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Abstracts

The meeting was organised by Giovanni Cioni (Stella Maris Scientific Institute and INPE University of Pisa, Pisa, Italy) in cooperation with David Burr, Adriana Fiorentini, and Concetta Morrone (Institute of Neurophysiology, CNR, Pisa, Italy); e-mail: cioni@inpe.unipi.it

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OPENING SESSION

◆ **The autonomy of the visual areas of the human brain and the modularity of consciousness**
S Zeki (Wellcome Department of Cognitive Neurology, University College London, London WC1E 6BT, UK)

The most fundamental function of the visual brain is to acquire knowledge about the constant, essential, properties of the visual world, in conditions in which the information reaching the brain is never constant from moment to moment. This requires the brain to undertake complex operations on the incoming visual signals, discounting all that is not essential for it to acquire knowledge about the world, selecting that which is important and subjecting the latter to operations that make the brain independent of the continually changing and nonessential information reaching it. One strategy that the brain uses in undertaking this task is that of functional specialisation, through which different essential features, such as motion and colour, are extracted in specialised and geographically distinct visual areas lying outside the primary visual cortex area V1. Our recent psychophysical experiments show that, just as the processing systems for different attributes of vision are separate, so are the final perceptual systems, since different attributes of the visual scene such as colour, form, and motion are perceived at different times, with colour leading motion by about 80 ms, which brings about perceptual asynchrony in terms of real time. The end-result of the operations in these individual areas is the acquisition of knowledge. But knowledge can only be acquired in the conscious state. A conscious awareness is therefore the corollary of activity in the specialised visual areas. Recent experiments in which imaging and time resolution methods as well as patients blinded by lesions either in V1 or in more extensive parts of the visual cortex have been used show that the activity in one or a small number of visual areas, without involvement of V1, can give rise to both conscious experience and a crude knowledge about the visual world. This leads us to the conclusion that consciousness itself may be modular.

[The work of our laboratory is supported by the Wellcome Trust, London.]

ORAL PRESENTATIONS

EYE MOVEMENTS

◆ **Development of the optokinetic system in macaque monkeys**

C Distler, K-P Hoffman, F Vital-Durand¶ (Allgemeine Zoologie und Neurobiologie, Ruhr-Universität Bochum, Postf. 102148, D 44780 Bochum, Germany; ¶ INSERM U371 Cerveau et Vision, F 69500 Bron, France)

Using electrooculography we for the first time investigated quantitatively the development of the horizontal optokinetic nystagmus (OKN) in baby monkeys. Six macaque monkeys (*Macaque fascicularis*) were studied longitudinally on a weekly basis during the first four months of life. Eye movements were recorded during monocular and binocular whole-field stimulation with bright dots of varying size moving in clockwise or counterclockwise direction at velocities ranging from $10^\circ\ s^{-1}$ to $120^\circ\ s^{-1}$. The data were compared to findings in two normal adults measured in the same setup. At low stimulus velocities ($10^\circ\ s^{-1}$ and $20^\circ\ s^{-1}$), monocular OKN was largely symmetrical already at about 3 – 5 weeks of age, ie stimulation from nasal to temporal (null direction) was almost as effective as stimulation from temporal to nasal (preferred direction). By contrast, steady state monocular OKN was much more asymmetric at higher stimulus velocities ($40^\circ\ s^{-1} - 120^\circ\ s^{-1}$), ie temporal to nasal stimulation elicited higher gain OKN than stimulation from nasal to temporal. Symmetry at higher stimulus velocities was reached at 3 months of life ($40^\circ\ s^{-1}$) or even later ($80^\circ\ s^{-1} - 120^\circ\ s^{-1}$). This increase in symmetry was largely due to a stronger increase of eye velocity in response to stimulation in the null direction. The gain of OKN continued to increase slightly, especially at higher stimulus velocities, even at the end of the period investigated. The largely symmetrical OKN at low stimulus velocities can be explained by the bilateral retinal input to the subcortical OKN pathway present in primates. By contrast the slower development of symmetry at higher stimulus velocities may be related to the maturation of the cortical pathway for motion analysis.

[Supported by a Lise Meitner stipend to C Distler.]

◆ **Directional biases of monocular visual motion processing in young infants**

J Wattam-Bell, R Andrew (Visual Development Unit, University College London, London WC1E 6BT, UK)

The asymmetry of monocular optokinetic nystagmus (mOKN) in young infants is well known: mOKN is more readily elicited by nasalwards than by temporalwards motion, especially at higher velocities. Traditionally, this has been assumed to reflect asymmetrical motion processing in a subcortical pathway involving the nucleus of the optic tract. More recent evidence, however, suggests that directional asymmetries in cortical motion processing may also be involved. If so, then it is possible that these asymmetries affect all aspects of motion processing in young infants, and not just the control of smooth eye movements, and will appear in other behavioural responses—eg fixation preference in forced-choice preferential looking (FPL). The experiment described here examined this. 16 infants 6 – 10 weeks old were presented in an FPL experiment with a pair of random-dot patterns separated horizontally by 15 deg. One pattern moved rightwards, the other leftwards, at 18.8 deg s^{-1}. The infants viewed the patterns monocularly. 2 of the infants had both eyes tested, the remainder 1 eye only. Results were obtained from 8 right and 10 left eyes; the mean number of trials per eye was 24.8 (range 9 – 36). Overall, infants preferred nasalwards motion in 60.7% of the trials. Though modest, this was significantly greater than 50% ($t = 3.4$, $p < 0.005$), and quite consistent across subjects: 14 out of the 18 eyes tested showed a nasalwards preference. mOKN was also assessed in 12 of the infants, again with the use of a forced choice procedure. The infants showed the expected asymmetry: nasalwards stimulus motion elicited appropriately directed OKN in 89% of trials, compared with 34% for temporalwards motion. These results suggest that a nasalwards directional bias is a general characteristic of motion processing in young infants which extends beyond the pathways responsible for OKN.

[Supported by Medical Research Council programme grant G7908507.]

◆ **OKN asymmetry in infants and children with early-onset esotropia**

C A Westall¶#, M Eizenman¶, S Kraft¶# (¶ Department of Ophthalmology, University of Toronto; # Department of Ophthalmology, Hospital for Sick Children, Toronto, M5G 1X8, Canada)

The purpose of this study was to investigate (1) the effect of age, (2) the effect of sensory fusion, and (3) the effect of surgical correction of esotropia on OKN asymmetry in infants and children with early-onset esotropia. Subjects were 14 children with early-onset esotropia (8 months to 7 years) and 8 children with normal visual development (6 months to 7 years). 4 children were tested before and after surgical correction of esotropia. Monocular OKN was recorded with Ag – AgCl electrodes in response to a 40 deg s^{-1} square-wave grating (0.2 cycle deg^{-1}). Slow-phase eye velocity (SPV) of OKN

was calculated for each child. OKN asymmetry was defined as [(mean nasalward SPV OKN−mean temporalward SPV OKN)/(mean nasalward SPV OKN + mean temporalward SPV OKN)] × 100. Total OKN asymmetry (no response to monocular nasalward to temporalward motion) equals OKN asymmetry of 100. Symmetrical OKN (equal monocular temporalward and nasalward OKN SPV) equals OKN asymmetry of 0. Sensory fusion was assessed with visual evoked potentials (VEPs) to dynamic random-dot correlogram after the angle of strabismus was corrected with prisms.

There was an inverse correlation between OKN asymmetry and age of children with early onset esotropia: asymmetry values were close to 100 (range 90 – 100) in those less than 3.5 years of age, while OKN asymmetry values in those over 4 years of age ranged from 65 to 80. There was no correlation between OKN asymmetry and VEP fusion. 6 children with early-onset esotropia showed significant VEP fusion. OKN asymmetry in these children (range 70 – 100) was no different from OKN asymmetry in children with no evidence of VEP fusion (range 65 – 100). There was no effect from surgical correction of esotropia on OKN asymmetry. It is concluded that (i) OKN asymmetry is greater in children with early-onset esotropia less than 3.5 years of age compared with those over 4 years of age; (ii) OKN asymmetry is not related to the presence of sensory fusion in esotropia; (iii) OKN asymmetry is not affected by surgical correction of the strabismus.

[Supported by Medical Research Council (Canada) grant MT-9624.]

