Kongsberg Vision Meeting 2010: Abstracts

Kongsberg Vision Meeting was arranged at Buskerud University College in Kongsberg for the third time on October 8, 2010. Rigmor C. Baraas and Gaute T. Einevoll organized the meeting. Keynote speakers were Joseph Carroll from the Medical College of Wisconsin, Milwaukee (USA) and Espen Hartveit from Department of Biomedicine, University of Bergen, Bergen (Norway).

The abstracts from the talks are presented in the order they were given.

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Imaging the human retina – development and disruption

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Abstract

The human fovea underlies the majority of our visual function, including colour vision and high spatial acuity vision. In fact, the fovea occupies only about 0.02% of the total retinal area, but some 40% of primary visual cortex is devoted to processing signals from the fovea. The fovea is distinguished anatomically by an avascular zone, an increase in cone density (and absence of rods at the foveal centre), and an excavation of inner retinal neurons (resulting in the foveal "pit") (Hendrickson, 2005). How this structure develops, and how it is disrupted during aging and disease, remain fundamental unanswered questions in retinal neurobiology.

All forms of albinism involve significant ocular manifestations, including iris transillumination, macular translucency, photosensitivity, refractive errors, astigmatism, nystagmus, impaired stereopsis, altered retinostriate decussation, and reduced visual acuity (Summers, 2009). Albinism is an inherited disorder of melanin biosynthesis, associated with absent or reduced melanin pigment in the eye, and often in the skin and hair. In the US the incidence of albinism is about 1 in 17,000 (King, Oetting, Summers, Creel, & Hearing, 2007). While they can have relatively large amounts of phenotypic overlap, the multiple forms of albinism can readily be distinguished from one another via molecular analyses. Foveal manifestations of albinism can include absence of a foveal avascular zone (Abadi & Pascal, 1989) foveal hypoplasia (absence of a foveal pit) (Kinnear, Jay, & Witkop, 1985), and loss of an annular reflex (Lee, King, & Summers, 2001). There is ambiguity surrounding foveal anatomy in albinism, specifically with regard to foveal cone specialization (Fulton, Albert, & Craft, 1978; Marmor, Choi, Zawadzki, & Werner, 2008). Recently, we have made progress in examining this issue.

High-resolution ophthalmic imaging techniques like optical coherence tomography and adaptive optics ophthalmoscopy have literally changed the way we see the retina. Using these tools, we have uncovered remarkable variation in foveal anatomy in individuals with albinism, and this anatomical variation appears to qualitatively mimic the developmental time course of the foveal region (McAllister et al., 2010). In general, a qualitative nomenclature is often used to describe the fovea in albinism and related conditions. Foveal hypoplasia literally refers to the absence of a pit. However, it has been suggested that the negative functional connotations that accompany this term are reason for a different classification – fovea plana (Marmor et al., 2008). Neither of these qualitative terms universally applies to albinism, and they are inadequate descriptors to capture even the purely anatomical phenotype associated with albinism!

Advances in retinal imaging have also enabled us to examine the etiology of colour vision defects. We have assembled a collection of individuals with various genetic mutations that all result in some type of cone dysfunction (Carroll, et al., 2009; Carroll, Neitz, Hofer, Neitz, & Williams, 2004; Carroll et al., 2010). Given the involvement of a single genetic locus, we have begun to construct a high-resolution genotype-phenotype map for these conditions. As a result, our understanding of these conditions has improved – a requisite first step for identifying therapeutic opportunities for individuals with these disorders.

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Short- and long-term repeatability of measurements of the parapapillary retina taken with the Heidelberg Spectralis OCT

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Abstract

The Heidelberg SpectralisTM OCT with integrated gaze-control (TruTrackTM) is a spectral domain optical coherence tomograph that allows cross-sectional imaging of the retina. The purpose with this study was to investigate short- (ST-) and long-term (LT-) repeatability of parapapillary measurements and to investigate the effect of covariables on the repeatability.

37 normal healthy young (aged 20-35) volunteers participated. One randomly chosen eye from each subject underwent 5 repeated OCT-measurements by one observer on each of 3 sessions over a period of 28±2 days. TruTrackTM was activated after the first session to control for gaze.

The following scans and measurements were obtained: i) Circular scan (3.4 mm) centered at the papilla. Point measurements of the nerve fiber layer- (NFLT) and retinal thickness (RT) were obtained at 17 locations separated by 15 deg intervals temporally; ii) Twelve radial scans were centered at the papilla. Point measurements of RT were obtained 500 µm distal to the scleral ring at 18 locations.

