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Kentucky recently enacted a state law which requires every child entering the public school system for the first time to present evidence of a complete eye exam either by an optometrist or an ophthalmologist. Although Kentucky has received positive feedback as a result of this legislation, many have wondered why the need for such a law. This thesis explains in detail reasons behind such laws, and argues strongly in favor of them. Not only do such laws help protect the visual health of children, but it helps them to be better prepared for the challenges of the educational system. Early intervention in this area is the first step to preventing amblyopia (lazy eye) and other vision disorders, many of which impact a child's ability to succeed in the classroom.

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Mandatory Preschool Vision Exams: Information for Parents, Teachers, and Policymakers

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Abstract

Kentucky recently enacted a state law which requires every child entering the public school system for the first time to present evidence of a complete eye exam either by an optometrist or an ophthalmologist. Although Kentucky has received positive feedback as a result of this legislation, many have wondered why the need for such a law.

This thesis explains in detail reasons behind such laws, and argues strongly in favor of them. Not only do such laws help protect the visual health of children, but it helps them to be better prepared for the challenges of the educational system. Early intervention in this area is the first step to preventing amblyopia (lazy eye) and other vision disorders, many of which impact a child's ability to succeed in the classroom.

Table of Contents

INTRODUCTION

The purpose for this research project is to present evidence in support of mandatory comprehensive vision examinations for children entering public schools. Recently this issue has become well publicized due to the passing of a law to that effect in Kentucky.[1] Beginning in the fall of 2000, all school children in Kentucky have been required to obtain a complete, comprehensive vision examination prior to January of their first year in school.

Now other states are considering enacting similar legislation.[2,3] In order to more fully understand the purpose of such laws, it is important to understand the issues involved. Undoubtedly, it might be a financial burden to have parents with low incomes or without insurance paying for these examinations. On the other hand, what of the children who have visual disorders and don't receive a proper diagnosis and treatment because they haven't been seen by the appropriate professional(s)?

Current statistics suggest that eye care professionals are not being utilized to the extent that would satisfy many parents.[4] In a recent survey of over 1000 American adults, it was discovered that 76% believe that children should have a comprehensive vision examination before entering school. That number jumps to 92% if financial help is available for those without insurance or financial stability. Seemingly most people support the idea of vision exams, but very few have them. In another study, it was found that only 14% of children less than 5 years of age have had a comprehensive vision exam. Also, of students considered problem learners, 60% have undetected vision disorders.[5]

According to the American Optometric Organization, vision examinations should be received at the ages of 6 months, 3 years, and prior to school entry.[6] However, very few children receive such thorough care of their vision. The scope of this paper will be limited to the recommended pre-school vision exam.

The goal of this paper is to explain the development of vision in children, with special attention given to the relationship between vision and learning. This paper will also focus on the potential visual problems that can and do occur regularly in children, why they are difficult to detect with a vision screening, and the scope and function of a comprehensive vision exam.

The tone throughout this paper will reflect a functional perspective; that vision is more than being able to see 20/20, and that true visual health should include more than just measures of physical health and acuity. The effects of refractive status, binocularity, facility, and endurance will also be discussed with relation to how they can affect school-children's ability to learn efficiently

We will look at the design of vision screening tests, and compare their efficacy with regard to detection of vision problems, particularly those which are learning-related. Also, we will present information regarding who should administer vision screenings and examinations. Lastly, we will review what major regulatory bodies have stated with regard to this subject, and what some states have done to improve the vision care of their school children.

VISION CARE NEEDS OF SCHOOL CHILDREN

ANATOMY OF THE HUMAN VISUAL SYSTEM [7-9]

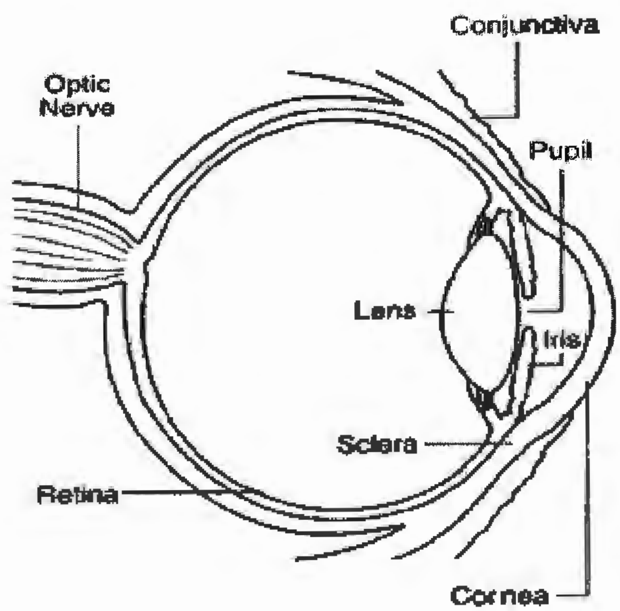

Image courtesy of National Eye Institute, National Institutes of Health

The framework of the human visual system, including the eyeball, the optic nerve, and brain represent one of the most interesting and complex systems of the entire body. In order to understand proper care of the human visual system, it is necessary to have at least a basic understanding of the system itself. The purpose of this section is to describe the basic components of the system and explain briefly the role each plays in the process of vision.

The eyeball itself is perhaps the most familiar to each of us as an organ of sight. Our explanation of visual anatomy will begin here, at the part of the eyeball where light first makes contact. The most frontward, or anterior, part of the eyeball is a transparent structure called the cornea (see figure). The transparency of the cornea allows light to pass through it, eventually becoming an image of the world on our retina (see figure). Should the cornea not have an equal curvature (i.e. not truly spherical, but ovoid), we may have a condition called astigmatism, which introduces both distortion and blur to the image we perceive of the world.

The sclera (see figure), also known as "the white part of your eye" forms a protective shell around the entire eyeball. The sclera is necessary to maintain the outer shape of the eyeball, and to provide a place for the extra-ocular muscles to attach.

The extra-ocular muscles are responsible for moving the eyeball into different positions of gaze It is important to note that the actions of the muscles are coordinated between the two eyes. In order to enjoy the benefits of binocular vision, both eyes must have the ability to "point" in the same direction at the same time. The fluid function of the extra-ocular muscles is therefore a prerequisite of healthy binocular function.

By looking through the cornea, you can easily see the iris (see figure). This portion of the eyeball gives individuals their eye color. Although a unique characteristic, the color differences between irises don't affect their function. The iris is actually an intraocular muscle, which expands or contracts, thus creating a different pupil size. The pupil is the dark circle formed by the iris.

Directly behind the iris is the crystalline lens (see figure). This lens is clear, like all optical elements in the eyeball, to facilitate the passage of light. Perhaps the most remarkable attribute of the crystalline lens is its ability to change shape. When the lens changes shape, it changes the overall focus of the eyeball. When the shape of the lens is at its flattest, the eye is generally in focus for distant objects. Nearer objects are brought into focus when the lens is rounder in shape. The shape of the lens is modified by the ciliary body.

The ciliary body is an intraocular muscle which surrounds the lens circumferentially. When the ciliary body contracts, the shape of the lens becomes more rounded, thus changing the focus of the eye for near objects. When the ciliary body relaxes, the lens becomes flatter, and the focus of the eye moves toward more distant objects.

A large fluid-filled cavity lies directly behind the posterior surface of the lens and extends to the retina. This gel-like fluid is called vitreous humor, which (along with the aqueous humor which fills the portion of the eyeball between the cornea and iris) helps to maintain the proper shape of the eyeball by exerting a slight pressure against the outer surfaces of its cavity.

The retina is represented on the back surface of the eyeball (see figure). The retina is responsible for capturing the energy present in light and converting that energy into electrical impulses. Highly specialized nerve cells called photoreceptors accomplish this task. A network of blood vessels weaves through the retina supplying oxygen and nutrients to these very active nerve fibers.

The most sensitive area of the retina (accomplished by having the highest concentration of photoreceptors) is called the fovea. The fovea is circular and has a diameter of approximately 1.5 mm. It is at this spot where light is focused most clearly, and where humans have the best visual discrimination. The ability to have 20/20 vision is due to the fovea.

Each of the individual nerves in the retina leaves the eye through the same location, at the optic disk. The optic nerve (see figure) is a therefore a large bundle of nerve fibers which leaves back of the eye and travels toward the brain. The nerves from each eye take a convoluted path, with "sub-stations" for further processing of the electrical information they carry. Eventually, the information which began at the retina reaches the occipital cortex at the back of the brain, where the impulses create the first sensations of form, color, and motion. After the information has been decoded, this information is sent yet further to other parts of the brain, most notably the frontal cortex, the center for higher thought. When the visual information reaches our frontal cortex, we then have the perception of sight.