◆ **Visual pursuit in infants**

D Lengyel, S Weinacht, J Charlier¶, I Gottlob (Department of Strabismus and Neuroophthalmology, Kantonsspital St Gallen, Switzerland; ¶ U279 INSERM, Lille, France)

There are few investigations of smooth pursuit in infants, and the results are conflicting. The aim of our study was to quantify visual pursuit in infants between 1 day and 16 weeks of age. Eye movements of 97 healthy infants between 1 day and 16 weeks of age were recorded 1 to 7 times (total of 305 examinations), by the infrared photo-oculographic technique. For stimulation of visual pursuit a 9.4 deg × 9.4 deg square with vertical gratings (0.1 to 0.8 cycles deg^{-1}) moved at a constant velocity of 7.5 deg s^{-1} for 38 s. In the first two weeks of life, periods of smooth pursuit up to a velocity of 7.93 deg s^{-1} (mean 5.47 deg s^{-1}, SD 2.04 deg s^{-1}), with a mean gain of 0.73 (SD 0.27) and a duration up to 3.16 s (mean 1.94 s, SD 0.80 s) were measured. In the sequential recordings no significant increase of these parameters was found [at 15 to 16 weeks: mean velocity 4.69 deg s^{-1} (SD 1.47 deg s^{-1}), mean gain 0.63 (SD 0.20), and mean duration 2.56 s (SD 0.85 s)]. However, the total time the subjects followed the stimulus (smooth plus saccadic pursuit) increased significantly ($p < 0.005$) with age (in the first two weeks of life: maximum of 30 s, mean 16.82 s, SD 9.05 s; at 15 to 16 weeks: maximum of 36 s, mean 23.88 s, SD 8.02 s). Thus we have demonstrated that smooth pursuit is already present in the first two weeks of life. We found no significant increase in velocity, gain, and duration in the first 16 weeks of life.

[Supported by the Schweizerischer Nationalfonds (No.32-31317-91, No.32-43233-95) and the OPOS Foundation, None.]

◆ **The development of the ability to disengage gaze**

P R Butcher, A F Kalverboer (Experimental Clinical Psychology, University of Groningen, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands)

Very young infants pass through a period in which they have great difficulty shifting their gaze from a fixated object to an equally salient stimulus in the periphery. Frequency of shifts in gaze is one component of most early measures of the quality of infant – mother interaction. Frequency and duration of gaze shifts to and away from a stimulus are also routinely used as an index of the quality of early information processing. However, as yet little is known about the emergence of the ability to shift gaze flexibly around the visual environment.

We report here the results of a longitudinal investigation of the emergence of ability to shift gaze from a central stimulus to fixate a peripheral target. 12 infants carried out a looking task at 2-weekly intervals from 6 weeks to 6 months of age. A brightly coloured moving pattern was presented on a central monitor. When the infant fixated the pattern, a second pattern was presented for 5 s, 30 deg to the left or the right. We found that at 6 weeks the infants looked from the central pattern to the peripheral target on 8% of the trials (range 0% – 15%). By 18 weeks of age they did so on 98% of the trials (range 95% – 100%). The age at which consistent looking to the target was first observed ranged from 8 weeks to 12 weeks. Some infants showed regressions in frequency of disengagement. We conclude that: (i) from the age of 14 – 16 weeks most infants can move their gaze flexibly between highly salient visual stimuli; (ii) the maturation of both overt and covert visual attentions systems is involved; (iii) procedures which rely on shifts in gaze to index information processing or communication made before this age will also be measuring the development of the visual attention systems in some subjects.

◆ **Accurate multiplanar eye-movement recordings in infants and young children with inborn ocular motor disorders: a modified DMI approach and a new 'ABC' scleral search coil**
P Apkarian, L J Bour¶, H Coliewijn, J T H N de Faber# (Department of Physiology, Erasmus University Medical Faculty, Rotterdam, The Netherlands; ¶ Department of Neurology, Academic Medical Centre, Amsterdam, The Netherlands; # Rotterdam Eye Hospital, Rotterdam, The Netherlands)

The main objective in the present study was to describe accurately and evaluate ocular motor profiles in paediatric patients with various infantile ocular motor disorders. The neuro-ophthalmogenetic patients tested ranged in age from 3 months to 6 years; the clinical test group included albino patients and those with idiopathic congenital nystagmus (CN). Left and right eye ocular motor characteristics were evaluated in a series of both longitudinal and cross-sectional studies. To facilitate assessment of visual pathway integrity, organisation, and maturation, as well as to confirm clinical diagnosis, multichannel visual evoked potential (VEP) testing also was implemented. For the ocular motor studies, eye movements in the horizontal and vertical planes were evaluated with a double magnetic induction method (DMI); the gold plated metallic DMI rings were custom-designed for immature corneal and scleral curvatures. A new 'ABC' coil, a modification of the classic scleral search coil, was also assessed. Full evaluation and implementation of the latter is now in progress. Interestingly, preliminary DMI recordings in patients with CN (idiopathic or concomitant with albinism) revealed classic CN wave forms in the horizontal planes together with the presence of well-defined foveation periods for even the youngest infants; CN wave forms and refixation saccades also were conjugate. In general, the 'ABC' scleral search coil technique is favoured over the DMI method as the former allows three-dimensional ocular motor recordings (horizontal, vertical, and torsion) and is also less sensitive to head and body movement artefacts. Our preliminary results suggest that more-accurate multiplanar recordings in paediatric patients, as described, are viable and also provide the opportunity to better understand, define, and diagnose inborn eye-movement anomalies and their maturational course.

DEVELOPMENT OF VISION

◆ **Development of the outer retina in monkey and man**
A Hendrickson, K Bumsted (Departments of Biological Structure and Ophthalmology, University of Washington, Seattle, WA 98119, USA)

A comparison of neuronal circuits, opsin amino acid sequences, and cell morphology in the adult retina argues that primate photoreceptors should be divided into three systems: (1) rods (R), (2) S cones, and (3) M or L cones. We have examined the developmental sequences of opsin expression and synapse formation in fetal monkey retinas to further test this idea. Opsin expression was studied in fetal macaque monkey with the use of specific mRNA probes or antisera generated from human sequences. The earliest opsin was R which appeared in and around the fovea at fetal day (Fd)66. This was followed by the simultaneous appearance at Fd75–77 of S or L/M in foveal cones. Outside the fovea opsin was expressed at different rates such that R was always found most peripherally followed closely behind by S with L/M the last to appear at each retinal eccentricity. All reached the retinal edge by Fd155. No photoreceptor double-labeled for more than one opsin at any stage of development. In both rods and cones, opsin expression was coincident with the initial stages of outer segment formation. There was a striking difference between the distribution of S cones in human and monkey fovea throughout development. Adult humans had a central 100 μm zone free of S cones while adult monkeys had a low density of S cones across the central fovea. This difference was apparent by midgestation, suggesting that it was regulated by early developmental events. Three different sequences of photoreceptor synaptic development were observed. Rods lacked obvious synapses for some time (3–4 weeks?) after opsin and outer segments were present. S cones demonstrated synapses and opsin within days of each other, while L/M cones formed synapses 2 weeks before opsin was expressed. Both opsin expression and synaptic formation developmental patterns indicate that R and L/M cones are distinctly different neural circuits, while S cones show characteristics of both.
[Supported by EY04536 and Research to Prevent Blindness, Inc.]

◆ **Infant visual cortex function evaluated by fMRI**
P Born¶§, E Rostrup¶, H B W Larsson¶, H Leth¶#, M Miranda¶#, B Peitersen#, H C Lou§ (¶ Center for Magnetic Resonance and # Department of Pediatrics, Hvidovre Hospital, Denmark; § The John F Kennedy Institute, Department of Neuropediatrics, DK-2600 Glostrup, Denmark)

With functional magnetic resonance imaging (fMRI) it has now become possible to noninvasively study the response of the visual cortex in infants from birth. We studied 30 infants from 28 weeks prematurity to 36 months of age; 8 were suspected for visual functional deficit, the others were

recruited from the neonatal unit or had clinical MRI scans performed as outpatients for conditions unrelated to visual function; 2 infants were healthy. All infants older than 6 weeks were sedated with chloral hydrate 100 – 150 mg kg^{-1}; they were clinically in quiet sleep during the examination. Visual stimulation was applied by a 8 Hz stroboscopic light administered through the sleeping infants' eyelids. Examinations were performed on a 1.5T Siemens Vision scanner with the use of a T2* weighted echoplanar sequence. 12 infants had to be excluded owing to motion; of these, 10 were unsedated newborn infants. In 17 infants, aged 5 days to 36 months, visual cortex activation could be demonstrated as areas of signal decrease in contrast to the signal increase usually seen in adults. Of these, only 3 infants were unsedated. 1 mature newborn infant showed no response. In the younger infants without visual functional deficit, the area of activation was smaller and located more anterior in the visual cortex compared to the older infants. In 2 infants with unilateral damage to the optic radiation on structural MRI, unilateral activation was seen. In 1 infant with widespread porencephalic degeneration including the extrastriate areas, the primary visual cortex responded as it did in the control infants. Activation following visual stimulation can be reliably studied in infants from birth; sedation seems necessary. The inverse BOLD response seems to be the normal response pattern of the infant brain; we suggest that it is caused by a greater relative increase of oxygen consumption than CBF. Functioning visual cortex can be detected following brain damage. The implications of these findings for later visual performance have to be assessed.