Scans were graded for quality based on the IR-image and the OCT-scan. Measurements were graded according to the vicinity and size of blood vessels, deviation from a perpendicular section, and agreement between subjectively assessed and instrument defined retinal layers. Repeatability was analyzed using Coefficient of Repeatability [$CR = 1.96 \times \sqrt{2} \times MSRES$, where MSRES is the mean square residual from a one-way repeated ANOVA (Bland & Altman, 1999)] and mean Coefficient of Variability ($CV = \sum (SDIND/Mean \times 100)/n$) where SDIND is the SD of measurements within individuals and n is sample size). Repeatability within session (ST-repeatability) was based on 5 consecutive measurements for each of 3 sessions (A, B and C), whereas repeatability between sessions (LT-repeatability) was based on 1 selected measurement per session with the best possible image quality. Multivariate analyses were used to assess the effect of covariables on CV. The effect of exclusion of poorly defined retinal layers on ST- and LT-repeatability was investigated in post-hoc analyses. Repeatability [Median CR (range)]: i) Circular scan – NFLT: ST: Session A: 24.4 µm (14.3-57.4); Session B: 10.9 µm (7.6-25.6); Session C: 14.8 µm (7.3-50.5). LT: 10.6 µm (6.8-26.8). Circular scan – RT: ST: Session A: 20.2 µm (11.8-29.8); Session B: 14.4 µm (9.9-20.1); Session C: 14.9 µm (10.2-36.5). LT: 15.8 µm (10.4-23.2); ii) Radial scan – RT: ST: Session A: 24.6 µm (13.6-128.3); Session B: 26.9 µm (8.0-58.7): Session C: 29.1 µm (8.7-38.3). LT: 17.8 µm (9.3-152.6).

In multivariate analysis correctly defined retinal limits was the most prominent covariable, with significant outcome ($p < 0.05$) in both short- and long-term repeatability with both scanning patterns.

Results indicate that the built-in gaze-control of the Spectralis has a positive effect on the repeatability of measurement of the parapapillary retinal thickness and nerve fiber layer thickness. Correctly defined retinal layers by the analysis software are a condition for measurements with good repeatability and should be checked by the operator.

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Is global motion processing limited by increased contrast noise?

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Abstract

In normal ageing there is a significant reduction in motion sensitivity to global patterns using natural scenes (Falkenberg & Bex, 2007), or more commonly using gratings or random dots (Allen, Hutchinson, Ledgeway, & Gayle, 2010; Snowden & Freeman, 2004). Generally, older observers show elevated motion thresholds (e.g. motion coherence/speed/direction) depending on the level of contrast and type of stimuli. Several studies show that observers are limited by two factors; increased levels of internal noise and reduced levels of sampling efficiency, and that both these factors contribute to the motion sensitivity loss seen in ageing (Barlow, 1956; Falkenberg & Bex, 2007; Kerrigan-Baumrind, Quigley, Pease, Kerrigan, & Mitchell, 2000). Allen and

colleagues (2010) suggested that impairment of motion coherence thresholds (MCTs) with age is mainly due to deficits in contrast sensitivity (and as such increased internal noise), rather than deficits in motion sensitivity. However, MCTs cannot separate the effect of internal noise and sampling efficiency.

The aim of this study is to use an equivalent noise (EN) paradigm (Dakin, Mareschal, & Bex, 2005) to directly test whether the age-related impairment in motion processing of global patterns is limited primarily by internal noise or by reduced sampling efficiency. The first stage is to determine the performance of young observers before we examine the performance of older adults. Here, we present results from four young observers.

Observers were asked to estimate the average direction (leftward or rightward of vertical) of an upward moving group of band-pass dot elements. Direction discrimination thresholds were measured as a function of directional variance and level of contrast on a standard computer display. The direction of each dot was drawn from a Gaussian distribution whose standard deviation was either low (i.e. all dots moved in similar directions) or high (i.e. all dots moved in different directions). The Michelson contrast varied between 3% and 50%. The EN paradigm was used to estimate how the underlying changes in internal noise and sampling efficiency are affected by contrast.

Our results show that the direction integration to global motion patterns varied with contrast levels. We found that both the precision with which the direction of each dot can be estimated and the number of dots used to estimate the average direction of all the dots, decreased as contrast levels decreased.

The EN analysis supports previous findings that the reduced motion sensitivity to global motion patterns with low contrast levels is limited by both increased internal noise and reduced sampling efficiency. The next stage is to examine the performance of older adults. Our results suggest that older adults will not only show higher levels of internal noise (due to impaired contrast sensitivity with age), but also lower levels of sampling efficiency (due to gradual neural degeneration and loss).