As a whole, the visual system is a very complex, yet very remarkable system. We now know more than at any other time about the inner workings of the visual system, and there is still more to discover. In summary, Sir Charles Sherrington put it thus:

"The tiny two-dimension up-side-down picture of the outside world which the eyeball paints on the beginnings of it's nerve fibres to the brain... that little picture sets up an electrical storm... electrical charges having in themselves not the faintest elements of the visual – having, for instance, nothing of distance, right-sideupness, nor vertical, nor horizontal, nor colour, nor brightness, nor transparency, nor opacity, nor near, nor far, nor visual anything – yet conjure up all these. A shower of little electrical leaks conjure up for me, when I look, the landscape, the castle on the height, or, when I look at him, my friend's face, and how distant he is from me. Taking their word for it, I go forward and my other senses confirm that he is there." [10]

FUNCTIONAL ASPECTS OF THE HUMAN VISUAL SYSTEM

Although the previous review of basic visual anatomy gives many clues to the functions of the visual system, it by no means describes all of the abilities of the system. In fact, it might more truly be stated that the system described above is more like a camera (with two lenses) than a human visual system. Basic concepts in the functional aspects of human vision (like **accommodation**, **convergence**, and **ocular motility**) require further explanation.

The term **accommodation** is used to describe the ability we have to adjust the focus of our eyes. Although this ability is reflexive for most, we are not born with this skill.[11, p. 63] Through the act of accommodating, we are able to focus on objects close to us, the more we accommodate, the closer our focus shifts. We can also relax our accommodation, or "de-accommodate" to move our focus farther away.

Accommodation is a process that is controlled by the ciliary body and crystalline lens within the eyeball. Very young children quickly develop a great ability to accommodate, which decreases over time. A result of this decreasing accommodative ability (or amplitude) is that many people need reading glasses, or a bifocal spectacle prescription in their early 40's. The crystalline lens continues to grow as we age; this is thought to contribute to the decreasing amplitude of accommodation.

The ability to accommodate accurately is very important. An object of interest must be seen clearly for our brain to perceive it properly. However, if we haven't learned how to accommodate properly, we may be focusing too far in front of or behind the object in question. The result is that the object is not focused clearly on our retina, and we perceive a blurry image.

Also important is the ability to accommodate quickly and efficiently. Normally, when we shift our attention from one object to another, we reflexively re-adjust our accommodative state to the new distance to maintain the clarity of the new object. This happens almost instantaneously. However, if our accommodative abilities are slowed, we may experience a few seconds of blurriness when we shift our attention from a close object to one farther away, while our de-accommodation catches up with our attention. It is also possible that our accommodation can "spasm", and the ciliary muscle be flexed and in a state of tonus, from which relaxation may be very difficult to achieve voluntarily. The result is persistent blur of distant objects.

Proper accommodative skills are supported with proper eye movements. Without being unnecessarily blunt, the eyes must be pointed at the object of regard in order to perceive that object. To point an eye towards an object requires that each of the six extra-ocular muscles controlling eye movements work synergistically. This is a learned skill, and young infants' eye movements are often erratic until this skill is developed, usually around six months of age.[12, p 51] If the two eyes are pointed at different locations, the result is usually double vision (diplopia).

It is important to note that the actions of the extra-ocular muscles are coordinated between the two eyes. When one eye looks to the left, the other also looks to the left. This is an example of a "version" movement; i.e., when both eyes look in the same direction relative to a "straight ahead" position.

Also important is the ability of the eyes to exhibit a "vergence" movement; i.e., when one eye looks in one direction relative to "straight ahead", the other eye moves in the opposite direction. Typically, there are two ways that this might occur, either through

convergence or divergence. Convergence happens when the two eyes move toward one another, similar to crossing one's eyes. A divergence movement is the opposite, or moving one's eyes from a crossed to an uncrossed state. Another way of stating this is that the closer something is to your nose, the more convergence is required to look at it; also, the further away something is the more divergence is required.

Ocular motility efficiency and accuracy are as important to proper visual function as proper accommodative efficiency and accuracy. The fact that humans have two eyes makes the goal of fluid, functional eye movements even more demanding. The brain must learn very early in life how to coordinate both eyes simultaneously. When both eyes are pointed at the same location in space, and accommodation is focused on the same location, we then are able to experience clear, single binocular vision.

Not only must both eyes have the ability to point at the same location in space (fixation), but they must also have the ability to quickly point to new locations (re-fixate). This type of movement is called a saccade. Saccadic movements are very quick eye movements which relocate the position of the eyes, so that new objects of interest are able to be viewed. When a person reads, his eye movements are comprised of alternating fixations and saccades. During a fixation, the eyes hold their positions while the brain processes the encoded written information, followed by a saccade, which relocates the eyes to a new position on the page, where a new fixation is begun, etc.

Yet another type of eye movement is called a pursuit. Pursuit eye movements occur when one must visually follow a moving target. During a pursuit movement, the eyes don't exhibit a series of jumps (as in reading), but show a smooth, fluid motion to maintain fixation upon the moving target.

Eye movements, though varied, each play a role in our ability to examine our visual world. In order for us to be adept at processing our environment (be it watching television, playing baseball, or reading), proper ocular movements must be efficient and accurate. The result of inefficient or inaccurate eye movements is decreased visual processing speed, which can slow or inhibit routine daily functions in a variety of ways. Double vision, headaches, and blurred words on a page are all some of the symptoms experienced by individuals with inefficient eye movements.

All muscles in the eye require energy, whether they are extra-ocular or intra-ocular (as in accommodation). Therefore, with increasing amounts of time in use they will begin to tire. Some use their visual systems more than others, and those who have higher demands on their vision are more likely to demonstrate signs of that stress. For example, to fixate a target at two feet takes more energy than fixating a target at 20 feet. The nearer target requires more energy for the increased accommodative and convergence demands. The longer a person is required to hold this viewing position, the sooner his visual system is going to fatigue. It is therefore a requirement of a healthy visual system to have endurance, or sustainability.

In the healthy adult human visual system, not only do accommodation and ocular motility function efficiently and with sustainability, but the various other elements of the eye and brain interact in a coordinated fashion to produce clear, comfortable, binocular vision. For many, when this system fails, it is simply due to optical errors (refractive error) which can easily be corrected with appropriate glasses. When others exhibit visual problems, it is not because of optical errors (although they may present simultaneously), but because of imbalances in ocular musculature, or inaccuracies in accommodation, etc.

This is the basis of what is termed a "functional" vision problem. Applying the term functional to visual health implies not only that no disease or physical problem is present, but also that the system is meeting the demands that are placed on it by the individual and his environment. When the system fails because of the pressures put on it, although not an intrinsic error, this is a functional vision problem.

DEVELOPMENT, NORMAL AND ABNORMAL

It is well known that the human visual system isn't fully developed at birth.[11] Newborn infants have very limited visual abilities and skills, which gradually develop towards higher levels of function. In normal visual development, the period of most rapid skills improvement is from birth to one year of age.[13, Ch. 2] By this time, many abilities have reached adult-like levels, although certain abilities continue to develop throughout childhood (like hand-eye coordination). Some tests which are generally conducted on these young individuals include visual acuity (e.g. 20/20), stereopsis (binocularity), accommodation (focusing ability), pursuits, and saccades.

Skill	**Age**
Fixation to lights	3 months
Optokinetic Nystagmus	Birth
Pursuits	6-8 weeks
Horizontal Saccades	Birth
Coordinated Eye-Head Movement	3 months

By examining the table above[13 p 15], it is clear to see that not all visual subsystems reach maturity at the same time. It is monumentally important for those examining young children to be aware of normal developmental stages, in order to better rationalize the existence or absence of a problem. In other words, a deficiency of vision doesn't necessarily exist if a child doesn't exhibit the visual performance of someone in a different age group (e.g. an adult).

The normal development of the infant visual system is dependent on many factors. It is important, for example, that the retina be exposed to a clear view of the world in order for the individual to demonstrate precise acuity (20/20).[12, v.] Also, in order for the eye to grow to the proper size, the eye must be given the appropriate stimulus (visual feedback).[11 p.153] Receiving appropriate visual stimulation is also the precursor to developing hand-eye coordination.[11 p.107] It seems that many subsystems of vision (anatomy, perception, and skill) are dependent not only on each other, but especially on visual input from the environment.

Impaired visual development can affect an individual's ability to learn. One of the earliest things an infant learns is to recognize objects by sight. Studies demonstrate that infants spend great amounts of time visually investigating their environment. By experiencing repeated exposures to the same or similar objects, infants develop a "visual memory". As adults, we can immediately recognize objects for what they are quickly, because we each have a facile visual memory. For infants, this must be developed, and the only way it develops is through normal eyesight.[14 p76-82]

Studies have demonstrated that certain forms of blindness can result if the developing visual system isn't exposed to normal visual experiences.[9] Specifically, if the visual system isn't exposed to light, patterns, and fine acuity tasks, the full visual potential will not develop. The good news is that when the limiting factor is removed before a certain age, the visual system seems able to recover and develop normally.[7,9] The time frame during which the limiting factor can be present and not cause irreversible damage is commonly referred to as the "critical period".[15 p117] In other words, if a cataract is found in a newborn, it isn't a foregone conclusion that the child will be blind. This would be likely to occur, however, if the cataract weren't removed until the child was in his teens. If the cataract were removed within the first months of life the risk of vision loss is significantly reduced.

