Is there meridional anisotropy in children with normal visual acuity and different astigmatic refractive errors?

An electrophysiology and psychophysical study.

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Purpose:
Astigmatism is an amblyogenic factor that may be important when monitoring and intervening in response to treatment. Given that little is known about orientation-specific cortical processing in children with amblyopia, it is important to first establish normative findings in children with normal visual acuity (VA) before checking for meridional effects in amblyopes.

The aim of the study was to determine the effects of astigmatic refractive error on orientation-specific pattern-onset visual evoked potentials (POVEP) in children with normal vision.

Methods:
Inclusion criteria: Children age 3–9 years old with normal VA (≥0.5 logMAR in each eye). Non-astigmates have ≤0.50 Dioptre Cylinder (DC). Astigmates have ≥0.50DC as low degrees of astigmatism can limit neural sensitivity.

Exclusion criteria: Amblyopia (defined by VA of either eye ≤0.30), strabismus, ocular diseases or abnormalities as determined by ocular health examination, binocular vision, ETDVS (HOTV logMAR chart) and refraction assessments.

Orientation-specific POVEP: Sinewave grating stimuli of 4.00 cycles per degree (cdd) oriented along and perpendicular to (on- and against-axes) to the subject’s aided principal astigmatic meridians of each eye were tested in random order (onset 100msec, offset 400msec, contrast 70%, 2Hz). Horizontal grating was arbitrarily assigned as on-axis in non-astigmates.

Grating acuity: Same meridians of each eye were tested (same settings) using two alternative fixed-choice preferential-looking with a 2 down 1 up staircase technique with 3dB step size (Matlab R2017a, MathWorks Inc, Massachusetts, USA).

Equipment: Espion system (Diagnosys, Cambridge, UK) ViSaSe stimulus generator (Cambridge Research Systems, UK), calibrated monitor (Sony CFP-G500 21” Trinitron CRT).

Analysis: Each subgroup (astigmates, non-astigmates) was analysed by running subject identifier as the subject variable, POVEP components (C3 amplitude, C3 latency; Fig. 3) and GA as the dependent variable, meridional anisotropies (on- or against- axes) and age as predictors in a linear model. Generalised estimating equations (GEE) was used to assess its average response changes and a follow-up analysis was conducted using linear mixed models (LMM) to assess the changes of individual responses over time by taking into account of inter-individual heterogeneity (multiple random effects for each variable). Logarithmic transformation was applied to C3 latency to satisfy normality assumptions of LMM.

Declaration: The research study adheres to the tenets of Helsinki. Informed consent was taken from parents of the child. Ethics approval was obtained from the Centralised Institutional Review Board (CIRB: R1083/98/2013). No financial interest.

Results:

Subjects: n=29; mean(SD) age=6.1(1.3)years

• 9/29 were astigmats (mostly with-the-rule); the rest were non-astigmats (excluded 1 subject due to poor record)

• Mean(SD) VA: OD 0.0.00(0.01) and OS 0.0.00(0.01) logMAR

• Mean spherical-cylindrical (sph/cyl) refractive errors (Astigmatism: OD: +0.83-1.59; OS: 0.92-1.66 axes 5-180 degrees; Non-astigmats: OD: 0.09-0.00 OS: 0.09-0.00)

Normal maturation:
• Age was a significant predictor for GA (Exp(B)=7.45, p<0.0001; Estimate=-2.66cpcd, p=0.002); 1.266cpcd improvement every year (95%CI:0.6–4.27)

• No effect of age for POVEP C3 amplitude (p=0.83) and log-latency (p=0.49).

Astigmats vs non-astigmats:
• Non-astigmats has significantly better GA compared to astigmats by about 5.25cspcd (95%CI: 0.34-10.17; p=0.04; Exp(B)=252.24, p=0.004) (Fig. 1)

• No significant difference between astigmats and non-astigmats for POVEP C3 amplitude (p=0.14) and log-latency (p=0.51) even though non-astigmats tend to have higher amplitudes than astigmats (Fig. 2)

Discussion:

This study suggests that GA is a sensitive test to demonstrate an effect on age and that non-astigmats have significantly better GA compared to astigmats. The absence of an association with POVEP may be attributed to poorer sensitivity from suprathreshold stimulus setting.

The improvement of GA with age reflects the continual maturation of GA beyond the age of 3 years old. Psychophysical GA differs from VA testing because: (1) GA reflects the neural sensitivity according to the subject’s principal astigmatic meridians, (2) GA was tested in pattern-onset mode where subjects have limited time to make a two-alternative fixed-choice decision compared to a paper-based VA chart, (3) letter-recognition in VA testing necessitates higher cognitive processing than GA, (4) GA uses sinusoidal gratings instead of square-waves as in the case of VA testing, and (5) the contrast of VA chart was 100% compared to 70% in psychophysical GA testing to avoid artefacts from the monitor.

The presence of early-onset astigmatism may have a deleterious influence on vision development. The findings in this study is consistent with previous work on astigmatic children<3 years old (>2.00DC) which similarly found reduced GA in both horizontal and vertical orientations even though they didn’t have meridional astigmatism.

Meridional anisotropies are present in young children with greater C3 amplitude response to against-axis than on-axis stimuli regardless whether they are or are not astigmatic.

Horizontal effect occurs where horizontal stimuli are worse than oblique stimuli[10,11] – a normal phenomenon that is observed when viewing natural visual scenes[10,11]. This is due to the well understood knowledge that the human visual resolution to oblique gratings tends to be diminished compared to the cardinal orientations (i.e. oblique effect)[12,13] due to reduced high spatial frequency exposure to oblique meridians compared to the cardinal meridians[14,15,16,17].

It is possible that young children may have more limited visual experiences than adults to develop these biases, while the horizontal effect may be a physiologically normal feature of an immature visual system which tends to process the salient aspects of objects whilst discounting visual contents (i.e. the horizontal orientations) that are already dominating natural visual scenes[10,11]

Conclusion:
Age effects were observed for GA during the normal maturation of young children and non-astigmats have better VA than astigmats, but these effects were not statistically significant in POVEP. Meridional anisotropy was observed for C3 amplitude where there is greater response with vertical stimuli than horizontal stimuli. This suggests that C3 amplitude is better at indicating meridional anisotropy than C3 latencies and GA. This horizontal effect may be physiologically normal in immature visual systems and these effects may extend beyond 5 years old.

References: