Kongsberg Vision Meeting 2011: Abstracts

Kongsberg Vision Meeting was arranged at Buskerud University College in Kongsberg for the fourth time on December 2, 2011. Rigmor C. Baraas and Gaute T. Einevoll organized the meeting. Keynote speakers were Marianne Fyhn from the University of Oslo (Norway) and Almut Kelber from Lund University (Sweden). The abstracts from the talks are presented in the order they were given.

Neural processing and plasticity in visual cortex of behaving animals

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Abstract

The way in which we perceive the world is highly influenced by previous experience and state of mind. The response properties of neurons in primary sensory cortex remain malleable throughout life, and the existence of perceptual learning suggests that changes in primary sensory cortex such as the visual cortex may mediate learning. While much knowledge of sensory systems has been gathered from animals under deep anaesthesia, the next step in neuroscience is to perform such studies in animals interacting with their environment. Recent advances in imaging techniques and electrophysiological recordings in combination with genetic perturbations have opened the door for long-term studies of neuronal morphology and function in the brain of living animals. It has long been assumed that structural changes in complex brain circuits provide the basis for long-lasting effects of learning and other processes of activity-dependent plasticity. Synaptic connections are capable of undergoing rapid change in response to new experiences, and serve as substrate for long-term memories. The contribution of different cell classes to activity-dependent plasticity at a single cell level is poorly understood. Recent evidence from repeated in vivo imaging of neurons in adult neocortex suggests cell type-specific patterns of synaptic remodelling and that plasticity associated with learning may differ from that of sensory deprivation.

The aim of our laboratory is to reveal fundamental principles of activity-dependent plasticity and learning, and identify cell type-specific contributions to these processes. We study the dynamic plasticity of neural circuits at multiple levels from morphological changes of dendritic spines to functional changes of network activity in behaving animals. We use large-scale electrophysiological recordings of single units, two-photon laser-scanning microscopy, and genetic tools for cell type-specific genetic labelling and interference to understand how representations emerge from neuronal activity in brain circuits. In my talk, I will present the possibilities that lie in these techniques and show preliminary data from our newly established laboratory at the University of Oslo.

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Modelling the local-field potential footprint of thalamocortical inputs to sensory cortex

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Abstract

The spatiotemporal footprint of local-field potentials (LFP), i.e. electric potentials recorded by electrodes within the brain, of the thalamocortical (TC) synaptic connection following firing in individual thalamic projection neurons, can be accurately measured by averaging (spike-triggering) cortical multi-contact electrode (ME) LFP signals over thousands of spontaneous thalamic firings (Swadlow, Gusev, & Bezdudnaya, 2002; Jin, Wang, Swadlow, & Alonso, 2011). LFPs have the same biophysical origin as EEG recorded outside the brain, and as for EEG, the interpretation of the detailed spatiotemporal profile of this LFP footprint is not trivial. The LFP signal reflects a weighted sum of contributions from all ionic currents going in and out of neurons located in the vicinity of the ME (Pettersen, Hagen, & Einevoll, 2008), and it is difficult to infer the activity of individual cells from the recorded activity. The results presented are from a biophysically detailed computational model of this footprint, focusing on the postsynaptic responses in layer 4 of mammal sensory cortex (Swadlow et al., 2002; Jin et al., 2011). As thalamic projection neurons are found to project to both principal cells and interneurons, the model considers cortical populations of postsynaptic regular spiking (RS) cells and/or fast spiking (FS) cells. We have built a model implementation using the Python programming language with the NEURON simulator, constrained to produce plausible excitatory postsynaptic currents (EPSCs) (Hull, Isaacson, & Scanziani, 2009) and excitatory postsynaptic potentials (EPSPs). In addition to calculating the LFP footprint, the ground-truth current source-density (CSD), i.e. the spatial density of membrane currents in vicinity of the electrode, is also calculated and used to test CSD estimation methods (Pettersen, Devor, Ulbert, Dale, & Einevoll, 2006) used in analysis of these recorded LFPs. Candidate models mimicking experimental findings (Swadlow et al., 2002, Jin et al., 2011) will be presented.

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Rate dynamics of the retina-LGN connection

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Abstract

Firing-rate models provide a practical tool for studying the dynamics of trial- or population-averaged neuronal signals. The derivation or extraction of such models through investigation of the firing-rate response characteristics of ensembles of neurons has been the subject of several studies (see references in Nordlie, Tetzlaff, and Einevoll, 2010). The majority of these focused on neurons that receive input spikes at a high rate through weak synapses (diffusion approximation). For many neural systems, however, this assumption cannot be justified. A prime example is the lateral geniculate nucleus (LGN) in the early visual system, where synapses between retinal ganglion cells and relay cells are so strong that single retinal spikes can initiate action potentials in the thalamic targets. Using a comprehensive numerical approach, we recently studied the firing-rate response properties of leaky integrate-and-fire (LIF) neurons receiving current input through strong synapses (Nordlie et al., 2010). Input spike trains were modelled as inhomogeneous Poisson point processes with sinusoidally modulated rate. Average rates, modulation amplitudes, and phases of the period-averaged spike responses were measured for a broad range of stimulus, synapse, and neuron parameters. The resulting responses could be described well by a linear first-order low-pass filter over a wide range of model parameters. Combining this filter with the nonlinear response characteristic for stationary inputs, we constructed a linear-nonlinear firing-rate model, which accurately predicted the population response for a variety of non-sinusoidal test stimuli. In the present study, we use the same approach to investigate whether linear-nonlinear firing-rate models can capture equally well the firing rate properties of LGN relay neuron models fitted to experimental data (Carandini, Horton, & Sincich, 2007; Casti, Hayot, Xiao, & Kaplan, 2008). Since retinal input to the LGN has been shown to be more regular than a Poisson process (Troy & Robson, 1992), we also studied the effect of signal regularity. This is work in progress, but preliminary results indicate that the approach works well for the data-fitted models, and that the non-linearities in the stationary responses may predict where the linear-nonlinear filter model works for modulated responses and where not.

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Acknowledgements

Animal colour vision in dim light

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Abstract

Humans and most vertebrates loose colour vision when night falls and there is less than half a moon in the sky, and rely on colour-blind rod vision in dim light. We have shown that nocturnal animals with three different eye designs can use colour vision in very dim light: nocturnal hawkmoths that possess superposition compound eyes learn to associate flower colours with a food reward at starlight levels (Kelber, Balkenius, & Warrant, 2002). Nocturnal carpenter bees with apposition compound eyes learn the colour of landmarks at the nest entrance (Somanathan, Borges, Warrant, & Kelber, 2008). This is surprising because apposition eyes are not very light-sensitive, and spatial and/or temporal summation is needed to achieve colour vision in starlight. Finally, among vertebrates with lens eyes, nocturnal geckos use colour in dim light (Roth & Kelber, 2004). All of these animals rely on one set of photoreceptors for vision during day and night. We have also performed two case studies on the limits of colour vision. For the first of these studies, we chose the horse, a mammal with an arrhythmic life style that possesses both rods and cones in the retina. Horses have the largest eyes of all terrestrial mammals, and thus potentially highly sensitive vision. However, they loose colour vision at about the same light intensity as humans do (Roth, Balkenius, & Kelber, 2008). Anatomical and optical studies show that a single cone in the horse retina is just about as sensitive as a human cone. Thus, the similar absolute sensitivities of horse and human colour vision can be explained on the single cone level. Obviously, horse eyes are adapted to highly resolved but colour-blind rod vision in dim light. For the second study, we chose two species of parrot (Lind & Kelber, 2009). While budgerigars are obligatorily day-active, Bourke's parrot flies to water holes well before sunrise and after sunset. Still, we find that both of these bird species loose colour

discrimination abilities at brighter light levels than humans do. The reason may be that birds have two sets of cones. About half of their cones, red-sensitive double cones, are probably used exclusively for colour-blind spatial vision while the other half, 4 types of single cones, are used for colour vision. Single cones are likely to be less sensitive than double cones. While animals with only one set of photoreceptors can develop highly sensitive colour vision, we find that animals with two sets of receptors, such as most vertebrates, tend to sacrifice colour vision abilities in dim light (Kelber & Lind, 2010).