The fascinating ability which the brain has to adapt to various insults like this in infancy is referred to as plasticity. "The function of this plasticity, presumably, is to tune the interacting combination of neural, optical, and oculomotor systems in the growing child, to achieve a level of precision in binocular vision that could not be attained by a more rigid pattern of development. However, there are clearly strong constraints on this plasticity, both in the level of mismatch between these systems that can be successfully adjusted, and in the period of development over which adjustment can take place."[11 p148] The key to addressing these potential problems in vision development is early detection.[15]

Generally speaking, developmental problems which interfere with potential visual acuity are classified as visual deprivation, defocus, or strabismus (eye turn). Although many other disease entities exist which contribute to loss of vision, they won't be considered "developmental" in this discussion.

Visual deprivation occurs when the retina is deprived of light or form. This could occur in cases of congenital cataracts, a corneal opacity, or congenital ptosis (abnormally flaccid upper lid which obscures the visual axis).[12]

Specific refractive errors (inherent mismatch between the retina and the point of best focus of the eye) may also lead to vision problems. Just as the image projected on the retina is blurry, so is the information transmitted to the brain. In cases like this, although there isn't necessarily a physiologic malfunction, certain adaptations to the refractive error may be harmful.

Strabismus is a condition where both eyes don't "point" towards the same location in space. Often one eye becomes the "preferred" eye, and this eye is used predominantly, to the exclusion of the other. Strabismus is of concern because it may not be easy to detect, it may become worse with age, and it may result in social stigma. It is also associated with severe visual deficits. Strabismus can be caused by a muscular control deficit, paralysis, mechanical disruption, poor image (signal), or refractive error. Esotropia (eye turned toward the nose) is a leading cause of amblyopia.[12 p96]

Each of these anomalies result in specific visual losses, but they each can result in a loss of acuity. The loss of acuity in an otherwise healthy eye is known as amblyopia or "lazy eye". A healthy adult eye can easily see 20/20. This is considered the normal limit to the human visual system's ability to resolve detail. In an eye with amblyopia, the limit to resolution is worse than 20/20, and may be anywhere from 20/30 to 20/400 or worse. (Legal blindness is defined as the inability to see better than 20/200 even with optical correction.) Treating amblyopia is difficult, and the amount of improvement in acuity varies with the age of the individual, the duration of treatment, and the associated refractive error. It has been documented that amblyopia causes more vision loss than all ocular disease and injury combined in persons under age 45.[16 p216]

Just as in other developmental anomalies, amblyopia is subject to a critical period, during which time therapy may have a tremendous effect. It has been shown that amblyopia responds well to therapy from age 2-8 years.[12, 17-18] Therapy is also recommended for those with amblyopia which is discovered later in life, but the predicted improvement of acuity level in these cases is generally less.[19-21] We know that amblyopia is a condition which stems from poor visual experience in childhood; therefore, particular efforts should be concentrated on preventing this condition in the early childhood years.

A particularly disturbing issue is that of awareness. Young children may not be aware that what they are experiencing visually is a cause for concern ("If the world has always been blurry, then that must be the natural state of the world.") Young children cannot communicate what their needs are like an adult can. If there is blurry vision, distorted vision, or double vision, it may be very difficult for the child to express their concerns to their parents and teachers. It becomes easier to understand how these types of vision problems can go undetected for years when we understand this perspective. This is yet another reason to support vision examinations for all children.

VISUAL HEALTH IN CHILDREN

What is good visual health? For some people, this means that they can pass a driver's vision test. For others, it means that they don't yet rely on a bifocal for reading. Others may say that it is the absence of glaucoma, cataracts, or macular degeneration. In order to justify vision examinations of every preschool child, it is necessary to define what constitutes true visual health (otherwise, how does one know when visual health is compromised?).

For simplicity and brevity, we will examine visual health from three different perspectives. First, we will explore the physical soundness of the eye and related structures. Second, we will analyze the presence of a refractive error (or need for glasses). Lastly, we will inspect functional problems, including accommodative and vergence imbalances, and strabismus and amblyopia.

OCULAR HEALTH

The term ocular refers directly to the eyeball, therefore ocular health refers to the health of the eyeball. Included in this implication would be normal physiology, shape and size, blood flow, and metabolism. Also, any internal interruption in the normal physiology or anatomy of the eyeball constitutes disease.

There are a great number of potential ocular disease conditions in children. One clinical resource lists over 70 different possible diseases found primarily in the eyes of children.[22] The overwhelming majority of these are non-infectious and occur through disruptions in normal embryologic development. Many of these result in obvious distortions of normal ocular appearance and are noticed at birth, sometimes sooner. Although these conditions do not all preclude the normal use of vision, sadly many of them do.

Many congenital ocular diseases are much more difficult to detect, and can only be positively identified through a thorough examination by a vision care professional, but these conditions are typically very rare (e.g. congenital histoplasmosis).[23]

Even considering the vast array of possible congenital ocular disorders, injuries and infections constitute a much larger number of clinical cases of children seen by eye health professionals.[23, 24]

Injuries to the eye may be in the form of a scratched cornea, a foreign body trapped under the eyelid, a blow to the eye, or a laceration. Although rare, permanent blindness can result from ocular injury.

Ocular infections, most notably conjunctival infections, or "pink eye", are extremely common in children.[24] Fortunately most of these are mild and do not cause permanent damage, especially when treated.

REFRACTIVE HEALTH

The term refractive health refers to the innate ability an eye has to project a clear, focused image onto the retina. If there is an imbalance in the power of the eye to focus light in comparison to the overall length of the eye, this will contribute to the refractive status of that eye. If such an imbalance exists, this is termed the refractive "error" of that eye. There are three broad classifications of refractive error; **myopia** (near-sightedness), **hyperopia** (far-sightedness), and **astigmatism** (more than one focal point).

Myopia is a condition which is caused by the axial (front to back) length of the eye being too long compared to the focal length of the eye. In other words, when light enters the eye, the light rays aren't focused on the retina, but in front of it. When the light rays do reach the retina, they are no longer in focus. Two ways to adjust the light rays to bring the image into focus are well understood, the use of glasses or getting closer to the blurry object. The effect of either of these remedies is to change the focal point of light entering the eye to coincide with the retina instead of in front of it, thereby decreasing the blur experienced. The fact that near objects appear clearer to myopic persons has led to the use of the term near-sightedness to describe this condition.

Approximately 18% of children who visit an eye doctor have visually significant myopia.[25] Generally myopia is easily treatable with the proper spectacle prescription.

Hyperopia is a condition caused by the axial length of the eyeball being too short for the focal length of the eye. The point of best focus in a hyperopic eye is actually located behind the retina. However, the light rays don't travel this far before they encounter the retina, at which point they are not in focus. The result is a blurred image. In this instance getting closer to the object doesn't help, in fact it does the opposite, and the image becomes even more out of focus. Generally speaking, distant objects are clearer than near objects, hence the term far-sighted applies to this condition.

Hyperopia can be more challenging to diagnose and treat than myopia. In hyperopia, the problem is that the light rays need to be brought further into focus, whereas in myopia the light rays were being focused too much. Light rays can be brought into further focus in two specific ways: by adding more focusing power to the eye as a whole, through the use of the appropriate spectacle correction, or through accommodation.

Accommodation is the ability we have to adjust the focus of our eyes for the appropriate distance. Accommodation is a way of increasing the focusing power of the eye (typically for near tasks, like reading). Because of this, hyperopic individuals can increase the overall power of their eye without glasses if they accommodate instead. This then brings distant objects into focus. However, the amount of accommodation needed depends directly on the amount of hyperopia that is present; the greater the hyperopia, the greater need for accommodation. In some situations (low amount of hyperopia, few demands of near vision) a hyperopic person will be very comfortable without a spectacle prescription. Should the near tasks be substantial or the amount of hyperopia greater, there will likely be difficulties maintaining clear, comfortable near vision. It should be no surprise that undiagnosed hyperopes often experience more difficulties with near learning tasks.

Hyperopia, like myopia is most commonly treated with spectacles. Among children, the prevalence of visually significant hyperopia is approximately 25%. In children under the age of six, the percentage is even higher (33%).[25]

Astigmatism is a condition which is not dependent on the length of the eye like myopia and hyperopia. Rather, it describes the inability of the optical components of the eye to bring all the incident light rays into a focus at the same plane within the eye. So, instead of the light rays all being focused in front of the retina or all behind the retina, some are focused at one point and the rest at another. The most common type of astigmatism results in two points of focus within the eye. This may be caused by imperfect curvature across the surface of the cornea, or a slightly misshapen lens, or a combination of both. The result is that both near and far objects appear blurry. No matter where a person looks (near or far) only half of the light rays can be in perfect focus on the retina at one time, the other half will be either in front or behind the retina. Astigmatism may coexist in an eye that has myopia or hyperopia.

