

## Essay

# Infant Vision Guidance: Fundamental Vision Development in Infancy

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### ABSTRACT

This paper reviews the general stages of infant vision development with specific emphasis on the environmental factors affecting the emergence of the basic vision functions (visual acuity, pursuits, saccades, binocularity, and visual perception). Vision guidance and optometric vision therapy activities are explained and demonstrated to educate and guide parents in playful interactions with their child. The activities are suited for the infant from birth to age three. The aim is to prevent vision abnormalities from developing by providing a comprehensive program of movement oriented vision stimulation.

### KEY WORDS

child development, fusion, guidance activities, perception, prevention, tracking, vision development, visual deprivation, visual stimulation, visual acuity



*Figure 1.*

### The importance of optometric vision therapy in infancy

It was Plato who said, “The beginning is half of the whole.” Parents embarking on the wondrous of all adventures, the launching of a totally new human being,

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Valenti C. Infant Vision Guidance: Fundamental Vision Development in Infancy. *Optom Vis Dev* 2006;37(3):147-155.

are the vital element in a child's beginning.<sup>1</sup> The National Research Council and Institute of Medicine<sup>2</sup> support this in their statement, “Parents and other regular caregivers in children's lives are ‘active ingredients’ of environmental influence during the early childhood period. Children grow and thrive in the context of close and dependable relationships that provide love and nurturance, security, responsive interaction, and encouragement for exploration. Without at least one such relationship, development is disrupted and the consequences can be severe and long lasting.” This is because they are primarily responsible for creating the environment that their child will see and participate in. Vision development begins in the womb, even before entering into a lighted world.

Even this early in fetal development, organs are developing and the dark pigment of the eyes can be seen. An abundance of studies commencing in the 1940's by developmental neuro-psychologists and developmental optometrists, as well as specialists in education and medicine, brought to our understanding the importance of the early years of life in the development of vision.<sup>3-7</sup>

A child is not born into the world with all of their vision skills in full operation. Rather, a child is born with the proper tools allowing their vision to interact with their environment in a meaningful way. It is the quality of this interaction that will ultimately determine the extent and ability of the child's vision development. We can simulate how the infant sees her mother's face over the course of the first year of life by taking a photograph and filtering the image according to the contrast sensitivity functions measured for the normal developing infant at one, two, three months and as an adult.<sup>8</sup>

In one of the initial experiments illustrating how abnormal vision experience can affect behavior, Held



Figure 2. Simulation of how the infant sees during the first year. Printed with permission by author.<sup>8</sup>

reared kittens in an environment consisting of only vertical stripes.<sup>7</sup> After approximately 30 hours of abnormal vision experience, it was as if the kittens developed a simulated blindness, or amblyopia, resulting in delayed visual reaction time which was evidenced by their failure to blink for quickly approaching objects. Depth perception was also adversely affected, in that the kittens didn't put out their

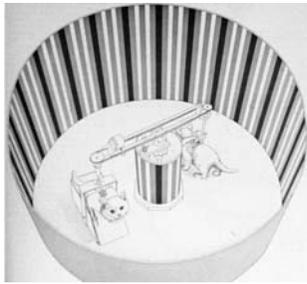


Figure 3. Vertical stripe environment. Printed with permission by author.<sup>7</sup>

paws when slowly lowered to a surface. These visual behaviors developed normally for the kittens that were actively moving in the abnormal environment as opposed to kittens that had the same abnormal visual experience but were passive. This demonstrates the important interaction of purposeful self guided movement in addition to varied and interesting visual input for the development of normal vision and vision behaviors. Some everyday clinically observable vision dysfunctions in children, such as functional amblyopia, develop during the beginning years of life. Early detection and treatment can almost entirely prevent the severity of these functional classes of vision dysfunctions.<sup>9-12</sup>

The recent legal adoption in the United States of children from Russian and Romanian orphanages has demonstrated how cortical development can be adversely affected from birth. In many of the Romanian state run institutions, orphans spent the entire day in cribs without toys, were housed in quiet, colorless rooms, wore uncomfortable clothes and had little contact with caregivers. These children often show the adverse affects when as infants they are deprived of varied and stimulating vision environments coupled with

movement and a loving and compassionate caregiver. In Pollack's study of 24 children reared in Eastern European orphanages, each one showed some delays in sensory-motor development for their age, specifically with poor balance and difficulty integrating movement of the right and left sides of their bodies.<sup>13</sup> In both studies of abnormal early vision experience, with kittens and orphans, the researchers reported that abnormalities began to normalize once natural and stimulating vision environments were restored.<sup>7,13</sup> This is an indication that there is a certain amount of plasticity to the cortical centers subserving vision and related behaviors, and underscores the significance of vision stimulation as an important constituent for optimal brain development.

In contrast to considering how vision deprivation adversely affected visually related behaviors, various studies have demonstrated positive cortical and behavioral changes in rats when they were placed in environments rich in vision stimulation and given opportunities for movement, play, and social interaction. The brains of the rats reared in complex environments, as compared to rats raised in cages, showed more mature synaptic structures, more dendritic spines, larger neuronal dendritic fields, more synapses per neuron, more supportive glial tissues, and increased capillary branching that increased blood volume and oxygen supply to the brain. In addition, rats reared in vision stimulating environments also outperformed rats raised alone or placed in barren laboratory cages on a variety of learning and problem- solving tasks.<sup>3,14-17</sup>

Vision is our dominant sense. There is more central nervous system area representing vision and related movement behaviors than with any of our other senses.<sup>18</sup> Our vision system, although extremely complex, has the potential to operate effortlessly.<sup>19</sup> Other areas of a child's development, including language, curiosity, imagination, social skills, emotional development, fine and gross motor skills, and cognition depend upon how vision develops. It is as if vision is the rudder guiding the entire ship of a child's development.<sup>4</sup>

Clinical experience has shown that guiding vision development through parent education, as well as encouraging parents to provide certain fundamental vision experiences for their child, is the most effective way to develop vision in infancy.<sup>20</sup>

## GENERAL CONSIDERATIONS

The visual world of the infant is vastly different than the world of adults. Adult vision sees the world through and with experience. Properties of distance, size, brightness, color, right sidedness, and a myriad of others are not innately intrinsic to the world of things, but rather are imposed upon the infant by the active process we

label as vision. For the infant who is taking in the world through their eyes for the first time, there needs to be a proper integration of vision with the other senses, and also a consistency in the infant's environment. This provides an opportunity to develop correct discernments and perceptions and thus allow vision to develop properly. There are many aspects of vision that are learned. With the proper environment and adequate vision stimulation, vision can be guided to assume its proper role as the dominant sense. As Arnold Gesell noted in his studies of human vision in infants, vision influences and is influenced by movement.<sup>4</sup> It is with movement that a vision therapy program can be constructed, so that have a positive affect on the developing vision system is seen.

## **GENERAL RULES**

### **When to perform vision activities**

The best schedule for babies are those which coincide with their natural rhythms.<sup>21</sup> Feeding, sleeping, and elimination occur in cycles. By three months of age infants have begun to incorporate a time for exploring and a time for playing. Optometric vision therapy will best be included during this time. It is important that the activities be carried out while the baby is happy and free of the desire to satisfy a particular need. Optometric vision therapy, while the infant is hungry, sleepy, or unhappy is of little benefit. An ideal time usually occurs just after the baby's bath.

### **Duration of vision activities**

A parent must use their experience and intuition in determining not only when to commence with an activity but also when to terminate an activity. Do not continue to train when the baby tells you she's had enough. It is best to end before that point is reached. This will help to keep the infant's interest when the activity is performed later. Activities will generally last between 5-15 minutes. The true change in vision behavior will come about by doing the activities on a regular basis as opposed to doing them for long stretches only intermittently. When you have several activities to choose from, it is not necessary to make sure that each one is completed. It is alright to have more than one session per day if the infant enjoys the activities. The optimal situation in optometric vision therapy occurs when a parent recognizes the underlying visual skill that is being emphasized in the activity. Next the parent can see the potential to develop the same skill with other similar but distinct activities that their baby engages in naturally. This provides an opportunity without disrupting the momentum and interest the baby displays as they instinctively and innately engage their environment.

## **Keep a log**

The best way to monitor change and notice improved development is to keep a record. Things to record are the activity performed, time of day, duration of activity, and general and specific observations of behavior. Look for signs of developing attention revealed by clues found in strong eye alignment, active pupillary changes, increased active looking, head and eye movement coordination, and increasing sustained fixation. Over the course of several months, if you note that the infant is absorbed for longer periods with each of the activities, then development is on a proper course and neurological benefits are taking place.

