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Might myopic defocus prevent myopia?

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Abstract

Introduction What is the relationship between clinical myopia resulting from intensive reading and experimental myopia resulting from animals wearing spectacle lenses?

Method We review several experiments on lens-compensation. Chicks wore either: (a) negative or positive lenses for brief intervals several times per day, otherwise in darkness, (b) positive lenses for brief intervals, otherwise in a normal lighted cage, (c) negative and positive lenses alternately, (d) positive lenses together with light diffusers. Refractive error and axial dimensions were measured before and after lens-wear.

Results First, the temporal pattern of lens-wear is an important determinant of how much compensation occurred. Furthermore, the ocular length and choroidal responses can be independent with different patterns of lens-wear or when light diffusers are combined with lenses. Most significantly, even short periods of positive-lens-wear can promote compensation, despite normal vision the rest of the day, or even if the objects seen are too distant to be focused clearly.

Conclusions Positive lenses exert their effect by imposing myopic defocus, not by increasing sharp vision. Therefore, encouraging periods of myopic defocus in children to offset the periods of hyperopic defocus during reading might prove a useful prophylaxis against myopia.

For decades before experimental studies of myopia in animals lent some credibility to the notion that visual conditions led to myopia, an eccentric minority held the view that the presence of hyperopic defocus (or the ocular accommodation that it stimulated) during reading led to ocular elongation and myopia ("school myopia"). For this reason they held that it was desirable to avoid optically correcting myopia in children because the correction restored the hyperopic defocus that was the problem in the first place. This view of myopia as a iatrogenic condition has been asserted, dismissed, but never seriously tested, probably in part because of ethical considerations.

In recent years, it has become clear that chicks and monkeys can compensate for the defocus imposed by spectacle lenses (1, 3, 6). For example, if hyperopic defocus is imposed by negative lenses, myopia develops, which compensates for the imposed hyperopia. Might this compensation for imposed defocus be a model for school myopia? Reading is an activity that is unusual in that it causes long periods of steady hyperopic defocus (as a result of the output of ocular accommodation being less than what the visual input demands). Furthermore, reading seems the most plausible environmental component of education that might account for the high incidence of myopia among university students in many countries (8, 12). It is puzzling, in view of this strong epidemiological association, that studies attempting to relate the amount of reading and other near work in individual children to myopic progression have yielded rather weak associations (11). We take this as suggesting that it is not the total time spent on reading that is the relevant variable, but something else about the pattern of reading that has not yet been identified.

We have studied compensation for lenses in chicks under several visual conditions. We measured both refractive error and two anatomical components: the total length of the eye and the thickness of the choroid, both of which contribute to the position of the retina with respect to the retinal image. Both of these components contribute to the compensation for spectacle lenses in both chicks and monkeys (2, 9). We have found that if chicks wear lenses for several episodes during the day, the duration of each episode and the periods between the episodes is as important as the total number of minutes of lens-wear (10). Furthermore, the same pattern that caused compensation for positive lenses did not cause compensation for negative lenses. Even more surprising, the effects on the two anatomical components that contribute to compensation differed. For example, even very brief periods of positive lens-wear caused the ocular elongation to be reduced almost as much as by continuous lens-wear, but the same periods of lens-wear did not cause choroidal expansion. One would be tempted to conclude that the ocular elongation mechanism is more sensitive than the choroid and simply needs less "stimulation," except that with negative lenses the situation is reversed: long periods of lens-wear are required to affect the ocular elongation. These results imply that the retina must send several different signals that modulate refractive status. This notion of separate retinal signals for modulating different ocular components is also supported by our finding that superimposing mild diffusers over positive lenses had no effect on the inhibition of ocular elongation, but reduced the choroidal expansion that normally accompanies it.

These findings that different temporal conditions modulate the effects of wearing positive and negative lenses successively led us to raise chicks alternately wearing positive and negative lenses for brief periods (being in darkness the rest of the time). To our surprise, the two lenses did not cancel out each other's effects; instead, the effect of the positive lens dominated, even if it was worn one-fifth as much as the negative lens. This could be seen as further evidence of there being separate signals for the two directions of lens compensation. These results led us to try an experiment which had a more astonishing outcome: We raised chicks under normal lighting without lenses, except that every two hours we put positive lenses on for two minutes. This small amount of time wearing positive lenses caused the eyes to grow in the compensatory direction (toward hyperopia).

We conclude from this experiment that the eye must be responding to the myopic defocus produced by the positive lens. The alternative possibility—that the lens acts by increasing the amount of sharply focused images—seems implausible. It is likely that the animal gets much more sharp vision from normal experience, either by viewing distant objects without accommodation or by viewing near objects with accommodation (chicks have 20 D of accommodation), than it does by wearing positive lenses a few minutes a day. Furthermore, we have found, as have Schaeffel and Dieter (5), that chicks compensate for positive lenses even if they wear them when centered in a drum with the walls too far away to be in focus. Finally, if we raise a chick with positive lenses over both eyes and add a light diffuser to one eye, that eye shows a stronger inhibition of ocular elongation, despite experiencing less sharp vision, than does the eye without the diffuser. This is quite incompatible with the claim that the response to positive lenses results from the enhanced sharpness of the vision. (The probable explanation for the stronger ocular length inhibition is that the diffuser reduces the choroidal response, leaving more defocus for the ocular elongation to compensate for.) These results imply that brief periods of myopic defocus have much more powerful effects than do similar periods of hyperopic defocus. However, we expect that only within a certain range is myopic defocus so effective. In mammals, the range of myopic defocus that is effective in producing lens compensation is quite narrow (7). Even in chickens, large amounts of myopic defocus can result in form-deprivation myopia, rather than growth away from myopia (4).

If the amount of myopic defocus determines the direction of compensation in chicks alternately wearing positive and negative lenses, it seems possible that what determines whether a human eye becomes myopic during long periods of reading is not so much the presence of hyperopic defocus, as the absence of any significant amount of myopic defocus. This distinguishes reading from more natural kinds of close work. For example, when examining a small object held in ones hand or threading a needle, the slight hyperopic defocus caused by the insufficiency of accommodation is accompanied by massive myopic defocus of everything behind the object of regard. Thus our results suggest a new basis for visual prophylaxis for myopia—encouragement of myopic defocus.

If our reasoning is correct, the old saw that reading at close distances may be especially myopigenic might be true neither because of the degree of hyperopic defocus nor because of the amount of accommodative stimulus, but, instead, because reading at close distances reduces the world beyond the page, which would be myopically defocused.

Perhaps smaller books would help.

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