Approximately 22% of children have visually significant astigmatism, which is generally compensated with prescription eyewear.[25]

Certain combinations of refractive error have been identified as predisposing an individual to amblyopia and/or strabismus. Anisometropia is a condition where the two eyes have a significant difference in their respective refractive errors. When this occurs, it is very likely that only one eye will be able to perceive clear vision at a time, with the opposite eye receiving a blurred image. In cases like this, the brain adapts to the disparate input from the two eyes by ignoring, or suppressing, the image from one eye. This "suppressed" eye can develop amblyopia if the anisometropia isn't corrected.[26] Amblyopia can also develop if both eyes have the same refractive error and that error is very high. This could happen in cases of high myopia or hyperopia.

Strabismus can also develop if high bilateral (in both eyes) hyperopia is present. This occurs because the accommodative and convergence responses are linked. In other words, whenever we accommodate, our eyes naturally converge to help point our eyes in a new direction with the change of focus (closer). However, when a person has a high degree of hyperopia, viewing near objects requires a high degree of accommodation (assuming they wear no glasses), and they eyes naturally converge to a high degree as a result. When the eyes converge too far, and are no longer pointed at the same position in space, this produces esotropia, or an eye turned towards the nose.[27] The eye which is turned towards the nose will likely be suppressed, which predisposes it towards amblyopia.

FUNCTIONAL VISUAL HEALTH

Binocular vision, as described earlier, is the ability to use both eyes simultaneously to absorb visual information. Under normal circumstances, as long as both eyes are pointing to the same location, binocular vision is achievable. An underlying skill in binocular vision is ocular motility.

Ocular motility has also been described earlier as the ability for the eyes to move in both conjugate and disconjugate patterns. Conjugate patterns occur when the eyes move as a team (both left, both right, etc.). Disconjugate movement patterns occur when the eyes converge (both look in), or diverge (both look out). The simplest analogy is probably that of a person staring at a fly on his nose. The eyes appear “cross-eyed” because this person is maximally converging with his eyes. Maximal divergence is achieved by looking into the distance (20 ft or more). The ability to perform these “vergence” movements is dependent on the appropriate balance of ocular muscles.

Many deficiencies of vergence have been described, including convergence insufficiency, divergence insufficiency, convergence excess, divergence excess, and fusional vergence dysfunction.[28] In each of these syndromes, binocular vision is achieved, but is less stable. For example, in convergence insufficiency, the ability of the eyes to converge to read is decreased. It is still possible to maintain binocular vision, but the eyes are soon fatigued, which produces symptoms of eye aches, headaches, blurred vision, double vision, or words moving on the page. The visual stress created in this example may result in multiple consequences, including avoidance of the reading task.

One of the more common adaptations to this type of visual stress is suppression. Suppression is the act whereby higher brain centers “shut off” the visual input from one eye. Because the image of one eye is now blocked, that eye no longer receives a signal to point to the same location as the fellow eye. This relieves the visual stress because the motor demand to converge is removed. Although an effective means of relieving the stress, suppression can lead to the more serious consequence, amblyopia.[29]

Also important to functional visual health is the accommodative skill. Accommodation, as discussed previously, is the ability to maintain the appropriate focus for the target of regard. Specific accommodative skills include accuracy, facility, and sustainability. Accommodative accuracy is the ability to adjust the focus of the eyes for the appropriate distance. Facility refers to the speed at which accommodation can be adjusted for varying distances, as is done in copying notes from the chalkboard (continuous readjustment of focus from one's desk to the board and back). Sustainability is the ability to maintain focus (generally for near work) for extended periods.[28] The symptoms of accommodative dysfunction are similar to those of vergence dysfunction.

In one study of a clinical population of children, the prevalence of accommodative and vergence disorders was more than 8 times that of ocular disease.[25] However, recognizing these disorders can be more challenging than recognizing disease. Accommodative or vergence problems may only produce symptoms during specific visual tasks. Generally speaking, as more stress is placed on the system, the more likely it is that deficiencies will be exhibited. For example, reading a distance acuity chart during a vision screening places minimal stress on accommodation and convergence. However, reading fine print for ten minutes places a great stress on both accommodation and convergence. Theoretically, it is possible for an individual with perfect physiological eye health and no refractive error (no need for glasses) to experience symptoms of blur, eye ache, or double vision, all due to a functional problem with either his accommodation, vergence abilities, or both.

TREATMENT OF VISUAL CONDITIONS

Visual health is very important to the functional capacities of children. The prevalence of disease, while low, can be sight-threatening. The presence of refractive error, while not sight-threatening (unless it predisposes to strabismus and amblyopia), causes a serious disruption in the way children can respond to and interact with their environment. Functional visual health, comprising accommodation and vergence skills, becomes a stumbling block to the child who is uncomfortable reading or performing deskwork.

Each of these problems is most easily corrected the sooner it is discovered. The prevalence of vision disorders increases approximately 1.6% per year; among 5-7 yr. old children the prevalence is 18% overall, among 13-15 yr. olds it is 31%.[30] Vision disorders are currently ranked first among all handicapping conditions in childhood. When this statistic is combined with the fact that only 14% of American children under 5 have received a comprehensive eye examination from a vision care provider, the outlook is dim.[5]

The range of treatments for ocular disorders is as varied as the spectrum of disorders themselves. Surgery and medication are standards for ocular disease, prescription eyewear or contact lenses correct most refractive errors, and vision therapy (either with the use of therapeutic lenses or more traditional orthoptic eye exercises) helps to treat oculomotor and binocular vision disorders.

VISUAL FUNCTION AND LEARNING

"Vision is the learned ability to see for information and performance. Vision is the ability to understand the things we cannot touch, taste, smell, or hear. Vision is the process whereby we perceive space as a whole." [31] It is simple enough to understand that we must be able to see in order to be able to learn alongside our peers. Those with visual disorders, both mild and severe, are still able to learn, but standardized processes in typical classrooms will not be sufficient for such populations.

Defining learning and vision and their interrelatedness is a difficult task. Our analysis will be simple, but hopefully still beneficial in shedding light on sometimes overlooked variables in this relationship.

We begin using our sight to learn from a very young age, and a remarkable portion of our brains is devoted to this task. In a comparison between all the sensory modalities (sight, smell, touch, etc.), four-fifths of the sensory information received by the brain comes from the visual system.[32] This fact also explains why the loss of sight is such a devastating prognosis for those with irreversible, progressive vision loss.

Not coincidentally, the learning environment of an early elementary classroom is such that nearly every learning task has a visual component (learning to recognize the alphabet, handwriting, etc.). Synthesis of these facts leads to the question of how much vision loss or disability can exist without a similar loss of learning ability and potential. If a correlation exists between vision skills and learning potential, the preservation of optimum visual function, especially in children, becomes even more important.

Obviously, children with significant refractive error are at higher risk for learning problems. If the written word on the chalkboard or in a textbook is blurry, keeping up with the rest of the class in a group instruction setting is going to be challenging, if not impossible. Glasses are of paramount importance in cases such as this.

Although sometimes overlooked, visual problems can produce dramatic learning difficulties. In one study, two groups of boys, matched for IQ and educational achievement, received a complete optometric examination. All boys in both groups were in need of help with their vision. The first group was given the appropriate help (glasses, vision training, etc.). The second group didn't receive any treatment. At the end of a four month period, both groups were retested. The group which received the intervention had improved their grade standing by 1.2 years. The group with no treatment improved their grade standing by only .6 years. In other words, the group with intervention improved twice as fast as the group without help. Among the conclusions from this study were: a significantly large number of school children have visual skills which are below the levels required for efficient performance of their tasks, a relationship can be demonstrated between the visual skill status of school children and their academic achievement, and the improvement of visual skills through professional attention leads to more rapid progress in school achievement.[34] This results of this study were published in 1954, demonstrating that we have been aware of this correlation for quite some time. Although it would be unethical to perform this type of experiment today (it would be unthinkable to withhold indicated treatment in children), the results of the study cannot be ignored.

Efficient binocular visual skills are also important in school success. Simple procedures performed by those with the proper training can demonstrate this. Two binocular skills tested in one study were those of oculomotor pursuits and convergence. The results of the study showed a correlation between those students who performed poorly on pursuits and convergence with low academic performance.[35]

Another unique study demonstrated a correlation between hand-eye coordination (visual-motor integration) and reading ability. Specifically, subjects (students) were asked to draw a bicycle, and points were awarded for completeness and symmetry. Visual sub-skills that were tested include: visual motor integration, visual analysis, and visual spatial skills. A significant correlation was found between those students scoring low on the test and their reading scores. Also, those who scored the highest on the drawing task tended to have the highest reading scores.[36]

In our analysis of vision and learning, we will attempt to highlight common visual problems that can contribute to learning difficulties, with specific emphasis on symptoms that might result from those problems. These "lists" aren't intended to be comprehensive, but to serve as examples of more commonly demonstrated behaviors in children with visual impediments to efficient learning.