## **Making sounds and having fun**

Babies have an intrinsic alerting and orienting response to sounds. If the activity calls for the infant's eyes to be directed in a certain place, for example eye contact with the parent, the addition of clucking and cooing sounds will help to bring the baby's gaze in the proper direction. Make these kinds of sounds continuously and then introduce a sudden change. You can even talk to older infants. The more the infant experiences your genuine excitement and enjoyment playing with them, the more the infant will enjoy the activity for themselves.

## **VISION ACTIVITIES**

The following activities are used by parents with their infant to develop visual contact with the object of regard, visual discriminations, visual attention, binocular coordination, and stereopsis; as well as accommodative flexibility, eye hand coordination, tracking, and perceptual awareness. It is recommended that parents do these activities as part of play. The human interaction of the parent with their child, in a caring and safe encounter, with the knowledge of directing this encounter to stimulate a particular area of vision development, is the necessary ingredients for success.

### **Nearpoint of convergence push-up**

#### **Purpose**

As objects move closer to the infant, each eye should coordinate to move equally inward toward their nose in order to keep binocular alignment on the approaching target. This activity will provide the opportunity for the infant to make a convergence movement and develop the appropriate visual response to objects coming toward her. This sets the stage for comfortable and efficient convergence later on when sitting at a desk for long periods.

#### **Procedure**

Hold the infant up above your head with your arms extended. Make eye contact and slowly lower the infant



Figure 4. Starting position for convergence.



Figure 5. Completion of near point of convergence. Next return out to starting point.

activity can also be carried out with the infant reclining and the parent slowly approaching inward while maintaining eye contact.

## Saccadic toys

### Purpose

The type of eye movement made when looking from one object to another is an important skill for the infant to learn. This procedure will help the infant to experience this type of eye movement, which is a fundamental stepping stone in establishing the eye movements needed for reading and moving quickly and efficiently from one word to the next.

### Procedure

Sit the infant down directly across from you. On your lap or out of view, place an array of brightly colored, attractive toys. Toys that can be squeezed and produce a noise are particularly good for this activity. Take one toy and hold it out to the side of the infant just far enough so that it catches the infant's attention and requires an eye movement to fixate it. Allow the infant to touch it and confirm its location. Then hide the toy and with your other hand introduce a new toy on the other side of the infant. Move this toy until once again it catches the peripheral vision attention of the infant and induces another eye movement to the other side. Keep going back and forth with the toys as quickly as the infant can make appropriate eye movements. They can confirm its location with touch. Another variation on this activity is

closer to your face until you actually touch noses.

Maintain eye contact during the whole transit and observe the convergence movement with the eyes as the infant approaches.

Continue to work the procedure in reverse, starting up close and slowly pushing the infant up and away until arms are extended. Repeat the procedure with the infant slightly torqued to one side or the other to promote an asymmetrical convergence movement. This

to play peek-a-boo using a pillow with your face covered. Reveal your face from behind and after you make eye contact hide your face again. Repeat from a different side each time you come around from the pillow: up, down, left, right and each diagonal corner. Randomize the side you emerge from and change your expression while observing if the infant can visually discriminate them. This is an activity that many infants enjoy doing for long periods of time.

Because of their interest you can begin to increase the speed and rhythm of the infant's saccadic fixation and develop this important vision skill to a high degree.

## Pointer and ring

### Purpose

In the early developing years, vision is guided by hand manipulation. Activities by which the infant's hands are engaged in the midline provide opportunities for developing effective, sustained vision fixation and binocular control.

### Procedure

Have the infant sit comfortably in one parent's lap. Allow them to use their finger or use a pointer, such as a soft pipe cleaner. Another parent holds a ring of at least one inch diameter directly in front of the infant approximately six inches from the nose. You can use pipe cleaners to easily make rings of various diameters. The hole of the ring should be facing the infant who is then encouraged to poke the pointer through the ring. With appropriately timed reinforcement, the activity will be readily repeated by the infant. As consistency and



Figure 6. Left saccade.



Figure 7. Right saccade.



Figure 8. Peek-a-boo variation.