◆ **Visual noise masking and the development of VEP contrast sensitivity in infants**

A M Skoczenski, A M Norcia (Smith-Kettlewell Eye Research Institute, 2232 Webster Street, San Francisco, CA 94115, USA)

Contrast masking studies provide insight into how the visual system varies its sensitivity according to the prevailing contrast. We attempted to answer the question whether very young infants who have deficits in contrast sensitivity relative to adults also have immaturities in contrast gain control mechanisms. We measured VEP contrast responses in 30 infants ranging in age from 7 to 30 weeks, and in 5 adults. The stimulus was a 5.5 Hz phase-reversing vertical sine-wave grating (1 cycle deg^{-1}) whose contrast was swept logarithmically; it was presented alone or with a two-dimensional dynamic noise mask (update frequency = 33 Hz). We recorded the amplitude and phase of the VEP response to the grating in various stimulus noise contrast conditions, and estimated contrast threshold by fitting a regression line to the linear portion of the VEP contrast response function and extrapolating to zero microvolts.

The stimulus noise was found to be an effective masker for all subjects: it elevated threshold, and shifted the contrast response functions in a parallel fashion. Compared with adults, infants had higher contrast thresholds in the no-mask condition, and their thresholds were affected relatively less by the stimulus noise masks. We estimated the threshold for masking as the mask contrast needed to elevate contrast threshold by 3 dB, and found that it was approximately 4 times higher in the youngest infants than in adults. This was similar to the contrast threshold difference between infants and adults. In order to better understand species similarities and differences in contrast processing, we compared human data with data collected earlier from young infant monkeys under equivalent experimental conditions. Human and monkey infants exhibited similar rates of contrast sensitivity development, and comparable thresholds as a function of age. In addition, both species showed a similar relationship between contrast threshold and threshold for masking. We conclude that, in spite of significant immaturities in contrast sensitivity, very young infants may possess contrast gain control mechanisms similar to adults.

[Supported by NIH EY06579, and a Rachel C Atkinson Fellowship.]

◆ **The development of spatial-frequency covariance channels for colour and luminance: psychophysical (FPL) and electrophysiological (sweep-VEP) studies**

D H Peterzell, S K Chang, J P Kelly, A L Hartzler, D Y Teller (Department of Psychology, University of Washington, Seattle, WA 98119, USA)

The purpose of these experiments was to investigate the spatial channels underlying contrast sensitivity functions (CSFs) for luminance-modulated and red/green (r/g) chromatic sine-wave gratings, in adults and infants. CSFs were measured on 10 adults (luminance-defined and isoluminant r/g gratings, within-subject, with the use of alternative forced choice), and on 22 infants 4 months old (r/g gratings only, with the use of forced-choice preferential looking). Spatial frequencies ranged from 0.27 to 2.16 cycles deg^{-1}. CSFs were also measured in adults and in infants 2 to 8 months old, with the use of luminance-modulated and isoluminant r/g gratings (0.3 to 8 cycles deg^{-1}, 6 Hz). Over 20 subjects participated at each age. Thresholds were estimated by means of swept-contrast VEP methods. A covariance (individual differences) analysis was performed for each experiment. We computed statistical sources of individual variability, used them to define covariance channels, and determined the number and frequency tuning of these

channels. Adults' CSFs for luminance-defined stimuli contained two covariance channels, while their CSFs for colour stimuli contained only one. The single channel serving adults' colour CSFs was also the low-frequency channel (<0.75 cycles deg $^{-1}$) underlying their luminance CSFs. Infants' colour CSFs contained 3 covariance channels. VEP CSFs for colour and luminance contained multiple (2 or 3) covariance channels at all ages. The channels appear to be independent for colour vs luminance, and to shift in scale to higher spatial frequencies with age, at similar rates for colour and luminance.

Our conclusions are as follows: (1) Only one channel underlies adults' psychophysical detection of all chromatic stimuli up to 2.16 cycles deg^{-1}, and this channel also detects luminance-modulated stimuli at very low spatial frequencies. Above 0.75 cycles deg^{-1}, adults' detection of luminance-defined and r/g stimuli is served by separate, independent spatial-frequency-tuned covariance channels. (2) Infants have multiple frequency-tuned covariance channels underlying their CSFs for both colour and luminance. (3) With maturity, the low-frequency channels either disappear or (more likely) shift in scale to higher spatial frequencies. These shifts in scale may coincide with developmental cone migration into the fovea and growth in eye size.

[Supported by NIH grants EY04470 and EY06706.]

◆ **The chromatic onset visual evoked potential (VEP): longitudinal development during the first postnatal year**

M A Crognale¶#, J P Kelly¶, A Weiss#, D Y Teller¶ (¶ Department of Psychology, University of Washington, Seattle, WA 98119, USA; # Department of Ophthalmology, University of Washington School of Medicine, Seattle, WA 98119, USA)

Previous research on adults has shown that a VEP onset paradigm, in conjunction with the use of low-spatial-frequency chromatic gratings, produces large and relatively simple chromatic VEP responses, with a single negative peak at about 150–200 ms. We used this paradigm to trace the development of onset VEPs to luminance-modulated and isoluminant chromatic stimuli. In order to trace changes in the VEP waveform over time within individual subjects, individual infants are being tested longitudinally. Patterns were 0.5 cycle deg^{-1} sinusoidal gratings presented in an onset mode (200 ms on; 800 ms off) on a CRT. Colours were modulated through white in a cone activation colour space along directions which selectively activate the achromatic or one of the two early opponent [L/M, S/(LM)] mechanisms. The maximum available instrument contrast was used for each colour direction. In addition, in order to match the rms cone contrasts of the achromatic and red/green gratings, achromatic stimuli of 14% contrast were also tested. To date, VEPs have been recorded from 3 infants at frequent intervals from 1 week to 10 or more months postnatal. For achromatic gratings, reliable onset VEP responses were obtained at 1–2 weeks for 100% contrast, and at 4 weeks for 14% contrast. Amplitudes were highly variable across subjects, but peaked at about 8–9 weeks. Latencies showed little variability across subjects, and decreased steadily with an asymptote near adult levels at about 12 weeks of age. In contrast, the waveforms of the early chromatic responses bore little resemblance to the adult waveforms. The chromatic waveforms evolved gradually through a complex series of changes that displayed some regularity across subjects; but the adult form of the chromatic response, with a negative peak [trough] at about 170 ms, did not appear at any time during at least the first 10 months postnatal. Infant chromatic waveforms after 10 months had multiple components and were largely triphasic. The latencies of none of these components agreed with predictions from the adult data. Collection of further longitudinal data on these and additional subjects is in progress.

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◆ **3-month-old infants respond to quadrature motion of isoluminant gratings**

B Lia¶, K R Dobkins§, A Hartzler¶, J Palmer¶, D Y Teller¶# (¶ Department of Psychology and # Department of Physiology/Biophysics, University of Washington, Seattle, WA 98119, USA; § Department of Psychology, University of California at San Diego, La Jolla, CA 92093, USA)

In adults, ratios for motion discrimination threshold to detection threshold ($M:D$) are 1:1 for luminance-defined stimuli, but elevated for isoluminant stimuli. In infants, both are near 1:1. For this and other reasons, we hypothesised that infant detection thresholds for moving chromatic stimuli might be mediated by the response of a luminance mechanism to colour-defined borders. To test this hypothesis, 3-month-old infants were tested with quadrature-shifted gratings, for which such border cues are directionally ambiguous. Stimuli were 0.25 cycle deg^{-1} luminance-defined and isoluminant red/green chromatic sinusoidal gratings, moving at 22 deg s^{-1} (5.6 Hz). We measured direction-of-motion thresholds using directionally appropriate eye-movement (DEM) judgments and detection thresholds using forced-choice preferential looking (FPL) methods. Both continuous motion (C) and 90° phase-shifted quadrature motion (Q) were used.

Infant discrimination thresholds were slightly elevated for Q vs C for both luminance-defined and isoluminant stimuli. Detection thresholds were about equal for Q vs C for both luminance-defined and isoluminant stimuli. As expected, in an $M:D$ paradigm, discrimination : detection ratios were elevated about equally for both luminance-defined ($\sim$1.6) and isoluminant ($\sim$2.0) stimuli. In sum, infants exhibit a small, but general deficit for discrimination of quadrature motion. Because 3-month-old infants code the direction of motion of isoluminant quadrature-shifted stimuli, we conclude that luminance channel signals arising from colour-defined borders are not necessary to allow coding of the direction of motion of isoluminant stimuli at this age.
[Supported by NIH EY06671, EY06527, and EY04470.]

