Real-time automatic strabismus screening using digital image analysis techniques

A. H. Dahlmann-Noor, Gill Adams, Ron Maor, Yuval Yashiv, Mike Stroud, Simon Barnard
1 NIHR Biomedical Research Centre for Ophthalmology at Moorfields Eye Hospital and UCL Institute of Ophthalmology, London, UK

Introduction
Strabismus is a risk factor for amblyopia and in pre-school children has a prevalence of 3.9%. Alignment tests may increase the sensitivity of preschool vision screening to detect strabismus. The Hirschberg test of ocular alignment evaluates centricity of corneal reflections (CR). This work presents a novel real-time strabismus screening device, based on automated processing and analysis of high-resolution digital photographs of the first Purkinje image. Advantages of this approach include portability, availability, low price, speed and ease of use of devices which can be used to acquire images. This poster presents the methodology and a first estimate of diagnostic test accuracy in a diagnostic and a screening setting.

The Research Ethics Committee of the UK Institute of Optometry approved relevant parts of the study.

Methods
Hardware and algorithm
We use a 14 million pixel camera with 1/2.3" CCD image sensor. Images have a size of 4288 X 3216 pixels. The device is light (212g) and small (196 X 56 X 26 mm), making it easily portable (Fig. 1).

Basic principle of algorithm
The algorithm uses colour, shape and surroundings of candidate structures to determine the location of entrance pupil and CR by pixel classification. The main landmarks it identifies are the pupil margin and the centre of the first Purkinje image of the camera flash light (Fig. 2-7). The algorithm then measures the distance between the centre of the entrance pupil and the centre of the CR.

Details of automation
1. Location of first Purkinje image (CR). Candidate areas (Fig. 2, red arrows) are defined as white areas and evaluated for colour, shape, size and surroundings.

2. Location of limbus as outer border of iris, defined as border between a white area (sclera) and areas of other colour, but not skin colour (iris) (Fig 3, red arrow).

3. Visible iris approximation.
Green dots and grey lines mark pixels with high likelihood of being iris and are surrounded by blue “house with a roof” (Fig 4).

4. Location of entrance pupil.
The pixels in the visible part of the iris are classified into categories by colour (Fig. 5). Pupil pixels are darker or less saturated than iris pixels.

Yellow square: first estimate of pupil.

Second iteration (Fig. 6): similarity to common colours inside and outside the yellow square.

Green dots: pupil
pink dots: iris
grey dots: indeterminate.

Distribution/density of green pixels (Fig. 7):
Yellow circle: best-fit circle enclosing as many green and excluding as many pink dots as possible.

4. Distance between CR and centre of pupil (Fig. 8, red arrow) is calculated and compared between right and left eye.

Clinical Study
We examined 331 individuals in primary schools (n=56) and an optometry practice (n=275). Age: 179 ± 10 years, 152 ± 11 years. We acquired three full-face photographs. All participants underwent unaided visual acuity (Logmar or crowded single letters/pictures), cover/uncover test and Randot stereopsis by a study-accredited optometrist.

Results
Prevalence of manifest strabismus in the study sample was 6.34%. Sensitivity of the device to detect strabismus was 95%, specificity 91%.

Conclusions
In order to further test the technology we are currently acquiring photographs from 500 strabismic children in a diagnostic setting. We will refine the technology to give a “pass/fail” output. A diagnostic test accuracy study will evaluate the final “Strabismus Screener” in population-based screening of pre-school children.

References

Acknowledgements
The research was funded by the developers of the device, who were also the study sponsor. AHDN receives salary funding from the NIHR Biomedical Research Centre at Moorfields Eye Hospital and UCL Institute of Ophthalmology.

Financial Disclosure: AHDN and GGWA: no personal financial interest in this work; RM, YY, MS, SB have a financial interest in the technology.