VISION SKILLS FOR LEARNING

The absence of ocular disease is a simple prerequisite for normal visual function in the classroom. Monitoring for acquired visual conditions should not be disregarded.

Visual acuity is obviously important for learning readiness in a visually rich environment. Acuity at far and near should both be considered.

Refractive status must also be analyzed. Although mild amounts of myopia, hyperopia, and astigmatism may not interfere with visual acuity, they may not provide the optimum visual stimulus. If refractive error is present, the correct prescription must be available for the student. Even with mild refractive error, it should be established that the absence of correction does not interfere with visual efficiency. For example, moderate degrees of uncorrected hyperopia have been associated with delayed visual-analysis skills.[37]

Ocular motility and binocularity are two very closely related skills. In order to perform a systematic visual examination of objects or patterns, oculomotor and binocular skills must be natural and reflexive. In reading (a complex visual task), poor oculomotor control can lead to losing one's place, skipping words or lines, and subsequent slower performance with lower comprehension. Although some study results have been ambiguous in determining links between motility skill and school performance, delays in this area still warrant timely intervention.[38 p59]

Accommodation and convergence are also very important. The ability to sustain attention on a near task for long periods of time (which often occurs in the learning environment) is dependent on both accommodation and convergence. These skills should have an appropriate amplitude (maximum performance ability) and facility (flexibility).

Visual perception comprises a set of skills which could be described as more cognitive than visual, but which are dependent on proper visual function to develop normally. Visual perception is the sum total of the operations which our brains use to analyze and extrapolate information from our environment. Sub-skills of visual perception include: visual spatial skills, visual analysis skills, and visual motor integration skills.[28 p597]

READING AND VISION

Reading is perhaps the most visually demanding task by which we learn, and the longer a child is in school the more reading is generally utilized or required. Reading is also perhaps the most difficult task that we must learn to perform in our early academic years. Considering this, it should be no surprise that learning to read is a difficult proposition which takes years for young children to master.

It is not uncommon for vision care professionals to hear concerns from parents that their child isn't doing well in school. Often there is a question of whether vision is playing a role. Answering this question can be difficult, because vision and reading and their interaction are so complex. To help explain the relationship between reading and vision, and to demonstrate this complexity, the following charts have been excerpted and quoted from *Optometric Management of Learning-Related Vision Problems.*[39]

Learning to Read[39 p130]

Task requirements:

Major emphasis on word recognition and recall.
Large type with few words on each page.
"Look-and-say" methods of teaching place premium on visual memory.
Phonic methods require careful scrutiny of internal details of individual words.
Activity usually does not extend over long periods.
Writing may be utilized to reinforce reading.

Important visual factors:

Accurate oculomotor control.
Visual form perception and visual discrimination, including the ability to deal with directional orientation.
Visual-memory.
Accommodation and binocular vision are usually not critical factors unless there is heavy utilization of ditto sheets or similar teaching aids.
Ability to integrate auditory and visual stimuli.
Eye-hand coordination becomes important when writing is used as a reinforcer for reading.

As children progress in development and reading ability, emphasis shifts from learning to read to reading to learn. That is, instead of reading simplistic texts ("See spot, see spot run, etc.) the reading task becomes centered more on reading for the information embedded in the text (social studies, history, etc.).

Reading to Learn[39 p132]

Task requirements:
Longer reading assignments.
Smaller type.
Context cues become increasingly important to word recognition.
Phonic and linguistic cues are more readily available.
Word analysis becomes more automatic with less need to depend primarily on form perception.
Emphasis shifts to comprehension and speed.

Important visual factors:
Accommodation and binocular vision become more important.
Oculomotor control is important to keep place and preserve continuity of input.
Form perception plays a decreasing role.

Many visual skills are utilized in reading, and the longer the reading task is sustained, the more endurance is required of those visual skills. Perhaps the three most utilized of these skills are oculomotor control, accommodation, and binocular vision. It is also true that dysfunction in these areas can result in marked difficulties with the reading task.

Relating Oculomotor Control to Learning[39 p137]

Beginning reading:
Beginner needs to attend to internal details of words, requiring precise oculomotor control.
Accurate sequential inspection of words is necessary for utilization of phonic analysis.
Oculomotor control is related to the ability to maintain attention.

Continued on next page

Sophisticated reading:
Less dependence on precision eye aiming to attend to internal details of words, since more methods can be utilized to identify words.
Oculomotor control becomes important for keeping place.
Omissions, substitutions, and "careless" errors may be attributable to inaccurate oculomotor control.
Reading comprehension can be adversely affected by poor oculomotor control.
One compensation for erratic oculomotor control is to slow the reading rate to avoid errors.

Relating Accommodation to Learning[39 p139]

Beginning reading:
Large type utilized.
Blur rarely reported even if accommodation is deficient.
Most lessons are of short duration minimizing the effects of fatigue from accommodative problems.
Extensive use of ditto sheets may change this and cause accommodative disorders to interfere.
Short attention span more likely than blur or asthenopia.

Sophisticated reading:
The emphasis in reading shifts from decoding to speed and comprehension.
Smaller type and longer time at reading make accommodation very important.
Fatigue often manifest as the primary symptom.
Abrupt decline in reading efficiency as a function of time at task.
Intermittent blur may be reported.
Asthenopia present when patient persists at reading despite accommodative inefficiency.
Mild brow headaches are common.
Symptoms can be avoided by just not reading.
Accommodative spasm may develop as adaptation among those who persist at reading despite asthenopia.

Relating Binocular Vision to Learning[39 p141]

Beginning reading:

Emphasis is on decoding and not sustaining.
Binocular vision problems may not always be a major factor even when present.
Binocular fusion problems can interfere when there is great emphasis on workbooks or ditto sheets with lengthy assignments.
Asthenopic symptoms are rare.
Avoidance, short attention span, or disruptive behavior are more common.

Sophisticated reading:

Reading emphasis is on speed and comprehension.
Sustaining ability becomes important.
Binocular dysfunctions become increasingly important as the work load increases.
Comprehension is adversely affected, and there may be need for excessive rereading.
Reading in a moving vehicle can produce nausea.
Headaches can be more severe than with accommodative problems and may be occipital as well as frontal or temporal.
Loss of place may occur, particularly if there is a high phoria.
Suppression is an adaptive response that can permit reading despite a binocular deficiency.
There may be an inverse relationship between the degree of binocular vision problem and the influence on reading.
Smaller and less obvious deficiencies in binocular vision can seriously reduce reading efficiency.

Many factors can contribute to a reading problem, and other disturbances can cause some of the same symptoms that are listed below. Additionally, visual problems can interfere with other areas of learning besides reading. However, because of the reliance on vision that accompanies reading, this is one of the most likely places that a visual problem will present itself in the classroom environment.

SYMPTOMS OF LEARNING-RELATED VISION PROBLEMS

Due to the prevalence of suspected visually-related reading disabilities, the American Optometric Association has compiled a number of symptom checklists which might suggest a visually related learning problem.[40, pp 15, 17, 24]

Signs and Symptoms of Ocular Motility Dysfunction:

Moving head excessively when reading
Skipping lines when reading
Omitting words and transposing words when reading
Losing place when reading
Requring finger or marker to keep place when reading
Experiencing confusion during the return sweep phase of reading
Having deficient ball-playing skills

Signs and Symptoms of Accommodative Vergence Dysfunction:

Asthenopia when reading or writing
Headaches associated with near visual tasks
Blurred vision at distance and near
Diplopia
Decreased attention for near visual tasks
Close near working distance
Overlapping letters/words in reading
Burning sensations or tearing of the eyes during near visual tasks

Signs and Symptoms of Visual Motor Integration Deficiency

Difficulty copying from the chalkboard
Writing delays, mistakes, confusions
Letter reversals or transpositions when writing
Poor spacing and organization of written work
Misalignment of vertical numbers in columns when doing math problems
Poorer written spelling than oral spelling
Poor posture when writing, with or without torticollis
Exaggerated paper rotation(s) when writing
Awkward pencil grip

The Oregon Optometric Organization also feels strongly about this issue. To that effect, they have produced a handbook for parents and teachers with many facts about how visual performance relates to academic performance. One of their checklists is reproduced here.[41, p4]

Checklist for Visually-Related Learning Problems

1. Child becomes easily distracted
2. Avoids near tasks
3. Has emotional outbursts
4. Poor self-image
5. Shows aggressive behaviors
6. Low comprehension
7. Poor concentration
8. Fails to complete assignments
9. Frustrated with school
10. Exaggerated head movements
11. Subvocalizes
12. Loses place and skips lines
13. Very close reading distance
14. Has no voice inflection with reading
15. Rapidly fatigues when reading
16. Motor overflow

While some would argue that vision problems don't contribute to learning disabilities,[42] the disagreement may simply be the result of defining the problem differently. If the only piece of the visual system that was analyzed in comparison to academic performance was ocular health, for example, then a correlation would be quite surprising, indeed. In our approach, vision is seen to be more than just health, or just refractive error, or even just binocular and oculomotor skills. It seems to hold true that when the visual performance of those who are excelling academically is compared with those who are struggling, the area which shows the most differences tends to be in the area of binocular vision and visual-motor integration skills.[34, 44-47]

Interestingly, recent research suggests that juvenile delinquents have more in common with certain learning-disabled populations than simply a propensity for poor school performance. The same binocular and visual-motor integration problems which can be elicited from learning-disabled students are exhibited in high percentages of juvenile delinquent populations.[48]

This raises some unique implications. Do uncorrected visual inefficiencies predispose one to delinquency? Or do the lifestyle and other psychosocial factors of delinquency interfere with normal visual development? It has been suggested that the delinquent population represents a subgroup of the learning-disabled population. If it could be demonstrated that intervention (in the form of glasses, vision training, etc.) in these populations resulted in lowered recidivism rates, this would lend credence to the assumption that visual inefficiencies predispose one to delinquency.