◆ **Late development of preference for the 'least salient' object in a visual scene**
R Sireteanu, I Encke (Max Planck Institute for Brain Research, D 60528 Frankfurt a.M., Germany)

Attentive adult observers perform equally well for both the 'most salient' and the 'least salient' item in a display; however, when their attention is engaged in a concurrent task, performance for the 'least salient' item is severely impaired, while performance for the 'most salient' item is only moderately affected. This impairment in performance mimics a lesion in area V4 of the macaque monkey. In a previous study, we have shown that infants in two age groups (4 – 6 and 7 – 9 months) do not show a preference for the 'least salient' object in a visual scene. In the present study, these results were extended to younger and older ages. We tested seven groups of subjects: informed adults ($n = 16$), adults naive as to the purpose of the study ($n = 16$), infants aged 1 – 3 months ($n = 12$), 4 – 6 months ($n = 12$), 7 – 9 months ($n = 12$), and 10 – 12 months ($n = 12$) and children 3 – 4 years of age ($n = 12$). All subjects were tested with a forced-choice preferential looking technique, on a display containing two texture fields. In half of the trials, one texture field contained a group of 16 larger blobs in a surround of small blobs ('most salient' task); in the other half, one texture field contained a group of 16 smaller blobs in a surround of large blobs ('least salient' task). The trials of the two tasks were randomly intermixed. Each session contained a minimum of 20 trials. All adult subjects showed high, statistically significant (one-sided Student t-test) preferences for the discrepant group in both tasks. For both groups of adult subjects, preferences for the 'least salient' stimulus were lower than for the 'most salient' stimulus. For naive subjects, performances in both tasks were lower than for the instructed subjects. All groups of infants showed statistically significant preferences for the 'most salient' stimulus, thus confirming earlier results of Sireteanu and Rieth. Children aged 3 – 4 years showed a highly significant preference for both tasks; however, infants under 1 year of age showed no preference for the 'least salient' stimulus. These results suggest that the attentional mechanisms responsible for orientation towards the 'least salient' object in a visual scene are not functional in the young infant, but develop between 1 and 3 years of age. Thus, to a certain extent, infants behave like Braun's 'non-attentive' or 'distracted' adults. Both are reminiscent of Schiller and Lee's macaque monkeys lacking area V4.

◆ **Pre-term and full-term infants: visual development**
I Gottlob, S Weinacht (Department of Ophthalmology, Kantonsspital St Gallen, St Gallen, Switzerland)

The aim of this study was to compare the development of parameters reflecting visual acuity and binocular vision in pre-term (PT) and full-term (FT) infants. A group of healthy FT infants ($n = 79$) with a gestational age between 38 and 42 weeks (mean 40.1 weeks) and a group of PT infants of low risk ($n = 18$), with a gestational age between 31 and 36 weeks (mean 33.5 weeks) and a birth weight greater than 1250 g (mean 2019 g) were tested biweekly between the 44th and the 54th week of postmenstrual age. Grating visual acuity was measured by infrared eye-movement recordings stimulated by moving gratings of different spatial frequencies (0.1 – 1.6 cycles deg^{-1}). Ocular alignment was measured by the Hirschberg and Cover test. Convergence was examined as an illuminated toy approached the infants face. Fusion was tested with the four-prisms base-out test. The optokinetic nystagmus (OKN) was measured by infrared eye- movement recordings while horizontally moving black and white stripes were presented on a TV screen.

The mean postnatal ages of the onset of ocular alignment, convergence, fusion, grating visual acuity to 1.6 cycles deg^{-1}, OKN from temporal to nasal, and OKN from nasal to temporal were respectively at 5.4, 7.4, 7.4, 11.2, 6.2, and 9.3 weeks for FT infants, and at 12.1, 13.2, 14.1, 17.9, 13.3, and 16.1 weeks for PT infants. The mean postmenstrual ages of onset for the corresponding parameters were at 45.6, 47.5, 47.6, 51.4, 46.5, and 49.5 weeks for FT infants, and at 45.7, 46.8, 47.6, 51.5, 46.6, and 49.3 weeks for PT infants. The time of onset of all tested parameters was significantly earlier in FT infants than in PT infants of the same postnatal age. However, no differences were found when the parameters were compared at postmenstrual ages. It is

concluded that additional visual experience gained by PT infants did not influence the development of grating visual acuity or binocular vision measured from the time of conception.
[Supported by the SNSF grant No 32-31317-91, 32-43233-95 and the OPOS Foundation, None.]

◆ **Randot and Titmus stereoacuity norms in children**
P Schmidt, M T Kulp (Exceptional Child and Infant Vision Testing Laboratory, The Ohio State University College of Optometry, Columbus, OH 43210-1240, USA)

Titmus and Randot stereotests are widely used clinical tests of stereopsis. Age-related stereoacuities reported for the Titmus test are 70 – 100 s arc at the age of 5 years improving to 40 s by the age of 8 years. Stereoacuities reported for the Randot test in this same age group are 70 – 250 s (medians, obtained with alternative-forced-choice procedures) and 22.5 – 30.5 s (means, obtained with stereothresholding procedures). The levels of stereoacuity reported from these studies are similar to levels now attributed to infants and toddlers. Have these earlier studies underestimated stereoacuity in 5- to 7-year-olds?

Masked investigations of 464 children between 5 and 7 years of age (231 males, 233 females) with normally developing vision were undertaken to establish age-related Randot and Titmus stereoacuities with procedures in common clinical use, and to compare stereoacuities obtained with contour (Titmus) and contour/random-dot (Randot) stereo targets. Stereoacuity was measured at 40 cm; the instructions provided with the stereotests were followed. Children were tested for normally developing vision on the basis of refractive state, visual acuity, ocular coordination, and ocular health status. The results from this study show that: (1) median Randot and Titmus stereoacuities for 5-year-olds are 50 s; (2) for children aged 6 years and in kindergarten and first grade, median Randot stereoacuities are 40 and 30 s, respectively; (3) median Titmus stereoacuity is 40 s for children aged 6 years and older. Comparisons of stereoacuity between tests by age and within tests by gender showed no significant difference in median stereoacuities ($p = 0.0700 – 0.894$). We conclude that previously established age-related norms for the Randot and Titmus stereotests are underestimates of stereoacuity in 5 – 7-year-old children with normally developing vision. Age-related stereoacuities do not differ between boys and girls or contour and contour/random-dot targets.
[Supported by OLERF 537172 and Pediatric Studies 539166 grants to P Schmidt.]

MINI-SYMPOSIUM: WILLIAMS SYNDROME

◆ **Neural basis of disordered visuo-spatial function in Williams syndrome**
Convenor: J Atkinson (Visual Development Unit, University College London, London WC1E 6BT, UK)

Williams syndrome (WS) is a rare, genetically based developmental disorder with a characteristic cognitive profile in which visuo-spatial abilities are particularly severely impaired. At CVRS '95 in Frankfurt we presented results of a range of visual and cognitive testing in a large group of WS children. We have pursued more detailed investigations of this group, focusing on two specific hypotheses: (a) that the difficulties of these children in spatial tasks may be associated with a deficit of visual-information processing in the dorsal cortical stream; (b) that they may have a deficit of frontal function linked to the selection and control of spatial behaviour. Evidence for both hypotheses is reported, along with neuroimaging data on early brain development in WS.

◆ **Global motion and form processing in Williams syndrome children**
O Braddick, J Atkinson, J Wattam-Bell, S Anker (Visual Development Unit, University College London, London WC1E 6BT, UK)

Coherence thresholds for motion detection are believed to be mediated by area V5, a key early station in the dorsal stream function in WS children. We tested them (a) for coherence thresholds in segregating opposite directions of motion; (b) for 'form coherence' thresholds to detect concentric circles of line segments, embedded in a background of randomly oriented segments. The tasks were designed so that both demanded similar attention and global integration, but with the latter task depending on ventral stream processing (eg in V4) rather than dorsal. Half the WS children showed abnormally poor motion coherence, compared to only 20% for form coherence, implying that deficits are generally more marked for dorsal than for ventral stream function in WS.

◆ **Dissociation of visually guided action from visual judgment in Williams syndrome children**
J King, J Atkinson, O Braddick, T Hartley, L Nokes, F Braddick (Visual Development Unit, University College London, London WC1E 6BT, UK)

Goodale and Milner have shown that in a patient believed to have selective damage to the ventral visual processing stream, the accuracy of posting a card through an oriented slot was maintained even though performance on rotating the card to match the slot orientation was almost random. We have adapted this task for children with mental age down to 4 years. A group of 11 WS children

aged 4 – 14 years showed only modest errors on the matching task, with over half the group falling within the range of normal controls. However, they were more severely impaired on the posting task, with many showing much larger errors than are found even with 4-year-old control, and qualitative anomalies of visually controlled manipulation. We conclude that in many WS children dorsal stream processing of visual information for manual control may be impaired even though equivalent visual information can be used in a perceptual judgment.