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The development of a pseudo-isochromatic grating stimulus

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Abstract

The aim was to develop a stimulus that can be used to study how the chromatic pathway processes spatial information without stimulating the luminance pathway. The stimulus was comprised of a Gabor patch with the spatial structure disrupted using spatially discrete spots whose size and spacing was varied. Spot luminance was randomized around a mean level, creating luminance noise. Each spot's chromaticity was determined by the mean colour of the region of the Gabor it covered. The space between spots was filled with a mean-luminance colour and, thus, no part of the underlying Gabor patch was visible in the stimulus, except that reconstructed by the chromatic pathway by grouping spots of similar hue. The principle of the design is similar to that used in pseudo-isochromatic tests. In this study, chromaticity of the Gabor patch was varied along the L- or M-cone axis in CIE 1931 (x, y) chromaticity diagram with mean chromaticity set to CIE illuminant E. Chromatic contrast sensitivity was measured at 12 spatial frequencies from 0.3-3.0 c/deg. Test stimuli were presen-

ted on a calibrated 22-inch CRT monitor. The following parameters were varied to find those that were optimal for examining spatial properties of the chromatic pathway (that is to make sure the gratings were effectively pseudo-isochromatic): range of luminance noise, Gabor size and spot size. A two-alternative forced-choice procedure was implemented and the contrast of the stimulus was altered using a single staircase method employing a three-down and one-up rule (3/1). Raw data from 3 × 80 trials were combined and fitted with a cumulative normal function by least chi-squares, in which the data are weighted by the binomial standard deviation calculated from the observed proportion correct and the number of trials tested at each level. The contrast thresholds were estimated from the 75% correct point of the psychometric function and 95% confidence intervals on this point were calculated with a bootstrap procedure, based on 1000 data sets simulated from the number of experimental trials at each level tested (Foster & Bischof, 1991). Preliminary results indicate that this stimulus allows us to measure spatial properties of the isolated chromatic pathway.

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How does speed affect sampling efficiency and internal noise in a motion discrimination task?

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Abstract

It is well-known that the visual system gets significantly less sensitive to global motion patterns as we get older. Commonly, older observers show elevated motion thresholds depending on the level of contrast and type of stimuli. In a global sensitivity task we have previously shown that old observers are worse at discriminating the direction of motion patterns compared to young observers, especially at low contrast (Bogfjellmo, Falkenberg, & Bex, 2011). Observers are mainly limited by two factors; increased levels of internal noise and reduced levels of sampling efficiency, and both these factors contribute to the motion sensitivity loss seen in ageing (Bogfjellmo et al., 2011; Falkenberg & Bex, 2007). It is also true that motion thresholds generally improve with increase in speed. Older observers tend to misjudge the speed of moving objects and require faster speeds to accurately discriminate the direction of moving patterns (Snowden & Kavanagh, 2006; Warren, Blackwell, & Morris, 1989). In this study we will investigate the direction discrimination of global

motion in ageing, and see how sampling efficiency and internal noise is affected by speed. 82 naive observers (aged 20-90 years) participated with informed consent. All observers had good visual acuities (better than 0.1 logMAR) with no ocular or co-existing medical conditions. Observers identified whether the overall motion of a group of upward moving band-pass dot elements was leftward or rightward of vertical in a 2AFC task with feedback. 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 very different directions). Direction discrimination thresholds were measured with various levels of added directional noise at two different speeds (5.6 and 1.5 deg/s) and four different contrast levels (4, 10, 20 and 30% Michelson contrast). Direction discrimination thresholds and 95% confidence intervals were estimated by Functional Adaptive Sequential Testing (Vul, Bergsma, & MacLeod, 2010), and collected separately for each speed and contrast level. Data from two runs were combined for each observer, and then averaged across age groups. An equivalent noise (EN) paradigm (Dakin, Mareschal, & Bex, 2005) was used to estimate how direction discrimination in ageing is limited by internal noise (i.e. raised directional uncertainty) and reduced sampling efficiency, and whether it changes with speed.