Figure 9. Pointer and soft pipe cleaner.

turned so that it is perpendicular to the infant's face where the infant must poke the ring from the side. The degree of turn and placement of the ring can be varied in order to provide a challenge to the infant whereby success in determining location depends on depth perception ability. You can also vary the hand which is holding the pointer. In this activity, the infant can learn to judge different distances with only one eye fixating. However, we want the infant's binocular system to be stimulated, so insure that both eyes are opened and fixating on the ring. This allows the infant the opportunity to stimulate neurons in the brain which only fire when both eyes are transmitting an impulse, and are silent when the input is only monocular.

### Marble in cup Purpose

The vision system initially learns how to calibrate space through the consequences of hand manipulation. By observing an object fall through space, the infant is provided the opportunity to understand that two areas can be visually related without being in physical contact. In



Figure 10. Block into cup.



Figure 11. Extension of arm while crossing midline for drop.

accuracy are displayed, increase the demand and expand flexibility by using smaller sized rings and by varying the location at which the ring is held. The task will be most challenging when the hole in the ring is

addition, hand activities provide opportunities for effective, sustained development of vision fixation and binocular control.

### Procedure

Have the infant seated comfortably in the parent's lap or sitting on their own. Give the infant a large marble or block to hold in one or two hands. Hold a large, plastic cup directly underneath the infant's hand with the marble and encourage the infant to drop it into the

cup. The sound from the marble dropping into the cup and appropriately timed reinforcement will soon stimulate the infant to engage in this activity. As the infant becomes more involved, hold the cup off to the left and then to the right. Keep alternating from side to side. In addition, lower the cup further down from the infant's hand so the marble can fall a greater distance through space. At all times encourage the infant to look forward toward the cup as the marble drops.

### Ball roll push-up Purpose

To provide an opportunity for the infant to make a coordinated eye movement inward and a divergent movement away, over a long distance. Once the eyes have been converging up close for a period of time, they must learn to easily and efficiently relocate to a distant view with a smooth divergent movement. This activity can help prepare the elementary school aged child for board copying, or refocusing on a white board in the classroom after using their eyes at a desk. It also helps to keep the focusing mechanisms of the eyes flexible to prevent the contracted state of visual system that typically accompanies the early stages of undesirable myopia development.

### Procedure

Have the infant sit down at one end of a room. The legs should be positioned so that a symmetrical "V" is formed. Orient yourself so that you are sitting five feet away, facing the infant. Take a large ball, at least ten inches in diameter, and roll it towards the infant so that the ball approaches on the midline. Watch for the convergence eye movement as the infant follows the approaching ball. Then roll the ball away and observe the infant's eyes follow the ball as it recedes. Look for a continuous divergent movement as their eyes track the smoothly rolling ball. Repeat this procedure at a farther distance, and with smaller size balls as well as faster speeds.



Figure 12. Ball roll push-up.

### Mirror rotations Purpose

To provide the opportunity for the infant to learn to use pursuit tracking while not moving their head. In addition, the mirror provides an optical situation whereby the reflection provides depth to the target. This



Figure 13. Mirror rotations.



Figure 13. High contrast black and white targets.

encourages the infant's focus to begin to move out and explore space. Placing a sticker on the mirror induces the infant to alternate focus from the plane of the mirror, i.e., the sticker, to their reflected image behind the plane.

**Procedure**

Have the infant in a sitting posture with you directly in front of them. Hold a mirror, at least 15cm by 15cm, at a distance of approximately 1 meter. Wait for the infant to notice their reflection, then slowly move the mirror in an up/down, left/right, diagonally from corresponding corners, or in a circular fashion to stimulate a pursuit movement as long as possible while the mirror is being moved. Be sure the position of the mirror is properly oriented so that the reflection comes directly back to the infant. The distance of the mirror from the infant can also be varied. The infant will also be attracted to simple outlines of faces and high contrast black and white targets.<sup>22</sup> These targets can be used in place of the mirror for pursuit tracking. There are many variations of high contrast black and white targets that are easily constructed as the example shows.<sup>23</sup> These types of targets stimulate edge detectors in the visual cortex, which are highly developed neuronal cells sensitive to borders of contrast.<sup>24</sup>

### Bed trampoline

#### Purpose

The foundation of good two-eyed coordination is good balance between the two sides of the entire body. Activities which simultaneously provide activation of muscles on each half of the body will provide experience for the infant to develop bilateral body coordination.