◆ **Frontal control processes in Williams syndrome children**
J Atkinson, F Braddick, L Nokes (Visual Development Unit, University College London, London WC1E 6BT, UK)

We have investigated frontal function in WS children by a 'counter-pointing' task (analogous to anti-saccade task but with pointing) and by a Stroop-like task derived from the work of Adele Diamond. Both tasks require subjects to inhibit a prepotent response. Many WS children showed delays or errors caused by intrusion of prepotent responses. Theories of the WS deficit cannot be restricted to posterior visuo-spatial brain areas but also need to consider interaction of parietal and frontal brain systems.

◆ **Visual acuity measures in a sample of Williams syndrome children**
S Anker, J Atkinson (Visual Development Unit, University College London, London WC1E 6BT, UK)

Visual acuity has been assessed in 69 WS children aged 3 to 13 years. We measured best acuity, with spectacle correction where prescribed, by automated forced-choice preferential look (FPL) or single or crowded letters from the Cambridge Crowding Cards, as appropriate to the child's abilities. Children aged up to 5 years achieved on average 15 cycles deg^{-1} on FPL. Those in the 5 – 10 year group achieved nearly 20 cycles deg^{-1} on FPL or the equivalent on single letters, but the majority were unable to complete the crowded letters task. Children aged 10 – 13 years showed similar average acuity but most could complete crowded letter testing. We conclude that over this age span the ability to perform a recognition task improves, but average acuity remains below the level expected for age.

CLINICAL STUDIES (NEUROLOGY)

◆ **Developmental surface dyslexia in Italian children: a psychophysiological analysis**
P Zoccolotti¶#, P Angelelli#, M De Luca#, E Di Pace#, A Judica#, D Spinelli¶#
(¶ Dipartimento di Psicologia, Università di Roma 'La Sapienza', Rome, Italy;
Centro Ricerche, IRCSS Ospedale S. Lucia, Rome, Italy)

In English, the language of most studies on dyslexia, the majority of children with reading problems have phonological dyslexia and only few of them (referred to as surface dyslexics) have specific problems in the access to a direct lexical route used by expert readers to read well-known words. In languages with more regular spelling – sound correspondences, such as German or Italian, this proportion is reversed, phonological dyslexics being extremely rare. Studies on the psychophysiological correlates of reading problems have ignored a cognitive analysis of dyslexia. Thus, deficits of the transient visual system have been reported in the literature in unselected groups of English dyslexics. In contrast, research on eye movements yielded inconsistent results. In the absence of a specification of the type of reading disturbance, most children studied were presumably suffering from phonological dyslexia. The aim of the study was to examine the psychophysiological correlates of a sample of Italian surface dyslexics. Ten children, who could be unequivocally described as surface dyslexics according to standard cognitive criteria (eg, all dyslexics performed at chance level in the comprehension-of-homophonic-word test) were examined. Contrast sensitivity thresholds to phase-reversal gratings were within normal limits for most subjects both for stimuli presented centrally and in the right parafovea. This indicates that developmental surface dyslexia is not associated with a deficit in the transient system. In contrast, sensitivity to high-spatial-frequency stationary stimuli was reduced. Eye-movement recordings during reading indicated increased number and reduced amplitude of rightward saccades and longer fixation durations. These changes were considerably more dramatic than those reported in the English literature. Overall, these findings stress the powerful modulating effect of type of dyslexia on the psychophysiological correlates of reading disorder.

◆ **Epileptic nystagmus: evidence of cortical oculomotor function from early infancy**
C M Harris, S Boyd, K Chong, A Kriss, B Neville (Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

Epileptic nystagmus (EN) is a rare type of paroxysmal nystagmus associated with epileptic seizures. Reports in adults with horizontal EN have shown a cortical origin in parieto-occipito-temporal (P-O-T) region contralateral to the direction of beats. It is thought that in some cases the

cortical area for smooth pursuit/OKN (homologue MST/V5) is excited. We report on an infant with intractable seizures and nystagmus since 10 days of age, who was referred at 9 months for evaluation for intracranial surgery for intractable epilepsy. EEG and eye-movement recording showed a right beating paroxysmal nystagmus that occurred simultaneously with abnormal large spikes over the left P-O-T. Between seizures no nystagmus was detected and full-field OKN was absent for leftward stimulus motion, but was normal in the opposite direction. Neuroimaging showed cortical dysplasia in the left middle temporal gyrus extending posteriorly to the occipital-parietal cortex: Brodmann areas 21, 37, 19, and 39. Surgical resection of the left temporal-occipital-parietal cortex was performed, and post-operatively the child has been seizure-free for over a year with no nystagmus. This extremely rare case is consistent with the cortical origin of horizontal EN, and the affected region overlaps the smooth pursuit centres and area V5 (Brodmann areas: 37, 19, and 39) contralateral to the beat direction. This case also demonstrates that neonatal cortex (albeit abnormal) is capable of generating eye movements.

◆ **Visual function in full term infants with brain lesions**
E Mercuri¶#, J Atkinson¶, O Braddick¶, S Anker¶, F Cowan#, J Pennock#, M Rutherford#, L Dubowitz# (¶ Visual Development Unit, University College London, London WC1E 6BT, UK; # Department of Paediatrics, Royal Postgraduate Medical School, Hammersmith Hospital, London W12 ONN, UK)

45 infants who showed lesions on neonatal MRI were assessed with a battery of tests designed to evaluate visual function in infancy (ABCDEFV) including measurements of acuity, fixation shift, visual fields, and phase and orientation reversal VEP. 14 of the 45 infants showed changes on MRI suggestive of cerebral infarction, the remaining 31 all suffered from hypoxic ischaemic encephalopathy (HIE). The aim of the study was to examine the functional effects of early lesions in the visual pathway and to identify early prognostic indicators of visual abnormalities.

A considerable incidence of visual abnormalities was observed in infants with focal lesions. The presence and the severity of these abnormalities, however, could not consistently be predicted by the site and extent of lesions which suggests that early focal lesions might, to some extent, be compensated for by the immature developing brain. In contrast, generalised lesions tended to be more frequently associated with abnormal visual function. Normal visual function was mainly found in those infants who showed early oedema followed by a normal scan after the end of the first week. All but 2 of the infants with diffuse hemispheric involvement also showed multiple visual abnormalities. The concomitant involvement of basal ganglia was always associated with a more severe visual outcome, suggesting a possible role of these subcortical structures in the development of visual function. This was also confirmed by the high incidence of abnormalities of visual function found in the 6 infants who showed isolated basal ganglia lesions and no cortical or white-matter involvement.

◆ **Visual perceptual abilities of 5-year-old children with neonatal ultrasound abnormalities**
E Vandenbussche¶, L S de Vries§, P Stiers¶#, M Haers¶, B M van den Hout‡, O van Nieuwenhuizen‡ (¶ Laboratory of Neuropsychology, K U Leuven, Medical School, B 3000 Leuven, Belgium; # Centre for Developmental Disabilities, University Hospital, B 3000 Leuven, Belgium; § Neonatology and ‡ Child Neurology, Wilhelmina Kinderziekenhuis, 3512 LK Utrecht, The Netherlands)

We investigated whether neonatal brain damage can give rise to visual perceptual deficits, in addition to the well documented impairments in visual acuity. Visual perceptual abilities of 41 children were assessed by means of L94, a set of four visual object recognition and three visuo-constructive tasks, at an age ranging from 5.02 to 5.89 years. These subjects were neonatal at risk owing to prematurity or birth asphyxia. From neonatal ultrasound scans, the occurrence of intracranial hemorrhage (ICH, $n = 17$), periventricular leukomalacia (PVL, $n = 15$), and/or white-matter damage due to either of these conditions (WMD, $n = 9$) was determined for each subject. Scans were normal in 14 children. The number of subjects performing at or below Pc 10 of same-age normal children was significantly above 10% for each task (range 27% – 49%). This was still true when mental instead of chronological age was used for comparison, as indicated by the results of 9 subjects for which intelligence data were available. This high incidence of impairment cannot be attributed to visual acuity impairment, since grating acuity was reduced in only 4 subjects ($14 - 19$ cycles deg^{-1}). The frequency of scores below Pc 10 correlated significantly with WMD in 6 tasks, with PVL in 4 tasks, but not with ICH. It is concluded that neonatal at-risk children are more likely to develop impaired visual perceptual skills, independently of mental disability and visual acuity loss. On ultrasound scans the condition most strongly associated with visual perceptual deficit is permanent white-matter abnormalities, whereas intracranial hemorrhage is unrelated.
[Supported by Praeventiefonds, The Netherlands, nr 2814061.]