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Electrical synapses between AII amacrine cells: function and modulation

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Abstract

The ability of the visual system to operate across a huge range of background light intensities represents a cardinal example of sensory adaptation. During a 24 hour day and night cycle, our eyes are exposed to intensities of light that vary by a factor of approximately 10^10. Our vision is fully operative throughout this range, despite the fact that the spike rate of retinal ganglion cells varies by only a factor of 10^2. The ability of the ganglion cells to cover this range is made possible through a series of mechanisms, both at receptor and post-receptor levels, which involve the tuning of specific retinal microcircuits. At the receptor level two different types of photoreceptors, rods and cones, mediate transduction, with different sensitivity to light. Rods and cones connect to two fundamentally different circuits in the retina: the rod and cone pathways. The two pathways share key cellular components and there is evidence that the switching between alternate processing pathways, active at different ambient light intensities, is mediated by regulating the strength of coupling of gap junctions serving as electrical synapses, thereby functionally optimizing the circuits for the background light intensity. These electrical synapses act both as primary connections in specific pathways and as substrates for signal averaging and noise reduction.

The presentation will review the functional properties of the AII amacrine cell, a retinal interneuron that plays an important role in visual signal processing in starlight, twilight, and daylight. The AII amacrine is a narrow-field amacrine cell with characteristic morphology and is a key cellular component in the link between the rod and cone pathways. Its dendritic morphology supports a distinct spatial segregation of synaptic inputs and outputs. The arboreal dendrites receive synaptic input via ionotropic glutamate receptors (iGluRs) from rod bipolar cells and are connected via electrical synapses to other AII amacrine cells and to axon terminals of ON-cone bipolar cells. The lobular appendages are the sites of inhibitory, glycinergic synapses to the axon terminals of OFF-cone bipolar cells, and can receive input via iGluRs from the same OFF-cone bipolar cells. When ambient light intensity falls below cone threshold, the cone pathway becomes non-functional. Visual signals from rods will now flow from rod bipolar cells to AII amacrine cells and be coupled into the ON- and OFF-cone pathways: via sign-conserving electrical synapses to the ON-cone bipolar cells and via sign-inverting inhibitory (glycinergic) synapses to OFF-cone bipolar cells and OFF-ganglion cells. There is also evidence that the electrical synapses between AII amacrines are subject to modulatory control, such that the strength of coupling is low in both darkness and under light-adapted conditions and maximal at intermediate intensities. The presentation will review current ideas concerning the cellular and molecular mechanisms that mediate this tuning of electrical coupling and the functional consequences for optimizing signal processing in the retina.

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Retinal function in relation to acute and chronic metabolic challenges

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Abstract

Retinal function responds to acute changes in the blood concentrations of glucose and oxygen. Generally, higher levels promote better function, as assessed by electroretinography (higher amplitudes and shorter latencies) or psychophysical methods (faster dark adaptation). Likewise, lower levels of circulating glucose or oxygen tend to suppress retinal function. Recently, we have found evidence that these acute effects are transient and their effect can be shown to be counter regulated if the perturbation of glycemia or oxemia persists (Holfort, Klemp, Kofoed, Sander, & Larsen, 2010; Klemp, Larsen et al., 2004; Klemp, Lund-Andersen et al., 2007; Klemp, Sander et al., 2005; Kofoed, Hasler et al., 2010; Kofoed, Munch et al., 2010; Kofoed, Sander et al.,2009). These new findings show that measures of retinal function need to be seen in the context not only of glycemia levels during the test, but also each subject's past glycaemia and oxemia history. Specifically, subjects living at high altitude have been shown to have higher electroretinographic amplitudes than lowlanders when both groups were examined at sea level. This supernormal characteristic of highlanders at sea level did not disappear within 72 days, despite normalization to sea level values of their haemoglobin and hematocrit values. Indication of similar long-term adaptational responses to changes in glycaemia in patients with diabetes has been found in multifocal electroretinography studies. Ongoing prospective studies examine the effects of persistent glycaemia reduction following initiation of insulin pump therapy in patients with diabetes.