Our results show that speed does affect the ability to discriminate the direction of global motion. Direction discrimination thresholds were significantly higher for speed 1.5 deg/s compared to 5.4 deg/s ($p < 0.05$). This can be contributed to both increased levels of internal noise and reduced sampling efficiency ($p < 0.05$) across all ages. In this study we show that internal noise increases and sampling efficiency is reduced with age and low contrast ($p < 0.05$). This study confirms previous findings that direction discrimination in normal ageing can be contributed to an increase in internal noise and a reduction in sampling efficiency. In addition, this study shows that both these factors contribute to the further loss in performance seen with slow speed. We suggest that the increase in internal noise is caused mainly by loss in contrast sensitivity with age, and that age-related neural degeneration and loss cause sampling efficiency to decline further in older observers.

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Bright illusions

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Abstract

We recorded by use of an infrared eye-tracker the pupil diameters of participants while they observed visual illusions of lightness or brightness. Four original illusions (based on Kanisza's and Kitaoka's examples) were manipulated to obtain control conditions in which the perceived illusory brightness was either eliminated or reduced. All stimuli were equiluminant so that constrictions in pupillary size could not be ascribed to changes in light energy. We found that the pupillary diameter varied according to perceived brightness and lightness. Differences in local contrast information could be ruled out since in a second experiment, the observers maintained eye fixation in the centre of the display; thus, differential stimulation of the fovea by local contrast change could not be responsible for the changes in pupil size. Hence, the most likely explanation for the present findings is that pupillary responses to ambient light reflect the perceived brightness or lightness of the scene and not, simply, the amount of physical light energy entering the eye.

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A study of the effect of ocular accommodation on measurements of the parapapillary retinal thickness using the Heidelberg SpectralisTM OCT

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Abstract

Heidelberg SpectralisTM is a spectral domain optical coherence tomograph (SD-OCT) that provides in situ measurements of the human retinal thickness. Although high scanning frequency (40000 scans/s) and integrated active eye tracking image alignment (TruTrackTM) may contribute to the precision of thickness measurements in the macular and parapapillary retina (Lid, Morisbakk, & Lundmark, 2010; Morisbakk, Lid, & Lundmark; 2010) it is still uncertain to what extent the dynamics of ocular refraction may influence the measured thickness. Therefore, the purpose of this study was to investigate the effect of ocular accommodation on measurements of the parapapillary retinal thickness in young healthy adults. Twenty healthy young volunteers were included. Ametropia was < ± 6 DS and < 1 DC, logMAR acuity better than 0.0, and accommodation amplitude > 8 D. Five repeated circular scans (1536 A-scans/B-scan, 2-16 frames) centred at the papilla were obtained from the parapapillary retina of the left eye with SD-OCT (SpectralisTM, Heidelberg Engineering) while the subject used the right eye to fixate on a letter chart at 5.00 m, 0.50 m, 0.25 m and 0.17 m. All scans were performed with image alignment activated (TrueTrackTM). Concurrent measurements of accommodation were sampled

at 12 Hz from the right eye with an autorefractor (PowerRef II, Plusoptix). Acquisitions of SD-OCT scans were timed stamped in the recording of accommodation. All scans were performed in sequence on the same day by one experienced observer. Average thickness measurements in microns of the nerve fibre layer (NFL) were obtained from 6 sectors using the built in analysis software (Heyex v.5.3.2). Point wise measurements in pixels of the retina and NFL at one location between the major arcades of blood vessels in the inferior portion of the scan were obtained by analysis of the longitudinal reflectivity profile (LRP) of exported images using ImageJ (v.1.44p). Measurements of accommodation were averaged for 1 s starting at 0.4 s before the timed stamped SD-OCT scan. The effect of accommodation on thickness measurements was analyzed by linear regression where accommodation- and thickness measurements (relative to baseline at 5.00 m) were entered as independent and dependent variables, respectively. Relative accommodation was 0.0, 1.1 ± 0.6, 2.8 ± 0.9 and 4.7 ± 1.4 D for fixation at 5.00 m, 0.50 m, 0.25 m and 0.17 m, respectively. Average number of repeated SD-OCT scans with corresponding measurements of accommodation were: 5 at 5.00 m, 4.8 at 0.50 m, 4.4 at 0.25 m and 3.7 at 0.17 m. Regression analyses indicated that accommodative efforts were associated with slightly thicker SD-OCT measurements of the NFL in the superior sector of the papillary retina (relative thickness = + 0.2 micrometer / D relative accommodation, $p < 0.05$) and slightly thinner measurements of the NFL thickness in the inferior sector (relative thickness = – 0.3 micrometer / D relative accommodation, $p < 0.05$). Similar results were found for point-wise thickness measurements. Although the shown effect of accommodation is clinically negligible, it may affect the repeatability of measurements in subjects with unstable accommodation.