◆ **Gaze disorders in cerebral palsy: from 'chaos' to an organisation**

M Papini¶, R Frosini#, A Pasquinelli¶, M Boschetto¶, J Hardoy¶ (¶ Child Neuropsychiatry and # Optic Physiopathology, University of Florence, 50121 Florence, Italy)

Clinical observation of cerebral palsy (CP) (particularly extrapyramidal forms) shows a high frequency of gaze disorders (GD): gaze is impaired in a complex way that appears as a condition of 'gaze chaos' (GC). Our purpose was to investigate the evolution of GC in children affected by pure or mixed forms of extrapyramidal CP. We studied 50 subjects (1st observation: range 4 months – 8 years 11 months, with a mean follow-up of 8 years 2 months). We excluded 4 subjects affected by severe disorders of vision, such as bilateral optic atrophy and we identified 15 subjects (1st observation: range 6 months – 7 years 11 months, with a mean follow up of 10 years 8 months) presenting a GC. For a better definition of GC we divided gaze into 3 essential phases: rest, reaching, and fixing. We described and analysed (on slow-motion video recordings) the most constant patterns of gaze in these phases. 6 out of these 15 subjects (follow-up range 10 years 6 months – 19 years 6 months) had been observed since the first year of life and followed with serial oculistic examinations and video recordings.

The long follow-up enabled us to identify 3 phases in the evolution of GC. In the 1st phase (2 – 3 years of life) GC appears as a result of multiple polimorphous and fluctuating patterns, such as positional instability, roving, and scanning during rest; avoiding, prolonged blink, arching, and 'chicane' trajectory during reaching; gaze overreaching, block in lateral extreme position, pendular nystagmus, evident/latent nystagmus, convergence spasmus and strabismus during fixing. In the 2nd phase, even if not constantly, it becomes possible to distinguish gaze alterations related to the strabological area from gaze alterations related to neurological damage, and to detect the decrease or the disappearance of some of the GC patterns. In the 3rd phase the semiological distinction reported above becomes more evident and constant. This gaze organisation and its timing seems to be related to several factors, such as association with other sensorimotor disabilities and poor general motor organisation related to low mental abilities. We conclude that in children affected by CP, and particularly in the extrapyramidal forms, GD are frequent and polimorphous. An analytical study makes it possible to identify a 'gaze style' often related to the subjects' postural and motor functioning. This style evolves in time together with the improving ability in adopting strategies towards adaptive aims.

◆ **A procedure for the clinical evaluation of visual perceptual impairment in spastic diplegic children**

E Fedrizzi, S Bova, R Bono, A Anderloni, S Savoiardo, M Farinotti (Istituto Neurologico Nazionale 'C Besta'—Divisione NPI Neurologia dello Sviluppo)

Visuo-perceptual impairment (VPI) is a specific pattern of neuropsychological dysfunction in diplegic children. The pathogenesis of VPI has been related to various factors, mainly to the periventricular leucomalacia involving the peritrigonal white matter of occipital and parietal lobe and the optic radiation, while the disability of fine manipulation and the disorders of visual output of ocular movements and tracking deficits have been less investigated. In order to study the clinical aspects of visuomotor behaviour of diplegic children during a visuo-perceptual task, the 'Animal House' subtest of the WPPSI has been adapted to videorecord the performance. The 'Animal House' figures were drawn on a transparent support held in vertical position and the eye and hand movements of the children during the task videorecorded. The procedure was used on a sample of 15 diplegic children aged between 4 and 7 years and on a control group of 50 normal children. The videorecorded performances were analysed and scored by 3 different observers. The following parameters were assessed: time to achieve goal, mistakes of omission, of shape and colour association, of segmental direction (top – bottom, left – right), of sequential scanning order and of target fitting, and the number of saccadic movements to the next target. The evaluation procedure was validated through a satisfactory interobserver agreement achieved in the assessment of the 50 normal children (K between 0.6 and 1). The statistical analysis of the data (ANOVA) showed in normal children a developmental course of the ability to perform the task: the time, the number of mistakes in sequential scanning and fitting the figures, and the number of anticipatory saccadic movements are significantly related to the age.

The diplegic children, whose performance scores were overall poorer than in the control group, showed a significantly higher number of mistakes of sequential scanning order and a significantly lower number of anticipatory saccadic movements than normal children. The preliminary results bring out the role of voluntary saccadic movement dysfunction in the pathogenesis of VPI of diplegic children.

CLINICAL STUDIES (OPHTHALMOLOGY)

◆ **A neonatal visual deprivation syndrome**

R G Boothe (Departments of Psychology, Ophthalmology, and Yerkes Primate Research Center, Emory University, Atlanta, GA 30322, USA)

It is now well established that a classic syndrome of clinical, behavioural, and neurological deficits is present in animals and humans following postnatal deprivation. Our understanding of this classic syndrome is derived from a combination of clinical studies of human patients and basic neuroscience studies of visual deprivation in animals [reviewed in R Boothe "Amblyopia", in *Principles and Practice of Ophthalmology: Basic Sciences* Eds D M Albert, F A Jakobiec (Philadelphia, PA: W B Saunders) 1993 pp 663 – 682]. Commonly reported findings include impaired acuity and binocular function, and neurological alterations in those parts of the brain that coordinate processing of inputs from the two eyes. Many conditions that lead to this syndrome in humans (eg strabismus and anisometropia) arise during postnatal development, but are not present at birth. There is accumulating evidence that visual deprivation conditions that occur during a very early neonatal period (eg congenital cataracts) can lead to a neonatal visual deprivation syndrome (NVDS) of behavioural and neural deficits that are distinct from those resulting from deprivation initiated later in infancy. One important aspect of NVDS is that the neurological mechanisms appear to involve a combination of deficits in brain stem and cortical visual areas. Another interesting finding is the evidence for a link between brain systems involved in motion processing and binocular functions. Behavioural/clinical manifestations include induced strabismus, latent nystagmus, and asymmetries in smooth pursuit eye movements, optokinetic nystagmus, motion VEPs, and perceived motion. Several research projects currently underway in the Division of Visual Science at the Yerkes Primate Center are using neonatal monkeys to model various aspects of NVDS, and current findings from the monkey studies are summarised within the context of the human clinical literature.

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◆ **Hyperopia and cataract in childhood—a crucial combination of ambiogenic factors**

E Schulz (Department of Orthoptics, University Eye Clinic, D 20246 Hamburg, Germany)

Grating acuity estimates are generally a good guideline both for indication for surgery and postoperative treatment of congenital cataract. If the density of the lens opacification and acuity estimates fail to correlate well, additional factors for low visual outcome should be considered. In an individual case, a girl was presented at the age of 6 weeks with a bilateral cataract of dominant inheritance. The density of the cataract was moderate; grating acuity estimates were far below age norm. Retinoscopy was possible and revealed a refractive error +11 D in both eyes. Spectacles were prescribed and the child performed better on a subsequent grating acuity testing. Repeated retinoscopy under atropine revealed a higher refractive error (of +14 D). New glasses were prescribed and tested by grating acuity at 3-week intervals. The acuity developed tremendously and reached the upper age norm at the age of 7 months. The density of the cataract remained the same up to that age and then increased until retinoscopy was no longer possible. An increase of axial length was documented by ultrasound measurement. Cataract surgery was recommended. To find out whether the visual outcome was less good in case of hyperopia in combination with early infantile cataract, microphthalmic and non-microphthalmic eyes of 63 patients who had undergone early surgery for congenital cataract were compared with respect to their visual acuity outcome. The mean visual acuity of microphthalmic patients ($n = 3$) was 0.21, that of non-microphthalmic eyes ($n = 60$) 0.30, the median being 0.25 and 0.24, respectively.

Individual observations provide evidence that high hyperopia is the preponderant amblyopia producing factor in coexisting moderate congenital cataract. In the literature, it is generally accepted that microphthalmic eyes perform less well in visual acuity tests after operation for congenital cataract. This might be due to the combination of hyperopia and cataract in this group of patients, though in our small series of microphthalmic eyes and early-operated bilateral congenital cataract, we could not confirm a significant difference. It is recommended that close attention be paid to potentially coexisting high hyperopia in babies with a congenital cataract and, if present, taken into consideration for further treatment strategies.

◆ **Changes in macular and paramacular derived VEPs to pattern-onset, pattern-reversal, and pattern-offset stimulation in amblyopia**

F S Shawkat, T Kriss, D Taylor (Department of Ophthalmology, Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

Pattern stimulation has proved itself to be an effective technique of studying the visual system in health and disease. However, there appear to be differences in VEPs elicited by different forms of pattern stimulation: pattern reversal, onset, and offset. We studied the macular and paramacular

components of these 3 main modes of pattern VEP stimulation. The effects of check size and experimental scotomata on onset, reversal, and offset VEPs were initially investigated in control subjects. To evaluate the clinical efficacy of these modes, the responses from amblyopic subjects (where macular function is compromised) were compared with those from controls. The 3 stimuli were delivered sequentially in a single recording epoch so that a direct comparison could be made for virtually identical subject and recording conditions. Half-field stimulation was adopted to better separate contributions from macular and paramacular areas of the visual field. 10 different check sizes (6 min to 110 min), and 4 central scotomata (subtending 0 – 1.5, 0 – 2, 0 – 3, and 0 – 4.5 deg) were used. A total of 41 normal and 18 amblyopic subjects were studied.