OUTLINE OF VISION CARE NEEDS

Physical health of the eye is the most simple, basic level of visual health. Without proper physical function, the entire scaffolding of visual performance fails. It is the responsibility of health care professionals to monitor the health of the eyes, be they primary care physicians, ophthalmologists, pediatricians, or optometrists. School nurses, teachers, and parents should also be prepared to help children receive proper attention when problems are noticed.

The sooner gross defects are recognized and remedied, the greater potential exists for visual improvement and classroom success. Eye problems, particularly eye diseases (but including things like eye-turns) should not be taken lightly. It is a mistake to assume that delaying treatment until the child is older will have no lasting impact.

Assuming a child has the potential to experience clear, comfortable vision both near and far; to deny him this is to provide him with a disability in the classroom.

Passing a vision screening, especially if it only consists of a distance acuity chart measure (this is the most common method, by both pediatricians and lay persons) does not give a measure of a child's refractive status, nor does it guarantee comfortable near vision. Vision screenings (which will be addressed shortly) are designed to uncover amblyopia and strabismus, not to be considered a "clean bill" of ocular health.

A link has been demonstrated between poor academic performance and binocular inefficiency and visual-motor integration. Vision care professionals are uniquely positioned not only to screen for these problems, but many are fluent in processes of binocular vision and visual perceptual training for those with deficits.

All children need to have comprehensive vision exams and eye care in the preschool years.[53] Statistics demonstrate that only very few children actually receive such an exam. The older a child is at the age of his first exam, the more likely it is that a problem will exist.[49] If no abnormality of vision is found, a vision exam still provides valuable information.[50] A baseline now exists to compare future examinations findings with, and chronic progressive disorders will be diagnosed sooner (degenerative myopia, for example).

There is no single age at which to best examine the visual health of children, as ocular health and visual development do not occur equally in all children.[51] However, guidelines have established that (as a minimum) exams should be given at 6 months of age, 3 years, 5 years (or preschool), and approximately every two years after that.[6, 52] The suggestion that exams be mandatory for children upon entering public education systems is in keeping with these pre-established guidelines for vision health. When one considers that strabismus and amblyopia (which threaten visual alignment and acuity) are most easily treated when diagnosed early, the suggestion of mandatory exams becomes even more reasonable. It should be no stretch to understand that children simply do not learn effectively if their world is blurry, fluctuating, or doubled (all of which may be corrected with appropriate glasses, the most likely result of a complete vision exam). Add to this the evidence that academic performance may be affected by poor binocular and visual perceptual skills, and mandatory exams become not only reasonable, but desirable for all children for classroom success.

OPTIONS TO MEET VISION CARE NEEDS OF SCHOOL CHILDREN

VISION SCREENING

"Recommendations for health screening programs require that a disorder suitable for mass screening should have a high prevalence in the population, should result in significant impairment to the individual, and should be treatable at the time of detection."[54]

"Vision screening and eye examination are vital for the detection of conditions that distort or suppress the normal visual image, which may lead to inadequate school performance or, at worst, blindness in children."[55, p153]

"Vision screening programs are intended to help identify children with eye or vision problems that threaten sight or impair their ability to develop and learn normally. However, vision screenings are a limited process and cannot be used to diagnose an eye or vision problem, but rather to indicate a potential need for further evaluation." [5]

Being able to enjoy clear, comfortable vision plays a major role in learning. If a child has a visual deficiency it may contribute to below average performance in the modern classroom.[5,6,55,56] Approximately 10% of preschool children in the United States have vision deficiencies.[57] Almost 25% of school age children have vision problems.[58-60] Many of these visual deficiencies can be treated to give students clear comfortable vision. The earlier treatment is given the better the prognosis.[51,61-65] Though the need for good vision in the school setting seems obvious, fewer than 20% of preschoolers are screened for vision problems, and less then 15% receive a comprehensive vision exam each year in the United States.[66] Given these facts, many organizations are striving to expand the number of young people receiving proper eye care. Vision screenings are one method being scrutinized as a way to ensure children with vision problems aren't left undiagnosed and disadvantaged.

WHAT IS A VISION SCREENING?

Traditionally, vision screenings have been used to find children at risk for having obvious sight-threatening conditions that interfere with proper visual development. Normal cortical (brain) development depends on the image transmitted to the brain from the eyes. The images from the eyes must be equally clear and focused for visual pathways to develop properly.[55] Hence, there is a need for eye evaluations early in life. Screenings are most commonly performed by pediatricians, primary care physicians, eye doctors (ophthalmologists and optometrists), school nurses, and various volunteer organizations (Prevent Blindness America, Lions, etc.).

The most common test utilized in vision screening is that of distance chart acuity, known to many as the Snellen test. This test is intended to determine what the acuity (or sharpness) of vision is at that distance (typically 10 feet for screenings). Each eye should be tested separately (so the other eye doesn't help 'cheat' on the test). The smallest line normally seen by healthy eyes without a significant refractive error (myopia, hyperopia, or astigmatism) is the "20/20" line. If the eye being tested is unable to distinguish the 20/20 line during testing, this warrants a referral for further testing (to determine the cause, be it disease, refractive error, or amblyopia). If the tested eye can see the 20/20 line, it can be stated that the eye doesn't have amblyopia or significant myopia, but this doesn't guarantee that subtle refractive error and/or disease are not present. In other words, without more complex testing, chart acuity is simply a test for the presence of amblyopia and myopia, (and doesn't definitively rule out hyperopia or subtle disease processes).

The second most common vision screening test is that for binocularity, or ocular alignment. As previously discussed, binocular vision allows for the perception of three dimensions (the first two being height and width), or depth perception (also called stereopsis). The degree of binocularity can be measured, and is termed stereo acuity. The more precise ocular alignment is the greater stereo acuity is predicted (assuming visual processing channels are functioning properly). Binocular vision represents a higher level of function than monocular (arising from one eye only) visual acuity. It requires not only the simultaneous pointing of the eyes in the same direction, but also the accurate assimilation of information which originates in each eye separately. The information is then processed in higher brain centers for the perception of depth (which is not possible when viewing with one eye only).

Binocular vision tests are typically identification tasks, with the person tested being asked to identify which target "floats" from the page. Testing continues until the highest degree of stereopsis is reached (meaning the level at which the person no longer perceives the float). When a person passes a depth perception test, it is generally safe to assume that the person doesn't have strabismus (which by definition means the eyes aren't pointing in the same direction at the same time). If a person cannot pass a depth perception test, it is reasonable to pursue further testing (to investigate the possibility of strabismus, amblyopia, or other disorders – some ocular diseases interfere with stereopsis). As with visual acuity, passing a stereopsis test doesn't rule out the possibility of refractive error or subtle ocular disease processes, it simply means that strabismus is most likely not present.

The most simple vision screenings consist of tests which can ascertain the presence or absence of amblyopia and strabismus. These are two disorders which are best addressed and respond more quickly to treatment when diagnosed as early as possible. The tests described above would be considered adequate if the goal were to rule out amblyopia and strabismus in a school age population, while taking a short time to complete (less than five minutes per child). With the appropriate tests, it is possible for minimally trained lay persons to administer these tests. Problems can occur, however, if strict referral criteria aren't adhered to, if children memorize the chart (by overhearing other test takers, for example), or if referrals for further evaluations aren't appropriately followed up.

Many more tests exist which can be administered during a screening, and deciding which tests to use depends on the purpose of the screening, the time allowed, and the training of the administrators. Although opinions differ,[6,67] traditional screening approaches generally include one or all of the following :[6,55] visual acuity, binocularity, external ocular inspection, ocular motility and eye muscle imbalance testing, pupil reflex testing, and an internal ocular inspection (via opthalmoscopy).

In a typical vision screening performed by a medical doctor, ophthalmologist, or optometrist, an opthalmoscope would be used to examine the health of the eyes. Using this instrument, the doctor is able to assess the eyes for subtle physical defects (cataracts or other opacities, retinal disease, or gross differences in refractive ability between the eyes). These tests are typically in addition to the tests described previously; however, not all tests are performed by all doctors all the time.