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Acknowledgements

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A Study of the Effect of Changes to the Scan Depth Setting on Measurements of the Foveal Thickness using the Heidelberg SpectralisTM OCT

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Abstract

Heidelberg SpectralisTM is a spectral-domain optical coherence tomograph (OCT) with integrated gaze-control (TruTrackTM). The instrument allows measurements to be obtained using scan-depth settings for eyes with axial length (AL) from < 22.5 mm to > 29.0 mm, however the effect of different settings on thickness measurements has not been investigated. Therefore, the purpose of this study was to investigate the effect of altering the scan-depth setting on measurements of the retinal thickness in central fovea of eyes with medium AL.

Nineteen healthy young volunteers were included. The test subjects had ametropia within < ± 6 DS and < 1 DC, logMAR acuity better than 0.0, and ocular AL 24.0 ± 2.5 mm (measured with IOLMaster, Carl Zeiss). Five repeated SD-OCT scans (two 15 deg radial scan, 768 A-scans/B-scan, 9 frames) were obtained from the fovea of each subject's right eye. All scans had image alignment (TruTrackTM) activated, and were obtained for each setting in the following order; scan-depth settings for eyes with short (S < 22.5 mm), medium (M: 24.0 ± 2.5 mm = default), long (L: 26.5–29.0 mm) and extra long (XL > 29.0 mm) axial lengths. Accommodation was suspended and pupils dilated with Cyclopentolate 1%. An experienced operator performed all the scans on the same day. Point-wise measurements of central foveal thickness (FT) defined as the distance between the reflexes of the inner limiting membrane and the retinal pigment epithelium/Bruch's membrane, were obtained from the section with best centring in the fovea using the built in analysis software (Heyex v.5.3.2). In addition, analyses of longitudinal reflectivity profile were carried out post-hoc on exported TIF images using ImageJ (v.1.44p). Limits of FT for the first reflectivity profile, LRP1, were defined as the central location of the border as indicated by Heyex. For the second reflectivity profile, LRP2, the coordinate with highest reflectivity and lowest pixel-value was defined as the inner retinal limit. The outer retinal limit was defined as the highest reflectivity with the highest pixel-value. For both LRP1 and LRP2 the measurements were based on average thickness of three adjacent sections. Average FT in microns from Heyex' analysis and FT in pixels from LRP1 and LRP2 was compared for each scan-depth setting by repeated measure analysis of variance (ANOVA).

Mean AL for eyes analyzed (n = 19) was 23.54 mm ± 0.77 (range 22.06-24.62 mm), while mean FT in microns analyzed with Heyex software were 220.1 ± 14.1, 220.0 ± 14.3, 219.9 ± 14.0, and 219.7 ± 13.3 μm for scan-depth settings S, M, L and XL, respectively. Repeated ANOVA indicated no significant effect of the scan-depth setting on FT analyzed with Heyex (p = 0.74), LRP1 (p = 0.71) or LRP2 (p = 0.95).

Results indicate that different scan-depth settings with Heidelberg Spectralis SD-OCT have no effect on measured central foveal thickness in eyes with axial lengths that are within the range of the default setting (Medium) analyzed with Heyex, LRP1 and LRP2. The subjective method of defining retinal limits (LRP2) tended to have higher variation.

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