Ipsilateral reversal components, onset (ipsilateral CII and contralateral P105), and, to a lesser extent, ipsilateral offset components were significantly enhanced by using small check sizes and were susceptible to small central scotomata. These components are thus predominantly of macular origin. Contralateral reversal and offset potentials (N105 and N115) and ipsilateral onset CI were enhanced by large checks and relatively unaffected by central scotomata, suggesting they are predominantly generated by paramacular function. These trends were confirmed in amblyopes, in whom macular vision is compromised, as ipsilateral reversal components, onset CII, and the contralateral P105 were significantly attenuated for stimulation of amblyopic eyes. Full statistical analysis of VEP components elicited by amblyopic eyes compared with fellow eyes demonstrated that pattern reversal showed the most conspicuous and reliable inter-eye differences. It is concluded that ipsilateral reversal components, onset ipsilateral CII, and onset contralateral P105 components predominantly reflect macular function and are selectively atten-uated in amblyopic eyes.

◆ **Treatment of amblyopia by spectacles: time course and magnitude of improvement**

M Neufeld, M J Moseley, A R Fielder (Academic Unit of Ophthalmology, Imperial College School of Medicine at St Mary's, The Western Eye Hospital, London NW1 5YE, UK)

The treatment of amblyopia typically involves the correction of refractive error combined with occlusion therapy. If spectacle wear and patching are prescribed simultaneously then the respective contributions to the therapeutic outcome of each treatment cannot be differentiated. As occlusion therapy is unpleasant for a child, delaying patching until the maximum benefit of spectacle wear has been achieved will ensure that the occlusion required will be minimised. Previous studies confirm that spectacles alone can raise amblyopic eye acuity (eg see J D Kivlin and J T Flynn 1981 "Therapy of anisometropic amblyopia" *Journal of Pediatric Ophthalmology and Strabismus* **18** 47 – 56) although the expected magnitude of improvement and the time taken to achieve this has not been satisfactorily determined. In a pilot study (M J Moseley, M Irwin, H S Jones, A R Fielder, and R Auld 1996 "Effect of spectacle wear and minimal occlusion therapy on the vision of amblyopic children" *Investigative Ophthalmology and Visual Science* **37** S941), we examined the visual performance of 8 children with amblyopia of refractive origin. The mean improvement (from the initial corrected) seen in the amblyopic eye was 0.19 log units in visual acuity and 0.09 log units in letter contrast sensitivity. These gains were attributable solely to spectacle wear and to practice and familiarisation effects arising from repeat testing. Though clinically significant, such improvements underestimated those that might ideally be obtained (occlusion was begun before all benefits of spectacle wear were manifest).

In the follow-up study we are recording the linear logMAR visual acuity at weekly intervals of presenting amblyopic children who have not previously worn spectacles or undergone occlusion therapy. All subjects undergo a minimum of 4 weeks of spectacle wear which is continued until acuity has ceased to improve over further periods of 4 weeks, or until amblyopia is no longer present. The findings should inform clinicians which amblyopic children (diagnosis, amount of refractive error, and initial depth of amblyopia) are likely to benefit from treatment, in the first instance, by spectacle wear alone.

◆ **Accommodation in infants and children with Down's syndrome**

M Cregg, J M Woodhouse, V H Pakeman, K J Saunders¶, M Parker, H L Gunter, W I Fraser#, P Sastry‡, S Lobo‡ (Department of Optometry and Vision Sciences, University of Wales Cardiff, Cardiff CF1 3XF, UK; ¶ Department of Vision Sciences, Glasgow Caledonian University, Glasgow G4 0BA, UK; # Welsh Centre for Learning Disability, University of Wales College of Medicine, Cardiff CF1 3BL, UK; ‡Community Health Unit, Lansdowne Hospital, Cardiff CF1 8UL, UK)

Accommodation in children with Down's syndrome has been shown to be defective from the earliest age of testing (twelve weeks). 74 children with Down's syndrome participated in the study. Accommodation was measured with a modified dynamic retinoscopy technique. Data from the longitudinal study show that if a child's refractive error increases, its accommodative response

increases accordingly to overcome the increased refractive error. It appears therefore that although the children do not accommodate accurately to a given stimulus, the amount of accommodation exerted does not represent their maximum amplitude of accommodation. Children with strabismus show significantly lower accommodation than strabismic children. 10 children developed a strabismus during the course of the study. The accommodative response of these children was lower than in non-strabismic subjects even before the onset of strabismus. This suggests that (a) defective accommodation is not due to physical constraints of the lens or ciliary muscle, and (b) binocularity plays a role in facilitating accurate accommodation.

◆ **Retinal function, eye growth, and refractive development**

A B Fulton, R M Hansen (Department of Ophthalmology, Children's Hospital and Harvard Medical School, Boston, MA 02115, USA)

The photoreceptors have a role in controlling eye growth and refractive development in avian models. Are the photoreceptors also involved in the control of human eye growth? To begin to answer this question we have evaluated rod photoreceptor function in infants and children with high refractive errors. Are there significant associations between the parameters of rod function and refractive error?

In an attempt to answer this, subjects with high myopia (> -4.00 D) or hyperopia ($> +5.00$ D) since early infancy were studied with electroretinographic (ERG) procedures. Diagnoses for the myopes were congenital stationary night blindness, Aland Island syndrome, and non-cicatricial retinopathy of prematurity (ROP); and for the hyperopes were achromatopsia and Alstrom syndrome. Rod photoresponse parameters—specifically, the amplification of the processes involved in the activation of phototransduction, and the saturated amplitude of the rod photoresponse—were derived from the ERG a-wave. Post-receptoral ERG components were also studied. Refractive errors and axial lengths were measured. Low amplitude and low amplification of the photoresponse were found to be associated with myopia in ROP, and also with the hyperopia of achromatopsia and Alstrom syndrome. In the ROP subjects, but not the hyperopes, the characteristics of activation of the photoresponse accounted for the post-receptoral response components. In other infantile myopes, including those with CSNB and Aland Island syndrome, saturated amplitude was low, but amplification was normal; the rod response amplitude and post-receptoral response amplitudes were correlated. We conclude that alterations of rod function are associated with high refractive errors in a variety of diagnostic categories. Thus, photoreceptor processes must be considered among the mechanisms controlling human eye growth.

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◆ **Ocular involvement in prematurity: retrospective study of 7 years**

P E Bianchi, R Guagliano, B Marenzi, W Misefari, G Ruberto, G Rondini¶ (Department of Ophthalmology, University of Pavia; ¶ Neonatal Intensive Care Unit, IRCCS Policlinico San Matteo, Pavia, Italy)

In this retrospective study we analysed the prevalence of retinopathy of prematurity (ROP) and its sequels in a sample of 267 premature infants with very low birth weight (<1500 g) referred to the Neonatal Intensive Care Unit of the IRCCS Policlinico San Matteo, Pavia. From January 1990 to July 1996, 267 infants underwent periodic indirect ophthalmoscopy of the fundus oculi during their stay in the Neonatal Intensive Care Unit. Acute stage III ROP was treated by cryotherapy. We followed the patients after they left hospital with periodic checkups: each infant underwent an orthoptic examination and examination of refraction, of the anterior segment, and of the fundus oculi. 67 (25%) of the premature infants examined suffered from acute ROP and 22 (8.2%) underwent cryotherapy. When the sample was divided into three gestational age categories the incidence of ROP was as follows: 1.35% in the 33–34-weeks-old group; 23.4% in the 27–32-weeks-old group; 63.4% in the $\leqslant$26-weeks-old group ($\chi^2_2 = 63.13$; $p < 0.0000005$). Of the 22 subjects treated with cryotherapy 15 (68.2%) had gestational ages $\leqslant$26 weeks, 7 (31.8%) had gestational ages between 27 and 32 weeks ($\chi^2_2 = 23.05$; $p < 0.00001$). Follow-up of 130 infants at 12 months gave the following results: (1) strabismus 19.2%; (2) >3 D hyperopia 7%; (3) myopia 22.2%; (4) >5 D myopia 1.9%. In the patients treated with cryotherapy the incidence of strabismus and >5 D myopia was greater then for untreated infants: 30% vs 10.7% (p = ns) and 14.7% vs 0% ($p = 0.0000005$), respectively. Our conclusions are: (i) The incidence of ROP in our sample (25%) does not differ from that found in similar studies and is inversely proportional to gestational age. (ii) The incidence of myopia and strabismus was high and differed from the population born at term (19.5% vs 4% and 22% vs 6%, respectively). (iii) Cryotherapy was successful in 91.9% of cases.