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Modeling the receptive field of LGN relay cells as a sum over a transient and a sustained contribution

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Abstract

Processing in the visual system seems to generate coarse information before information about fine details. In the dorsal lateral geniculate nucleus (dLGN) the neurons have receptive fields (RF) with center-surround organization. Interestingly, the center size changes during presentation of a visual stimulus. We studied the dynamics of RF-center size of single LGN neurons during response to static spot stimuli briefly presented in the RF, and estimated center size from a series of spatial summation curves made for successive 5 ms intervals after stimulus onset. The results showed that the changes of center size during the stimulus period consisted of two parts with distinctly different spatiotemporal characteristics: an initial short-latency, transient and highly dynamic part characterized by pronounced shrinkage of the RF center, and a subsequent sustained part with only minor changes of RF-center width. The results suggest that the transient and sustained parts reflect contributions from two distinctly different neuronal mechanisms that operate in parallel with partial temporal overlap. Results from mathematical modeling further supported this conclusion. The modeling demonstrated that a new model, in which the response is given by a sum of an early transient component and a partially overlapping sustained component, adequately accounts for our experimental data.

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MATLAB GUI model for temporal signal processing in the lateral geniculate nucleus

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Abstract

A striking feature of the organization of the early visual pathway is the significant feedback from visual cortex to cells in the lateral geniculate nucleus (LGN). Despite numerous experimental and modeling studies, the functional role of this feedback remains unclear. To elucidate this question, we present a firing-rate model for LGN-relay cells tailored to probe the relative importance of feed-forward and feedback effects in shaping their temporal receptive field structure. The model for LGN-relay ON cells includes feed-forward excitation and inhibition (via interneurons) from retinal ON cells and excitatory and inhibitory (via thalamic reticular nucleus cells and interneurons) feedback from cortical ON and OFF cells. From a general firing-rate model formulated in terms of Volterra integral equations, we derive a single delay differential equation with absolute delay governing the dynamics of the system. A freely available and easy-to-use GUI-based MATLAB version of the LGN circuit model is presented. The program can be downloaded from https://bebiservice.umb.no/projects-public/cnsweb/wiki/Miscellaneous/Downloads. It ships with some example retinal response inputs, such as impulse responses, sinusoidal and box inputs. In addition the user can provide arbitrary inputs in own data files.

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Modelling primate colour vision: from retina to LGN and beyond

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Abstract

We have previously considered the coding of colour in terms of firing rates in the afferent pathway. How is this transformed from the retina to the lateral geniculate nucleus (LGN)? On the basis of LGN firing rates, we could model perceptual colour space satisfactorily. However, the spontaneous firing rate of a cone-opponent cell of the macaque LGN is generally much lower than that of its retinal input (the pre-potential or S-potential). Why is this so, and how does this affect colour coding?

The activity of the pre-potential must reach a certain level before the targeted LGN responds, a level we shall call the "activation threshold". The existence of an activation threshold clearly separates information between ON and OFF cells. For ON cells this threshold appears at relatively low to moderate intensities, whereas for OFF cells it is the differential response to higher intensities that is removed. But information from the retina is not lost. The gradation of the response that is lost for ON cells at low luminance can be provided by OFF cells, and that which is lost for the OFF cells at high luminance can be recovered by ON cells, with some overlap between them. Thus, the information that is not available for ON cells appears as excitation in OFF cells and vice versa. We will discuss the consequence of implementing an activation threshold in a model for the perception of opposite lightness/brightness and blackness dimensions of surface colours. We will also discuss the consequence of implementing an activation threshold in a general model for colour perception.

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The weighting of rod and cone inputs to retinal ganglion cells

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Abstract

Recently we published a paper which showed that rod and cone inputs to magnocellular ganglion cells were linearly summed prior to saturation site (Cao, Lee, & Sun, 2010). Here we used a recently developed technique (Sun, Smithson, Zaidi, & Lee, 2006) to further estimate the magnitudes of rod inputs to retinal ganglion cells at various retinal illuminance levels. Isolated rod or cone modulation was generated using a four-primary photostimulator (Pokorny, Smithson, & Quinlan, 2004). The stimulus was a uniform field of which the photoreceptor excitation was modulated around circumferences of three rod-cone planes (rod vs. chromatic, rod vs. luminance, and rod vs. S-cone planes) in clockwise and anticlockwise directions. The preferred response vector of each neuron was directly related to the relative weights of rod and cone inputs to the cell. The data showed that there was a clear shift of preferred vector as illuminance level decreases from 200 Td to 0.2 Td, reflecting increased relative rod inputs.

