Infant: Cry Immediately  Have Good Color   
 Any Concerns During Birth? (oxygen deprived, seizures, etc.) \_\_\_\_\_

#### Considerations of Infant:

In Utero, Was Infant: Active  Passive  Comment \_\_\_\_\_  
 Since Birth, Is Infant: Active  Passive  Comment \_\_\_\_\_  
 Is Infant: Nursing  Formula  Poor Sucking  Abnormal Cry   
 Sleep: Regular  Irregular  Comment \_\_\_\_\_  
 Health: Jaundice  Ear Infections  Frequently Sick   
 Other Health Comments: \_\_\_\_\_  
 Temperament: \_\_\_\_\_

Movement:	Age	Early	Average	Late	Comment
Rolling:	_____	_____	_____	_____	_____
Sit alone:	_____	_____	_____	_____	_____
Crawling:	_____	_____	_____	_____	_____
Stand alone:	_____	_____	_____	_____	_____
Walk alone:	_____	_____	_____	_____	_____

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### Resources

Motor Development Chart-"My Motor Baby"  
[www.mymotorbaby.com](http://www.mymotorbaby.com)  
 Optokinetic Drum-pediatric and standard version, Bernell Optical  
 1-800-348-2225  
 Visual Acuity Tests  
 Cardiff Cards-LogMAR picture display test  
[www.keeler.co.uk/practessen/childrensighttests.htm](http://www.keeler.co.uk/practessen/childrensighttests.htm)  
 Face Dot Paddles-CSF using a forced choice testing procedure, 20/25 to 20/200 range.  
 Bernell Optical 1-800-348-2225  
 Patti Stripes Square Wave Grating Paddles-20/36 to 20/4600 range  
[www.precision-vision.com](http://www.precision-vision.com)  
 Teller II Acuity Cards, Stereo Optical  
[www.stereooptical.com](http://www.stereooptical.com)

## Appendix B

Curtis R. Baxstrom, OD

### CONSIDERATIONS IN THE DEVELOPMENT OF VISION

KEY - \* date or range of age

#### AREA AGE(in months, prenatal to postnatal)

AREA	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	3YR	4YR	5YR	
Corneal Diameter																													
Corneal Power																													
Pupillary Distance																													
Retinal Periphery																													
Retinal Fovea																													
LGN																													
Visual Pathways																													
Myelination																													
Acuity(FPL)																													
Acuity(VEP)																													
CSF																													
Refractive Error																													
Astigmatism																													
Accommodation																													
Binnocularly																													
Stereopsis																													
Vergence																													
Fixation																													
OKN																													
VOR																													
Saccades- speed																													
latency																													
accuracy																													
Pursuits																													
Visual Field(binocular hemifield)																													
Strabismus Onset(Kraskin)																													

Other Considerations: orientation and motion selective mechanisms

0 1 2 3 4 5 6 7 8 B 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 3YR 4YR 5YR

