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Changes in ocular properties can be predicted from retinal blur due to defocus during emmetropization in the chick eye

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INTRODUCTION:
Emmetropization is an active process involving retinal feedback and is likely driven by the amount of defocus of the image on the retina. Normal emmetropization has long been assumed to result in zero refractive error, but recently this has been questioned. We wish to objectively determine, in chicks, when emmetropization is complete and how much retinal blur due to defocus remains. Secondly, we examine ocular properties during emmetropization to determine which changes are proportional to the retinal blur due to defocus.

METHODS:
From literature values including work in our lab, functions were fit to MOR (mean ocular refraction or spherical equivalent) and optical axial length (OAL; anterior cornea to anterior retina) vs. age. Dioptric length (K') and eye power (F) were derived up to day 75 using our previously reported method to calculate equivalent eye power. Cornea and lens powers were also calculated. Pupil size data were used to calculate the angular and linear retinal blurs (EB and LRB) due to defocus. The relationships among parameters and between retinal blur and ocular parameters were examined.

RESULTS:
Eye power and K'decrease exponentially with age at slightly different rates until power and K'reach almost equal values about day 35. Subsequently, power and K'decrease almost identically with age. This gives an initial rapid exponential decrease in MOR, which reaches a relatively stable value of 0.8 D of hyperopia about day 30 to 40 The completion of emmetropization is defined as the time point beyond which MOR remains relatively stable. After emmetropization is complete, MOR and EB remain almost constant and LRB is almost constant or increases slowly from about day 60, suggesting a differing growth pattern following emmetropization. The radius of the blur on the retina is larger than the cone resolution prior to completion of emmetropization, and approaches cone resolution as emmetropization proceeds.

Because of its exponential decrease with age during emmetropization, the rate of change of MOR (D/day) varies linearly with MOR. However, it also varies approximately linearly with retinal blur (both EB and LRB; $p<0.001$) before and after emmetropization is complete. During emmetropization, the rate of increase of OAL decreases, as a linear function of decreasing retinal blur (EB $p=0.0009$ and LRB $p=0.004$). This relationship breaks down around the time that emmetropization is complete (~day 30). Similarly, during emmetropization, the rate of increase in corneal radius varies linearly with retinal blur (EB $p=0.0008$ and LRB $p=0.004$) and the rate of decrease in lens power varies linearly with the rate of change of retinal blur (EB $p=0.001$ and LRB $p=0.005$). As expected from the above results, the rate of change of corneal radius ($p<0.0001$) and lens power ($p<0.0001$) are proportional to the rate of change of OAL during but also following emmetropization.

CONCLUSIONS:
Concurrent variations in eye power and length combine to produce the smaller, more rapid changes in MOR as a function of age during normal emmetropization. The eye is slightly hyperopic at the time point when emmetropization is complete. This time point can be defined objectively. Emmetropization appears to produce an active reduction of angular retinal blur to a value close to cone resolution.

In chick during emmetropization, the rates of ocular elongation, corneal radius increase and lens power decrease are proportional to the size of the angular defocus blur on the retina until the blur approaches cone

resolution and emmetropization is complete. Beyond this time, MOR is relatively stable, and eye growth is slower to day 75. Many of these results are consistent with findings during emmetropization in infants but here we show a linear dependence on retinal blur.

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