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Perceived distance ordering is not consistent with real space within an expanding virtual room

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Abstract
Even though many studies have demonstrated that there are distortions in visual space, the traditional view on space representation is a geometric one that assumes a one-to-one correspondence between real and perceived space. If there truly was such a single internal representation of space, then there should be a transitive ordering of distance relations, i.e. the relational order of distances of objects should be preserved. In the experiments reported here, we show that the perceived location of objects does not always follow a transitive ordering with respect to physical space. We demonstrate this in the unusual situation of an expanding virtual room (Glennerster, Tcheang, Gilson, Fitzgibbon, & Parker, 2006), which appears stable to observers despite large changes in size.

In an immersive virtual reality environment, observers in a brick-textured room viewed a square reference object in one interval and judged whether a comparison object in the second interval was closer or farther away. The observers viewed the scene binocularly through a wide field of view head mounted display and moved from side to side to generate motion parallax. The virtual room was visible throughout the trial and it either remained static or smoothly increased in size by a factor of 4 between intervals. The expansion of the room was arranged so that distance judgements could not be performed based on a single monocular view. All structural elements in the room remained the same retinal size with expansion. The target objects too had a constant retinal size and were placed either in the middle of the room or adjacent to the wall, where the effect of room expansion on distance judgements was greater (Svarverud, Gilson, & Glennerster, 2010).

Interleaving 4 different combinations of object location and room expansion presented in a random sequence, we determined the distances at which four pairs of objects were perceived to be at the same distance, allowing us to infer the relative perceived distance of two objects (O1 and O2) via two different intermediate objects. The scene expansion caused large biases in the distance matches between pairs of objects, with the magnitude depending systematically on the location of the objects in the scene. Although the viewing conditions for O1 and O2 were kept constant, the results showed that the ordering of perceived distances varied depending on the intermediate scenes. Specifically, we found that O1 was reliably seen in front of O2 when the judgement was made via one intermediate object, while in the same environment, O1 was reliably seen behind O2 when the judgement was made via another intermediate object. Thus, our results demonstrate a paradoxical, intransitive ordering of perceived distance and challenge the idea of a one-to-one relationship between real and perceived spatial locations and a single representation of perceived space.

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Pain induced by visually demanding VDU work: Association with muscle activity and muscle blood flow in orbicularis oculi

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Abstract
Eye strain during visually demanding VDU work may be related to increased muscle tension and changes in muscle blood flow in m. orbicularis oculi (Blehm,Vishnu, Khattak, Mitra, & Yee, 2005; Gowrisankaran, Sheedy, & Hayes, 2007). The aim of this study was to investigate the development of asthenopia in relation to muscle activity and muscle blood flow in m.orbicularis oculi during visually demanding computer work.

A group of healthy young adults with normal vision (14 females and 6 males, 22 ± 4 years (mean ± SD)) at the Department of Optometry and Visual Science at Buskerud University College was randomly selected. Symptoms of asthenopia were measured on visual analogue scales (VAS) during a two hour working session on a laptop with visual stress. During the working period muscle tension and muscle blood flow were measured in m.orbicularis oculi by electromyography (EMG) and photoplethysmography (PPG), respectively. The locations of the EMG electrodes and the PPG probe on m.orbicularis were 15 mm beneath the lower lid margin, on both eyes, on a vertical line intersecting the pupil. The reference EMG electrode was placed on the maxillary bone. The EMG signal was normalized by performing calibration of the EMG response to force. The 0.1 s intervals of the sampled EMG were ranked to produce an amplitude distribution function (ADF). Static and median load were defined as the ADF levels 0.1 and 0.5, respectively. Photopletysmography (PPG) is originally a non-invasive optical technique for measuring peripheral blood circulation like skin perfusion.

The PPG technique for non-invasive monitoring from deeper vascular compartments has been further developed by using an appropriate combination of optical wavelengths and distance between the light source and photo detector (Sandberg, Zhang, Styf, Gerdle, & Lindberg, 2005). In this study a special custom-designed optical probe (Department of Biomedical Engineering, Linköping University, Sweden) was developed and optimized for measurement of blood flow in the orbital part of the orbicularis oculi muscle. A p-value less than 0.05 was considered statistically significant.

During the two hours of visually demanding computer work there was a significant increase in several symptoms of asthenopia, such as pain in and around the eyes, watery eyes and blurred vision. The EMG measurements showed significantly increased and stable orbicularis oculi muscle tension during the working session compared with during rest. Orbicularis oculi muscle blood flow increased gradually during the first 30 min of the work session after which there was a decreasing trend in blood flow. When blood flow reached its maximum in m.orbicularis after 30 min, there was a significant positive correlation between the pain experienced and muscle blood flow. No significant correlation was seen between pain and muscle tension. These results may indicate an association between muscle pain and elevated muscle blood flow in m.orbicularis oculi.

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