Growing In and Out of Focus

The eye adapts to avoid blurry images

By LISA SEACHRIST

To kids, parents seem to spend most of their time trying to prevent them from ruining something. "Don't eat those potato chips, you'll ruin your dinner." "Don't eat so much candy, you'll ruin your teeth." "Don't stomp through mud puddles, you'll ruin your shoes."

Most often, it seems, kids run the risk of ruining their eyesight. Parents routinely tell children to read with enough light, to pull their noses away from their books, and to sit farther from the television. All this despite the fact that doctors continually reassure parents that kids won't become nearsighted as a result of hours spent staring at video games or reading under the blanket with a flashlight at night.

Because nearsightedness runs in families, conventional wisdom has held that the genes one inherits, and only those genes, determine whether one has the visual acuity of a fighter pilot or that of the bumbling, shortsighted Mr. Magoo. Even though nearsightedness reaches epidemic proportions among people with advanced academic degrees and those who read a lot, the genetic evidence has maintained the upper hand.

Over the past decade, however, researchers studying chickens, tree shrews, and rhesus monkeys have begun to challenge this view. Mounting evidence indicates not only that close work, such as reading or sewing, spurs the eye to nearsightedness, but that the eye chooses nearsightedness in response to blurred vision. These findings add a new twist to the debate on whether nature or nurture plays the dominant role in determining nearsightedness.

"The nature vs. nurture argument has been a very emotional argument for decades," says Earl L. Smith of the University of Houston College of Optometry. "It hasn't been answered yet, but this is a very exciting time to be doing work in [visual acuity]."

Nearsightedness, or myopia, results when the eye becomes too long from front to back. Ordinarily, light passes through the corneal lens and focuses images on the rear portion of the eye, known as the retina. The myopic eye is so long that the images focus in front of the retina, making objects at a distance blurry. In the farsighted, or hyperopic, eye, the eye is short; images focus behind the retina, causing nearby objects to blur.

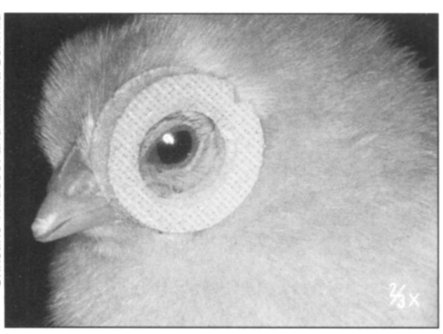
Animal and human babies usually begin life slightly hyperopic. As they grow, their eyes lengthen until all images fall perfectly on the retina, a process called emmetropization. By the first grade, nearly all children have perfect vision. Researchers don't know what mechanisms spur the eye to grow to a length that matches flawlessly the eye's optics.

It takes work to see at varying distances, even when vision is "perfect." Reading, for instance, requires tiny muscles in the eye to accommodate for the short focus by making the lens rounder. When this accommodation mechanism fails to keep images of the page in focus on the retina, whether as the result of myopia or hyperopia, corrective lenses can be recruited to do the work.

Increasingly, people in developed countries have come to rely on corrective lenses. Sometime between starting school with perfect vision and beginning high school, up to 50 percent of kids in the United States become myopic. In places like Taiwan and Hong Kong, where kids typically study 10 to 12 hours per day, 70 percent of older students need to squint to see the blackboard.

Myopic changes stabilize during high school, but another rash of nearsightedness occurs during early adulthood. This typically affects people who do a lot of reading—medical students, law students, and, ironically, military flight school recruits, whose training consists of intensive classroom work. In fact, so many Air Force recruits become myopic, and therefore ineligible to fly fighter jets, during their first year of training that the Air Force asked the National Research Council to convene a panel of specialists to investigate whether there was a myopia epidemic. The panel concluded that rates of myopia among Americans hadn't changed over the past couple of decades.