#### Procedure

Have the older infant stand toward the edge of the bed while you extend your hands or two forefingers for the infant to firmly grasp. Raise your hands so the infant's arms extend fully overhead. Depending on the height of the bed, it may be desirable for the parent to

stand on a stool so the infant can be more easily supported. Next, slowly lift the infant from the bed being careful to insure that both of the infant's arms are equally pulling on your fingers. After lifting the infant 15cm to 30 cm off the bed, slowly lower back down in contact with the bed. Repeat this cycle slowly several times. As the infant begins to feel more comfortable supporting themselves, encourage the legs to make equal pushing movements onto the bed by speeding up the rhythm and gentle bouncing on the bed. If the infant tends to pull more with one hand, or push more with one leg, provide a different amount of arm support to bring the weaker side more into play so their body is balanced.



Figure 14. Bed trampoline.

### The swinging ball

#### Purpose

In order for ocular muscle control to exist, a sufficiently large range of muscle stimulation and relaxation must be established. The swinging ball provides an excellent, attractive stimulus which can be used to gently expand ranges for all external ocular muscles.

#### Procedure

Suspend the ball from the ceiling at a height which coincides with the infant's eye level when seated in the parent's lap or on the floor. Start the ball moving left to right so that it is swinging no more than 15cm across. This should provide enough stimuli for the infant to fixate on the ball and follow it with their eyes. Next, swing the ball to and fro taking care not to have it swing more than 15cm to 30cm. As the infant places more attention on the ball, gradually increase the sweep of the ball. This will



Figure 16. Swinging ball sitting position.

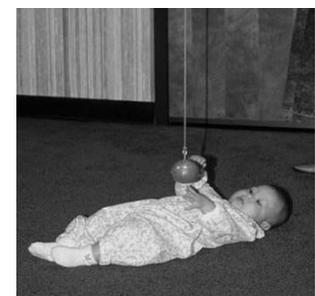


Figure 17. Swinging ball supine position.

encourage wider and wider eye movements. When the ball is swinging to and fro, the infant is gaining experience with binocular coordination as well as accommodation. Encourage the infant to touch the ball as it comes within reach, which will teach the basic understanding of visual motor cause and effect. If the ball seems to be moving too fast for tracking to take hold, you can replace the ball with a colorful, large balloon which will swing as the ball, but with a drift to make it slow enough for the infant to follow. If you place your infant on their back, and suspend the ball over head, then you are encouraging visual tracking with minimum head support and maximum eye movement.

### Visual sit up

#### Purpose

The cranial nerves III, IV, and VI, responsible for all eye movements, are located in the area of the neck and lower head, surrounded by bone and muscle.<sup>25</sup> The infant needs to coordinate the movement of the neck with proper eye alignment and fixation. The resulting sensory impression should be a stable visual world. The posture of the neck muscles will influence the alignment of the eyes and vice versa.



Figure 18. Visual sit up – starting position.

#### Procedure

Carry out the activity in a well lit room that is filled with objects, but not too busy. Place the infant down on his back while you are on your knees by the infant's feet, directly facing him, or standing and leaning over the bed with the infant reclining. Grasp the infant by the hands firmly, and encourage him to grasp your fingers. Slowly raise the infant to a sitting posture while taking care not to cause a jerking in the neck. Maintain eye contact while the infant is being raised. Watch for proper alignment and brightness of the eyes, which means proper focusing is occurring. Once the infant reaches a sitting position, repeat the process in reverse by slowly lowering the infant to the lying position. Encourage the infant to maintain an erect and a firmly, self supported head posture.



Figure 19. Visual sit up – upright position.

### Roll over

#### Purpose

Whenever the infant's body is rolled over, the eyes are engaged in movement through cortical interconnections between the eyes and the inner ear.<sup>26</sup> In addition when the body makes a large turning movement the eyes are encouraged to move in the direction of that movement. This activity helps to develop organized ocular movements.



Figure 20. Roll over – infant.

#### Procedure

Place the infant face down on a soft carpet or bed. They will naturally lie with their head turned to one side. Make sure the infant's arms are down by their side, then physically take the infant in hand and roll them over one complete revolution so as to return back to the original position. Conduct up to three consecutive revolutions. As you continue this procedure, see if the infant will initiate the movement on their own by grasping the legs or ankles and gently turning one leg over the other causing the hips to gently twist in an asymmetrical and out of balance position that is relieved by the infant following through on their own by rolling over. Carefully watch your infant's eyes to see if they are leading the body movement. As the infant begins to turn, the eye that is most visible should make a swinging movement in the direction of the turn. If you don't notice this, encourage the eyes to move by calling to the infant over the shoulder where you cannot initially be seen or by attracting the infant's attention with a penlight or brightly colored toy. Be sure to have the infant turn in both directions to give equal stimulation to both eyes and sides of the body.



