Eye-tracking technology in low vision: implications for functional diagnosis and rehabilitation

Chairs:
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Symposium abstract:
Our eyes are amongst the most important sensors in our body to interact with our surroundings. The making of eye movements is controlled by the oculomotor system, which closely interacts with the visual system. The integrity of both systems is crucial for visual, cognitive and social development. Over the past three decades, however, the incidence of cerebral damage and brain development disorders in children has increased. As a result, cerebral visual impairments (CVI) have become highly prevalent, especially in children born preterm and children with neurological damage. Various methods are currently used to asses visual impairments in these children. Yet, new and additional methods are required to assess visual functions in infants, children and elderly with (multiple) disabilities. Recently, the feasibility to measure the quality of visual functions using eye movements has been explored and reported. The key feature of these studies is the assessment of eye movements using (remote) eye tracking technology. While a test person is shown specific visual content on a monitor, her or his eye movements are measured based on infrared pupil detection. The resulting gaze coordinates and pupil sizes can be interpreted with respect to the shown visual content. In this symposium, an overview is presented of the potential role of eye movements in functional diagnosis and rehabilitation in subjects with visual dysfunctions.

Presentations:

1. Salience-driven and visually-guided eye movement responses
   Johan Pel, dept. of Neuroscience, Erasmus MC, Rotterdam, The Netherlands
2. Detection of areas at risk for glaucomatous visual field loss using Eye Movement Perimetry
   Deepmala Mazumdar, Vision Research Foundation, Sankara Nethralaya, Chennai, India
3. An approach to quantify the pupil response using an eye tracker based pupilometer
   Najiya Kadavath Meethal, Vision Research Foundation, Sankara Nethralaya, Chennai, India
4. Early detection and rehabilitation of visual processing impairments in children born extremely preterm
   Marlou Kooiker, dept. of Neuroscience, Erasmus MC, Rotterdam, The Netherlands
5. Optimizing eyetracker-based communication for children with multiple disabilities
   Jan Koopman, Royal Dutch Visio, Huizen, The Netherlands

1. Salience-driven and visually-guided eye movement responses

Summary: In this presentation, a method is introduced in which eye movements during orienting behavior and visual search are used as a tool to quantify the effectiveness of processing visual information. Prolonged response times and fixations to specific visual features may indicate lower-order (acuity, visual field, contrast) or higher-order (form or motion coherence) visual processing dysfunctions.

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Purpose

To investigated the interaction between eye movement response times and salience in target areas of visual stimuli in typically developing children, children with cerebral visual impairment (CVI) and children with infantile nystagmus syndrome (INS) between 1-12 years of age.

Methods

A preferential looking (PL) paradigm consisting of stimuli with six different visual modalities (cartoons, contrast, form, local motion, color, global motion) was combined with the measurement of eye movements. Visual salience of each target area relative to its background was calculated.

Results

In the control group, the development of response times with age was dependent on the salience level of the stimuli. The response times to targets with high salience reached stable values earlier in development (around 4 years of age) than to targets with low salience (around 9 years of age). We found that the children with CVI and INS showed general slowing in orienting responses compared to controls. The children with CVI had significantly prolonged responses to Cartoon compared to the children with nystagmus, whereas the children with nystagmus had prolonged responses to Motion detection and larger fixation areas.

Conclusion

The present age-dependent and salience-related results provide a quantitative and theoretical framework to assess the development of visuospatial attention, and to distinguish between children with visual processing deficits.

2. Variability of Saccadic Reaction Time in areas at risk for glaucomatous visual field loss using Eye Movement Perimetry.

Summary: Eye Movements are made to redirect the fovea to the suddenly appearing visual targets or other features of interest in the visual field. In this presentation, an eye movement –based perimeter is introduced to detect areas at risk for glaucomatous visual field.

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Purpose: To determine the variability of Saccadic Reaction Time (SRT) within and on repeat testing of visual field using Eye Movement Perimeter (EMP) and its association with stimulus eccentricity.

Methods: Normal healthy volunteers between 20-28 years with normal visual fields on the Humphrey Visual Field analyzer were included for the study. Goldmann Size III stimuli were projected at 26 test locations on a monitor at a contrast level of 162cd/m^2 against background of 140 cd/m^2. The tested eye was shielded from the fellow eye using dichroic mirrors to allow binocular gaze tracking (Tobii pro X3-120,Sweden) while only one eye was tested. Subjects were asked to fixate at a central stimulus while peripheral stimuli were presented randomly. SRT was calculated from a reliably seen response.The test was repeated within a day for assessing short term variability. The visual field was divided into 3 zones i.e. central, mid-peripheral and peripheral based on distance from the centre.