WHAT A VISION SCREENING ISN'T

Even with all the tests performed during a screening (and recall that the vast majority of screenings consist simply of distance visual acuity with no further testing) no evaluation is performed for refractive error. This means that although low visual acuity may be observed during a screening of visual acuity, there is no attempt made to ascertain the cause, be it myopia (near-sightedness), hyperopia (far-sightedness), or astigmatism. If the screening is not performed by an ophthalmologist or an optometrist, a referral should be made in these cases to an appropriate eye care professional. This should result in the proper diagnosis and treatment of the acuity loss.

Given the low percentage of the pediatric population who receive comprehensive vision exams, there is a large push to use screening programs as a cost effective way to reach more of this population. Screenings were not designed to take the place of comprehensive exams. They are simply a tool used to monitor large numbers of the population and find those with reduced visual abilities. These people need to get further professional care. Passing a screening evaluation does not mean that there are no problems with the eyes, nor does it mean that a child will be comfortable using his eyes at all distances (especially near work, like reading) for longer periods than those used during screenings (typically a few minutes). Screenings are not intended to diagnose specific vision disorders.[6,55,68]

There is a growing sentiment among some eye care professionals that screenings may do more harm than good for the school population.[6,68-70] A screening will often miss a visual deficiency or inefficiency that a comprehensive exam would help diagnose, and educators and parents may falsely assume that their child is free of visual problems that could interfere with learning. In a recent North Carolina study, for example, it was shown that 81% of children who passed a vision screening had significant visual dysfunction later found on their first comprehensive eye exam.[2]

SCREENINGS CURRENTLY UNDER SCRUTINY

As a result of recent legislation mandating eye exams for pre-school children in Kentucky[1], the concept of vision screening has become the subject of much debate. The issues debated center around the question of whether current screening practices are adequate, and to what degree they may need to be modified to become adequate. Some of these questions are: Is there a standard battery that should be used? Do we need to include more tests in our battery than what is traditionally done? Who should perform the screenings? How successful are screenings at finding at-risk children? What percentage of children referred for a complete examination actually receive one? Does a false sense of security after passing a screening prevent or delay necessary eye care?

In an attempt to answer similar questions posed in 1954, a landmark study was undertaken in Orinda, California. The purpose of the study was to develop a standard vision screening program that: "could be achieved in an average community and school system; would find essentially all children with significant eye problems that most ophthalmologists and optometrists would agree needed to be under professional care, whether therapy was to be recommended or not; would avoid or minimize a conflict of opinion in each professional group or between the eye professions, or between the schools and eye professions; and would minimize the over-referral problem with its attendant costs and complaints."[30] One thousand Orinda elementary students participated in this three year longitudinal study.

The Orinda study compared several different screening methods with each other and with clinical examinations. The study found that of the various screening techniques tested, "the most effective procedure, by a considerable margin, was the Modified Clinical Technique (MCT)."[30] It was remarkably efficient, economical, and had the fewest over or under-referrals. The MCT consists of a battery of tests that have become the standard against which all other vision screening programs are judged. In many ways the MCT is very similar to a comprehensive exam, hence the name. In fact, the results of the study were that the screening technique was the most successful when performed by an eye care professional. The tests included in the MCT were visual acuity, cover test, retinoscopy, and ophthalmoscopy (retinoscopy and opthalmoscopy are generally performed and interpreted by experienced eye care professionals).

One important drawback to the MCT in the study was the lack of enthusiasm for follow-up when a referral was indicated.[30] This is unfortunately a common occurrence with most screening programs. Even if a screening finds a need for a complete exam, referrals often get lost in the cracks and those who may need the help most never get it.[6,71-73]

Other drawbacks to the MCT include the need for trained health care professionals to administer the screenings, and smaller schools may not have the appropriate funding for such measures. As a result, specific research has been aimed at finding methods which are just as successful, but utilize lay personnel. A technique called photorefraction is one of the methods under investigation. However, until further research is completed, no vision screening battery matches the MCT for its effectiveness.[68]

The enactment of law mandating vision exams has prompted specific screening studies. Two studies are currently underway, Vision In Preschoolers (VIP)[74] and Project Universal Preschool Vision Screening (PUPVS)[75], which are aimed at answering persistent questions about vision screenings. The questions of which tests are both most valuable and can be performed and interpreted by lay personnel are foremost. The question of follow-up for referrals is not under investigation.

Whatever the results of the studies, we know that vision screenings cannot and should not replace comprehensive vision exams in either scope or purpose. Current studies may even show identical results to the Orinda study, namely that the most effective, efficient screenings are those performed by eye care professionals. In this case, the question of whether to continue to perform screenings by lay personnel, with the attendant limitations, may be called into question. These lingering questions have played a part in Kentucky requiring complete exams for preschoolers.

COMPREHENSIVE VISION EXAMS

A comprehensive vision exam is just that, a comprehensive examination of vision. A comprehensive eye exam can only be performed by a licensed health care professional, typically an optometrist or an ophthalmologist. The purpose of a complete exam is to examine the entire visual system (physical, optical, and functional) for both obvious and subtle defects, whether or not they are currently producing symptoms for the patient under examination.

A typical examination includes both gross and microscopic examination of the physical structures of the eye, including tests of ocular motility and pupillary reflexes. Visual acuity, ocular alignment, and binocular vision are tested. Refractive testing is performed to determine if a prescription is needed. Visual efficiency skills (accommodation and convergence) are tested. In addition, screening tests for glaucoma are routinely performed. Through these tests and many others at the immediate disposal of the eye care professional, not only are vision problems detected, but also some overall health concerns (diabetes, hypertension, myasthenia gravis, and thyroid disease may all be discovered during an eye exam).[76]

Optometry has been categorized as a primary care profession. Primary care professionals serve as the first contact many have to the health care system as a whole. It is often the primary care doctor who first identifies health problems, provides needed referrals for higher levels of care (either to a primary care physician or an ophthalmologist, for example), and helps to coordinate the services of needed specialists.

In primary care, a great emphasis is placed on the practice of preventive health care, and this is true for eye and vision health just as it is for overall health. Preventive care is the idea that through regular examinations and screenings, in combination with appropriate education, many potential health problems can either be prevented entirely or discovered soon enough to allow timely and cost-effective treatment.

Eye care professionals serve in a preventive fashion through:[77] early detection and referral of ocular and systemic pathology; early infant and childhood vision care, guidance, management, and treatment; awareness of nutritional problems affecting the visual system; awareness of the value of a planned regular physical exercise program and its importance to the visual system; prevention, reversal or control of refractive conditions; prevention, reversal or control of binocular dysfunctions; early detection and treatment of functional vision problems; guidance regarding environmental factors, affecting or influencing visual behavior; early detection and remediation of visually related reading or learning problems; early detection or remediation of vision problems related directly or indirectly to social behavior (i.e. juvenile delinquency); detection and remediation of vision problems which limit vocational or avocational performance or opportunities; prevention of hereditary-congenital defects and vision problems by counseling or referral of prospective parent-carriers.

Most patients who visit an eye care professional (be it an optometrist or an ophthalmologist) have their vision needs taken care of immediately. That is, they do not need to be referred to someone with more expertise to remediate problems. This is an example of the distinct advantage of complete exams compared to screenings. All of the needed equipment to perform a detailed examination is at hand, and so is the necessary treatment, in most cases. In a vision screening, even if a problem is noted, there is a question of whether the child will receive the appropriate follow-up. In some cases of school-sponsored vision screenings, questions may arise regarding who pays for the exam (school or parents) if it is determined that a visual disorder is creating a learning disability for the child in question (in many states, testing and remediation of learning disability costs are born by the school district). When vision exams are required of all children, these questions no longer arise.

WHY ALL CHILDREN NEED A COMPLETE EYE EXAM

Vision serves as the major avenue for learning. It has been stated that a well-functioning visual system is one of the key tools necessary for learning, and as such is just as important as pencil and paper to the successful student. It would be unthinkable to ask a student to take a math test without a pencil, and it should be just as unthinkable to ask students without proper vision correction or intervention to perform analogous feats and expect them to be successful.

Vision problems occur with a predictable frequency in children, and they occur at rates sufficient to warrant not only frequent vision screenings, but also periodic full vision examinations. National studies have shown that 20 to 25% of children ages 5 to 14 have vision problems that require professional treatment.[60] In response to these numbers, the American Optometric Association supports the adoption of mandatory eye examinations as a prerequisite to school attendance.[76]

State legislative bodies are also aware of these numbers, and have created systematic screening procedures to curb this trend. Although most states currently mandate vision screening,[77] estimates are that only 20% of children actually receive such screening.[69]

The American Optometric Association, the American Academy of Ophthalmology, and the American Public Health Association each recommend that vision screening and examination occur at 6 months, 3 years, 5 to 6 years, and periodically thereafter.[6, 52, 57] Unfortunately, although eye care professionals recognize the need for vision examinations, and state agencies have attempted to mandate vision screenings, most children have not received an eye examination by the time they enter the public school system.[78]

Considering the gap that exists between the recommendation that all children receive proper eye examinations and the current usage rates (less than 20%) in most states, and the fact that undetected vision problems contribute not only to amblyopia and strabismus (which are more preventable and treatable the earlier they are discovered) but also to delayed learning abilities in the classroom, something must be done to correct this problem.