Figure 21. Roll over – toddler.

### Wheelbarrow

#### Purpose

Vigorous muscular involvement is a potent stimulus for vision attention. In addition, when the muscular movements are patterned, the vision response becomes more organized. The wheelbarrow is an excellent,



Figure 22. Wheelbarrow – prone position.



Figure 23. Wheelbarrow – supine position.

enjoyable activity where organized vision attention can develop.

### Procedure

Have the older infant lie flat on their stomach with arms outstretched overhead. Grasp the infant by their ankles and slowly lift the infant 30 degrees from the ground, encouraging them to hold themselves up with their own

hands and your support. As the infant begins to feel stable, gently push forward on the infant's legs being very careful not to push so hard as to cause the infant to lose support from their hands. We are trying to get the infant to make an alternating hand movement by walking with the hands across the floor. If there is trouble getting started, alternately flex each leg at the knee in order to get the hands moving by stimulating the crawling reflex. As the infant begins to move, observe if the head alternately shifts from side to side. This would indicate that the eyes are regarding each hand as they move and thereby training good fixation skills. For younger infants, you can support their body by placing their abdomens on a soft ball, encouraging their hands to pull themselves along as the ball rolls forward. You can encourage hand movement by placing a toy or a bean bag in front of them to grasp. If the infant seems to enjoy being supported by the ball, you can turn them on their back which will help to develop strong lower back muscles and give them a unique and stimulating upside down look at the world. In order for eye tracking to be precise and efficient, it is essential that the infant develop strong lower back muscles to support their trunk. If the trunk is unstable, then the infant would have to coordinate both the movement of the eyes and the trunk.

### CONCLUSION

The best test of the appropriateness of an educational setting is found not in the particular program employed, but rather in the joy and excitement that the child displays for learning. Knowledge acquired in the backdrop of quiet, unfeigned enthusiasm sustains for a lifetime, and brings with it the anticipation and curiosity for continued

learning, a desire to learn more, a belief in oneself and one's abilities, with the result of a more fulfilled life. In five short years, the playfulness of natural discovery and exploration found in infancy transfers to the environment of the classroom and formal education commences. Society asks a lot of our children. They are charged with sitting at a desk, sustaining attention and concentration, absorbing information and facts, understanding concepts, and in turn are required to express and demonstrate their knowledge. When the child enters this world fully prepared with well developed vision skills, then the process of learning is supported. When vision skills are not well developed, then learning is encumbered. Children not succeeding in school have been studied closely and were found to have a higher incidence of poorly developed vision skills compared to children succeeding in school.<sup>27-29</sup> What is particularly interesting to note about these studies is that the vision problems found to be deficient were not major eye diseases. No cataracts, glaucoma, retinal detachment, or high measurements of myopia were noted. Instead, the problems uncovered were subtle and included the cluster of the very same vision skills that infants and young children develop over the course of 5 years leading up to the entrance of school. It therefore makes sense as a parent to invest the time necessary to learn the fundamental vision skills which develop in infancy and carry out simple and enjoyable activities to insure that these important skills for learning are developed to their fullest capabilities. It is worth the effort if the outcome is the potential to make school more successful and enjoyable for children, as well as contribute to the generation of a lifelong and enduring enthusiasm for learning. Even so, when considering the complexity of the learning process, there is no immunity to learning disabilities or potential struggles in the educational environment. If a child, however, does encounter difficulty in school and at that point in time is evaluated by a professional and found to have a number of developmental vision deficiencies as contributing factors to their learning difficulties, activities can be carried out in a formal optometric vision therapy program to improve vision skills.<sup>30,31</sup> A better prognosis for improvement is afforded the child who developed and possessed good vision skills



Figure 24. Simple target used to lock fixation for stimulation of pursuit tracking movements.

at one time in infancy. To never have learned them is more devastating than simply losing some of the earlier skills. This is the real value of developmental awareness, early intervention and prevention. This also demonstrates the need for infant optometric vision therapy to acquire fundamental vision development in infancy.

### Acknowledgement

The author thanks pre-optometry student, Lernik Mesropian, for assistance with the editing of this article.

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