Results: Fourteen healthy subjects of mean (SD) age 24.78 (5.65) years were included. Significant (p=0.05) difference in mean SRT was found between superior [311.31(96.65)ms] & inferior [286.80(90.08)ms] visual field. One way ANOVA showed no statistically significant (p=0.24) difference in SRT across Central [285.55(87.28)ms], mid-peripheral [295.14(76.31)ms] and peripheral [304.99(102.28)ms] zones of tested visual field.SRTs were shorter on repeat testing across the zones, where a significant shortening of SRT was found at the peripheral zone [mean difference 26.33(112.56)ms, p=0.005].

Conclusion: Although the variability of SRT was low on repeat testing, the significant mean difference in the extreme peripheral zone is suggestive of a minimum learning effect. The variability analysis of SRT can aid in refining the use of SRT as an index for plotting visual field.

3. An approach to quantify the pupil response using an eye tracker based pupilometer

Summary: Traditional clinical examination uses a pen-flash light method to evaluate pupillary response and a pupil gauge to estimate pupil size. In this presentation, the test-retest repeatability of an eye tracker based pupilometer is presented.

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Purpose: This study aimed to quantify the light evoked pupillary response using an eye tracker based pupilometer and to assess its test-retest repeatability.

Methods: Fourteen healthy volunteers were recruited after a comprehensive ophthalmic evaluation along with conventional pupil assessment. Each subject was instructed to fixate at a red circular target projected by the pupilometer. Each eye was stimulated to induce pupil constriction and dilatation by implementing two cycles. First was a simultaneous stimulation of both eyes (light reflex) whereas the second cycle was an alternating stimulation (swinging flash cycle). Each eye stimulation was shielded from the fellow eye using dichroic mirrors. Gaze and pupil sizes were recorded using an Infrared based eye tracker (Tobii pro X3-120, Tobii Sweden).Each subject repeated the test within an interval of 24 hours and Bland Altman plots were used for assessing the test-retest repeatability for light reflex and swinging flash cycles.

Results: Twenty two eyes of eleven healthy subjects [male: female 4:7 with mean age 26.91 (SD 6.76) years] were included for the final analysis. Three subjects were excluded due to blink artifacts and unreliable data. Bland Altman plot showed low variability in both the test cycles across the measurement series. A mean (95 % CI) PD difference of 0.09 (0.35 to -0.18) mm was noted on dilatation and 0.04 (0.37 to -0.30) mm on constriction in light reflex cycle. Mean PD difference in swinging flash cycle was 0.01 (0.32 to -0.30) mm and 0.02 (0.35 to -0.31) mm for dilatation and constriction respectively.

Conclusion: Eye tracking technology successfully quantified pupil responses with low variability on repeated measures. Further refinement of the method by evaluating neuro ophthalmic and glaucoma cases can improve the clinical applicability of this technology.

4. Early detection and rehabilitation of visual processing dysfunctions in children born extremely preterm

Summary: A recent study with an eyetracking-based preferential looking paradigm showed evidence for visual processing delays at 1 year of corrected age (CA) in children born extremely preterm. In this presentation, follow-up data is presented at 2y CA in relation with structural brain damage.

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Purpose: Children born extremely preterm (<30 weeks) are at high risk of neurological damage and concurrent cerebral visual processing dysfunctions. With a recently developed method based on eye tracking, functional visual processing can nonverbally be assessed. A recent study with this method showed evidence for visual processing delays at 1 year of corrected age (CA) in children born extremely preterm. The aim of the present study was to follow functional visual processing in these children up to 2y CA, and to examine the relation with structural brain damage.

Methods: We included 91 children born extremely preterm at 1y CA. 40% of them did not show brain damage on MRI at 30 weeks, the other 60% had evident brain damage. 40 children were assessed again at 2y CA. At both occassions we quantitatively measured viewing reaction times to specific visual information (form, color, motion, contrast) using an automated eye tracking-based paradigm.

Results: The majority of children born extremely preterm showed delayed reaction times to various types of visual information at 1y and 2y CA. Preterm children with brain damage had significantly slower reaction times to color, form and motion at both occassions than children without brain damage.

Conclusion: We showed evidence for delayed visual processing up to 2y CA in children born extremely preterm. Neonatal brain damage was a risk for stronger delays, particularly in cerebrally mediated visual processing functions. Now that the early detection of visual processing delays has become highly feasible, the next step is to provide affected children with support. In a multidisciplinary care chain, we are currently designing and evaluating early visual rehabilitation programs starting at 1y CA.

Jan Koopman

Summary: A communication system based on eye movements may facilitate people, who are not able to use verbal communication, e.g. people with ALS, RETT-syndrome or people with multiple disabilities. In this presentation, an eyetracker-based method is presented to assess the orienting behavior of a client. The results can be used to provide practical recommendations for the use of an eyetracker-based communication system.

Another open abstract is included in symposium