A simple and elegant solution, which has already been put in place in Kentucky, is the use of mandatory preschool eye examinations, as a prerequisite to public school attendance.

PROFESSIONS INVOLVED

To achieve success in any public health measure, whether it is an immunization schedule for infants or the eradication of disease, there must be a coordinated involvement of the many professions involved with the problem. This is particularly true with the issue of vision exams for children, because there are a great number of professions involved.

School teachers, school nurses, optometrists, ophthalmologists, medical doctors, and pediatricians all have some part to play in the visual health of children. There is also some redundancy in this system. For example, a child may receive a visual acuity test when he visits the doctor for a physical check-up during the summer months, and pass with flying colors. He may also receive the same visual acuity test from a school nurse when he enters school in the fall and pass again. As a result, his parents may conclude (perhaps erroneously) that he therefore has normal visual health and will have no problems with school work. Unfortunately that is not a correct assumption, although probably a common one.

Just as it is important for each entity involved in the care of children's visual health to perform their function(s) properly, it is important for those unfamiliar with each profession to have a basic understanding of the training each receives and the intervention that can be initiated by each of them.

The role of the school teacher is perhaps the most important (yet overlooked) in this system. Although school teachers are not likely to have extensive training in the diagnosis of vision disorders, they spend much more time in the presence of school children than other professionals. They are therefore in a unique position to monitor the visual performance of students on a more functional, day-to-day level. They will be able to tell when a child is struggling to keep his place when reading, for example. When a teacher suspects that a vision problem exists and may be interfering with a child's ability to learn, it is imperative that he/she suggest that the child receive a vision examination.

School nurses, while not present in every school or school system, are frequently the first to recognize that a vision problem exists. This would be the typical scenario of a child failing a distance visual acuity task administered by the school nurse. In this case, a referral for a complete vision exam (by either an optometrist or an ophthalmologist) is necessary. Some school nurses are trained to perform more extensive testing during screenings, but the extent to which this is implemented varies widely across the nation.[79] Many schools simply don't have access to school nurses. In Oregon more than 50% of school districts have no school nurses.[80]

Many volunteer organizations exist which perform vision screening services not only in schools, but also in local communities. These screenings are comparable to the screenings performed by school nurses, and are more likely to include measures beyond simple distance visual acuity.[81]

According to the American Optometric Association, an optometrist is "an independent primary health care provider who may examine, diagnose, treat and manage diseases and disorders of the visual system, the eye and associated structures as well as diagnose related systemic disease conditions."[82] An optometrist typically receives four years of education (beyond a bachelor's degree) specializing in the care of the visual system. Although optometrists are often thought of only as the person who gives a prescription for glasses or contact lenses, they are responsible for much more. Optometrists perform a complete examination of vision, including eye health and function, often with particular emphasis on visual efficiency. Any person failing a school screening should be referred to an optometrist or an ophthalmologist.

If during the examination by an optometrist a disease or disorder is discovered which requires advanced medical attention, the optometrist will likely refer that person to either an ophthalmologist or another specialist for necessary treatment.

Ophthalmologists are physicians who receive advanced medical training in the treatment of physical disease processes of the eye. They typically receive four years of training (beyond medical school) with emphasis on surgical treatment of the eyes. Ophthalmologists remove cataracts, perform corneal transplants, and may use laser surgery to correct refractive error (a relatively new procedure).

Ophthalmologists are licensed to perform all of the procedures which optometrists perform, and as such represent a profession to whom referrals may be made based on a failed screening. Ophthalmologists, as surgical specialists, are not considered a "primary care" profession.

Medical doctors and pediatricians (medical doctors who have specialized in the treatment of children) are also important in the care of children's vision. Each performs general physical evaluations of children, which should include a vision screening. The vision testing typically includes a measure of visual acuity (likely a distance measure), followed by gross inspection of the external ocular structures, which is then followed by a brief inspection of the internal ocular structures. If a child fails the acuity or health screenings he is likely to be referred to an optometrist or an ophthalmologist for further care.

When each of the above professions plays their role properly, it is reasonable to assume that the visual health of a child within the health care system will be treated appropriately and properly. However, if a child isn't introduced to the system any existing problems will go undiagnosed, and no treatment can be offered. Just as frustrating is the fact that even those who are correctly identified by the system aren't always given the appropriate treatment either because a referral to the appropriate provider wasn't made or simply not followed by the child/parent.

Once again, a simple way to ensure that each child gets proper care within the system is to bypass screenings completely and send him or her directly to a primary vision care professional, where not only diagnosis of any problems is most likely but the appropriate treatment can be initiated immediately without further referral.

RECOMMENDATIONS REGARDING MANDATORY VISION EXAMS

Perhaps at no other time in our nation's history have we been so obsessed about our health. Additionally, advances in medical technology and insurance coverage allow more and more people to have access to higher levels of health care. For many people who don't want to wear glasses anymore and have the financial resources, laser surgery is available which can give them 20/20 vision without their glasses.

Yet in a time when the potential benefit from health care continues to climb, with new surgeries being attempted and treatments available to ever more people, the majority of school children have never received a simple eye exam.[78]

SUMMARY OF THE PROBLEM

Vision disorders are the most prevalent handicapping condition during childhood, and the fourth most common disability (of all age groups) in the United States.[83] We are blessed to live in an age where infectious diseases are no longer the leading handicapping conditions of our nation's children. It is imperative that we put into practice that which we have learned considering the human visual system. We know that if amblyopia (decreased visually acuity not correctable with glasses) is discovered after a child is ten years old, it may not respond to treatment, but when discovered by age five or six, the treatment is much more likely to have a dramatic effect.[12, 17-18] We know that strabismus (even when it isn't obvious) can lead to amblyopia, and amblyopia can lead to strabismus.[12 p 96]

We know that uncorrected refractive error and visual inefficiencies may contribute to learning disabilities or prevent children from learning at the pace which they might with appropriate intervention and treatment.[5, 6, 32, 34-36, 55, 56]

We know that vision screening programs, though effective at finding individuals who may have amblyopia, strabismus, and myopia, have drawbacks. Screenings do not consistently identify hyperopes, and do not test near visual skills (which are most necessary in a classroom environment). Referrals from vision screenings may not occur, and some which do occur are not followed up or acted upon by the parent/child. Even with the best screening programs in place, some school systems don't have trained personnel with which to administer the screenings.

We know the recommendations of public health and health care professionals: eye exams should be given to all children, starting at 6 months of age, again at 2 years, and approximately every 2 years thereafter, even when no visual health abnormalities exist.[6, 52]

We know that very few children are receiving the vision care recommended.[58-60, 66] If this were true of an adult population, it may be less of a concern. An adult has the freedom to choose whether he/she gets the proper care. Children do not have the proper knowledge and means to make decisions regarding their own health care, however. In this case, they may need someone to advocate for their needs.

COMPREHENSIVE VISION EXAMS SHOULD BE MANDATORY

Although it would be inappropriate perhaps to require that each child get every vision exam recommended by health care professionals (6 months, 2-3 years, etc.), it is entirely feasible to require each child to receive at least one complete vision exam prior to entering the public school system. This is the most efficient way to ensure that children both have their ocular health needs met, and that they truly are prepared to engage in learning (from a visual perspective) in a meaningful way.

As mentioned before, this is the approach that has already been taken by the state of Kentucky.[1] The results of this sweeping legislation have been evaluated in part by the Kentucky Optometric Organization.[84] It was found that (based on 5,316 examinations studied) 13.9% of children needed eye glasses, and 13.7% required professional follow-up for health conditions like conjunctivitis, eyelid inflammation, and one case of a detached retina. These children benefited by having the appropriate treatment initiated immediately, without the process of referral. The children who didn't need treatment now have a doctor's signature stating that their vision has been professionally evaluated (not just screened), and that it shouldn't represent a stumbling block in the learning process.

Another interesting piece of information concerning the success of this program has also come to light. Kentucky originally set aside $250,000 to subsidize the cost of vision examinations for those who might not be able to afford them otherwise. During the first full year of this program's operation, only 66 exams were paid for from these funds. As a result, the amount of appropriated funds has been reduced to $50,000. It was determined that adequate resources existed to take care of those in need.[1]

Other states (Florida, Kansas, Kentucky, Massachusetts, Missouri, New Jersey, New York, Ohio, South Carolina, Tennessee, Virginia, and Wisconsin) have considered legislation mandating preschool eye exams.[84] Many other states are also reexamining their statutes to see if changes are necessary in school vision screening criteria.

Considering the deficiencies inherent in simple vision screening programs, and considering the health (and education) benefit which follows a complete vision exam, and considering the success that has been achieved in Kentucky with regard to mandatory preschool exams, it is our conclusion that comprehensive vision exams should be mandatory for children entering public school systems.

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