In addition to ending an aspiring fighter pilot's career, myopia carries significant health risks. Myopics are more likely to develop glaucoma, a sometimes blinding increase in eye pressure, and retinal detachment. Some even suffer a progressive form of myopia that leads swiftly to blindness. Understanding the mechanisms behind emmetropization and myopia could enable researchers someday to prevent or lessen myopic changes and blindness.

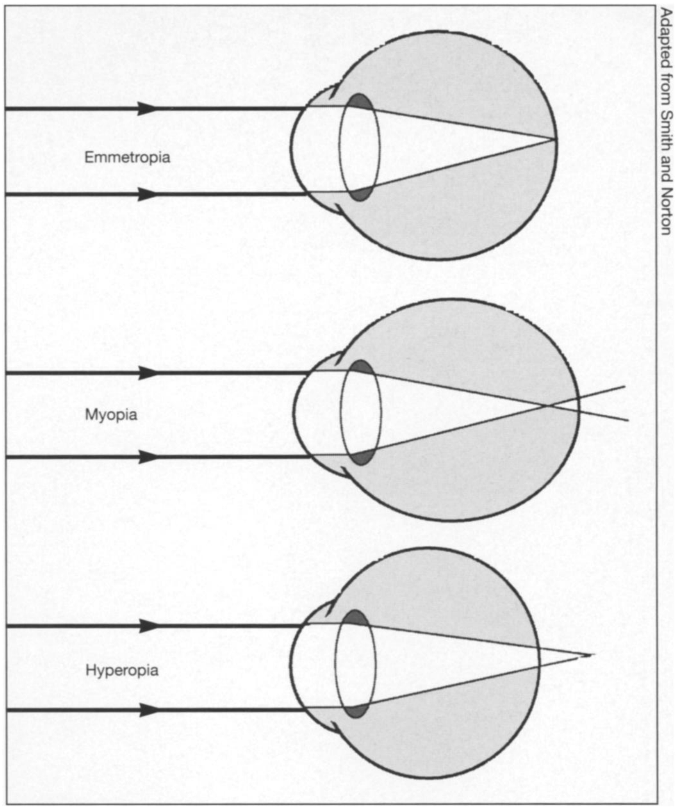


A chick wearing spectacle lenses to simulate nearsightedness shows that its eyes grew to compensate for blurred vision. Because chick eyes develop very differently from human eyes, studies in the tree shrew—a mammal closely related to primates—were needed to indicate that the eyes of higher animals also grow in response to blurred vision.

An abundance of epidemiological studies and anecdotal observations indicates that close work contributes to myopia. In Israeli religous schools, for example, boys, who must spend more time studying than girls, are more likely to become nearsighted. But these studies don't explain how close work exerts its effect.

In the mid-1970s, researchers studying emmetropization found that when they

In order to get images to focus directly on the retina in the back of the eye—a desirable condition known as emmetropia—muscles surrounding the eye elongate or contract the eye. When the eye is too long for these muscles to accommodate to the distance, images focus in front of the retina and the person suffers from myopia. In an eye that is too short, the image forms behind the retina, resulting in hyperopia.



sewed shut the eyelids of young chicks, tree shrews (mammals closely related to primates), and monkeys, the animals developed severe myopia. These crude visual manipulations showed that without something to focus on, the eyes elongated and the animals suffered from myopia of deprivation.

Frank Schaeffel of University Eye Hospital in Tübingen, Germany, and Howard C. Howland of Cornell University refined those experiments by fitting the chicks with refractive lenses. Josh Wallman of the City University of New York continued that work. By fitting chicks with a "minus" lens, Wallman and his colleagues made the animals functionally farsighted; a "plus" lens made chicks functionally myopic. In response to the blurring caused by farsightedness, the eyes grew until images passing through them landed exactly on the retina. In the nearsighted chicks, the eyes almost stopped growing in response.

"The exciting part was that it only took a few days for the chicks' eyes to compensate for the blur created by the lenses," says Wallman. "And when we removed the lenses, [the chicks'] eyes quickly compensated for their absence."

To test whether the changes in the chick's eyes actually resulted from the images the animals saw, Wallman and his colleagues placed a diffuser over part of each eye to stimulate a partial case of myopia of deprivation. Only the part of the eye behind the diffuser elongated.

Babies' eyes develop somewhat differently than chicks' eyes. After an initial growth spurt, babies' eyes grow more slowly. Chicks' eyes, on the other hand, never experience slowed growth. For this reason, Thomas T. Norton of the University of Alabama at Birmingham School of Optometry chose to do similar experiments on the tree shrew, an animal whose eyes more closely resemble humans'. Like Wallman, he found the animals' eyes either elongated or stopped growing in response to refractive lenses.

"I find it stunning that the eye grows to a specific target, where it matches the optics and then stops," says Norton. "Without any guidance or feedback, I find it hard to believe that there could be such precision."

In the August Nature Medicine, Smith reported that monkeys' eyes, too, employ a feedback mechanism to compensate for refractive lenses. Smith's team fitted the monkeys with goggles that contained one refractive lens and one lens that "was basically a piece of window glass." The refractive lens was either plus or minus, and the animals wore the goggles for 12 weeks. Smith chose to use only one refractive lens in order to control for genetic influences of myopia.

The eye with the refractive lens either grew or stopped growing until the animal could see clearly with it. In the ensuing year without goggles, the animals' eyes slowly grew to compensate for the lack of lenses until the eyes became balanced again.

"What's amazing is that the eye can tell the difference between a hyperopic blur and a myopic blur and compensate accordingly," says Wallman. "We certainly can't do that. We need trial and error to focus a camera, for example."

The eye's ability to compensate for blurring may contribute to the myopia associated with reading, the researchers contend. Reading requires the eye to focus at a very short distance for long periods of time. As a result, the scientists argue, the eye, which has evolved to see things at a distance, experiences a slight hyperopic blurring. Once the feedback mechanism engages, the eye will elongate to eliminate the blurring—becoming myopic in the process. Some researchers speculate that correcting the myopia may set off a vicious cycle of blurring, compensation resulting in myopia, and then stronger lens prescriptions to correct the loss of distance vision.

Smith points out, however, that "these experiments have all been done on infant animals, and we don't know if or how the compensation mechanism works in older children or adults." Wallman notes that failing to correct myopia could result in myopia of deprivation. Other researchers have suggested that myopic children be given bifocals to solve the problem, but studies so far indicate that that strategy may work for only a subset of myopic children.

While scientists concur that close work contributes to myopia, genetics still plays an important role. Karla Zadnik of the University of California, Berkeley, is conducting a study sponsored by the National Eye Institute in Bethesda, Md., that follows school children in Orinda, Calif., for 7 years. She has found that even though close work may contribute to myopia, children with two myopic parents inherit a tendency to develop the disorder.

For that reason, she suggests that researchers focus on "pharmacologic and biochemical prevention for myopia" rather than on refractive lenses to modify blurring. Such remedies for myopia don't exist yet, Wallman notes, because scientists don't know how the eye compensates for blurring. However, Smith points out that many scientists are looking into "how the signal for blurring transforms itself into a biochemical growth signal," which could one day lead to such therapies.

Clinicians need more information before employing corrective lenses to alleviate the hyperopic blurring associated with reading and nose-against-the-TV Nintendo playing among schoolchildren, says Smith. "It is a logical hypothesis that near work causes the eye to become more nearsighted. It's a hypothesis I am sort of willing to bet on, but as a clinician I certainly don't know enough about it to make decisions about another person's eyes."

While scientists hammer out the details of how myopia develops and how to prevent it, kids may do well to heed parental nagging. After all, too much candy does cause cavities. And too much near focus may ruin your eyesight. □