◆ **Function versus morphology in treated eyes with threshold retinopathy of prematurity at the age of 2 years**

A Zubcov, K Vanselow-Mauck, P Kaiser, R Schlösser¶, N Stärk (University Eye Hospital, ¶ Department of Pediatrics, Theodor-Stern-Kai 7, D 60590 Frankfurt, Germany)

We followed up visual function and fundus morphology of 26 children with threshold retinopathy of prematurity (ROP) treated either with cryotherapy and/or laser coagulation. Function and morphology of 49 treated eyes of 26 infants (birth weight <1530 g) were assessed by the Teller acuity cards test, retinoscopy, orthoptic status, and retinal examination at 2 years corrected gestational age (mean 2.07 years; median 2 years). Favourable visual function was defined as >4.8 cycles deg^{-1}. Favourable morphological outcome was defined as having no pathological findings in the posterior pole or stage 4A residua of ROP. Grating acuity at 2 years corrected age ranged between 0.32 – 13.0 cycles deg^{-1} in 56% (28/49) eyes with measurable visual acuity. In infants with birth weight below 1251 g, 65% (22/34) did not reach any measurable visual acuity. 20% (7/34) had a poor functional outcome and only 15% (5/34) were labeled as favourable (34.8 cycles deg^{-1}). In the birth-weight group above 1251 g all eyes reached a measurable visual function of which 80% (12/15) had a favourable visual acuity. 47% (23/49) of the eyes were myopic at the 2 year control retinoscopy. Severe myopia (>-6.0 D) was found in 24% (12/49). 46% did show an esotropia or exotropia. Thus we found that in the low birth-weight group (<1251 g) the majority of eyes developed a nonmeasurable or unfavourable visual function. A discrepancy between fundus morphology and visual function was found. Only 20% (5/25) of morphologically favourable eyes (stage 4A/normal posterior pole) reached a favourable visual function.

MINI-SYMPOSIUM: VIDEOREFRACTION

◆ **Coordinated infant videorefractive screening programmes in six European centres**

J Atkinson, O Braddick, S Anker, D Ehrlich, J King, T Hartley, A Castanera de Molina¶, M L Giner Muñoz¶, R Sireteanu#, I Bachert#, O Alves da Silva§, A Mendes§, M Heitor§, L Mendanha Dias§, F Vital-Durand‡, G Pinzaru∗, M Angi†, S Atkinson‖ (University College London, London WC1E 6BT, UK; ¶ Instituto de Oftalmologia Pediátrica, Barcelona, Spain; # Max Planck Institute for Brain Research, D 60528 Frankfurt, Germany; § Santa Maria Hospital, Lisbon, Portugal; ‡ INSERM 371, Bron, France; ∗ UHEIM, Lyon, France; † University of Padova, Padua, Italy; ‖ South Thames Regional Health Authority, London W2, UK)

This current EC programme is briefly described, followed by short presentations from a number of the participating centres reporting the experience of videorefractive screening in their own country and health service. In the programme a harmonised protocol has been used across six European countries for refractive and orthoptic screening of infant populations at 8 – 10 months. The aims are (a) to establish a common database; (b) compare incidence across countries of strabismus and strabismogenic and amblyogenic refractive errors in the first year of life; (c) comparative evaluation of screening by two videorefractors (ViVA and VPR1); (d) cost-effectiveness analysis of videorefractive screening compared to existing surveillance methods in the context of different health care systems. The criteria for referral were: manifest strabismus, hyperopia ($\geqslant+2.0$ D accommodative lag, predictive of $\geqslant+3.5$ D under cycloplegia), anisometropia $\geqslant 1.5$ D, myopic focus -2 D or greater. Those referred were refracted with the use of retinoscopy under cycloplegia, and given other vision testing, alongside a control group of infants from the same screening populations. The positive predictive value for significant cycloplegic refractive error from accommodative lag is discussed. In addition a comparison of the incidence of significant refractive errors across different countries is given together with a preliminary analysis of costs in different health services.

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◆ **Visual screening of infants in Portugal**

O Alves da Silva, L Mendanha Dias, A Mendes, M Heitor (Santa Maria Hospital, Lisbon, Portugal)

In Portugal visual screening is usually made by the paediatrician, who uses the appropriate protocol in his office. This screening starts at birth and covers different types of observations till the age of 8 years. The VPR is not routinely used in the National Health System. Our experience with the VPR revealed the need for good preparation of the technicians who work with the apparatus. We have also used the preferential looking test. The association of these two tests have revealed advantages for visual screening. For two years we have worked with a population whose main characteristic was that of being born in a university hospital. For this reason we have found a low rate of ocular pathology, because the screened babies aged 8 to 10 months had already been screened and were under treatment. Particular conditions such as leucocoria, congenital glaucoma, aniridia, and congenital squint were detected before our screening. We also carried out a second observation of these children and noted changes in the refraction and in the oculomotor state

in comparison with the previous examination. We conclude that the screening programme of children 8–10 months should as the first step concern itself with the determination of the amblyogenic factors. Thereafter a follow-up is required.

◆ **Distribution and ranges of refractive errors in infancy. A database for future programmes of amblyopia prevention**

M L Giner Muñoz, A Castanera de Molina (Instituto de Oftalmología Pediátrica, 08021 Barcelona, Spain)

We are aiming to establish mean values, distribution, and normal ranges of refractive errors during infancy and childhood between 6 and 12 months of age, as well as to evaluate their emmetropisation trend in a longitudinal study at ages between 12 and 24 months, in order to allow the development of future programmes of prevention of amblyopia and strabismus. 1664 infants, included in European Concerted Action which started on 1 May 1994 on videorefractive screening programmes, were examined by retinoscopy under cycloplegia with 1% cyclopentholate at the age of 6–12 months (mean of 9.1 months). 397 of them reached the age of 20–24 months (mean 23.38 months) by 30 October 1996, when they were again examined under cycloplegia to evaluate the hypothetical emmetropisation trend of their respective refractive errors. Spheric hyperopia was, as expected, the most common refractive error found in both age groups, followed by astigmatic, anisometropic, and myopic errors. Mean values for hyperopia were $+2.29 \pm 1.29$ D at the first examination, and $+2.06 \pm 1.141$ D at the second. Astigmatic errors ranged from -0.078 ± 1.16 D (against the rule, astigmatisms are positive) at 9 months to -0.015 ± 0.85 D at 23 months of age. Spherical anisometropia (RE – LE) ranged from -0.021 ± 0.45 D, to -0.03 ± 0.35 D, whereas astigmatic anisometropia extended from 0.089 ± 0.63 D, to 0.011 ± 0.35 D. Differences of means between the two groups were significant for each of these refractive errors. The present study allows us to establish normal, at risk, and pathologic ranges of retinoscopy values in infancy, and to quantify their emmetropisation trend. On the basis of these data, prevention programmes based on the early diagnosis of amblyogenic factors may be developed.

◆ **Infant emmetropisation from 9 months of age**

D Ehrlich, O Braddick, J Atkinson, S Anker, F Weeks, T Hartley, J Wade, A Rudenski¶ (Visual Development Unit, University College London, London WC1N 3JH, UK; ¶ Addenbrookes Hospital, Cambridge, UK)

Rapid emmetropisation is described in pediatrically normal infants from 9 months of age over the following year. The infants, obtained from various categories of the Cambridge population screening programme, provided a broad range of refractive errors. The large group of 254 non-anisometropic infants studied allowed the mean rate of change and dependence on the initial refraction value to be determined. Refraction was measured by retinoscopy following cycloplegia. Rapid emmetropisation changes occurred in the following refractive components: mean spherical equivalent (MSE), astigmatism magnitude, the horizontal astigmatism component, the infant's most positive meridian, and the infant's most negative meridian. The MSE and astigmatism rates of change (dioptres/year), were highly dependent on their respective initial powers ($r = -0.61$ and $r = -0.76$). The percentage weighted mean proportional rate of change for MSE was -30% (SE = 4%) and for astigmatism magnitude -59% (SE = 14%). There was much individual variation, with some exhibiting fast emmetropisation and others not. The MSE and astigmatism changes, however, were almost independent of each other. The refractive errors of the most positive and most negative meridians emmetropise because they are both derived from the MSE and half the astigmatism. With-the-Rule astigmatism was more prevalent than Against-the-Rule astigmatism at 9 months of age, and With-the-Rule astigmatism exhibited a greater proportional rate of change. A new component 'MOMS' is introduced—the maximum ocular meridional separation when both eyes are considered. This incorporating astigmatism and anisometropia may be a good single indicator of conditions associated with later amblyopia. We conclude that the almost independent emmetropisation of the MSE and astigmatism components is an important result for consideration in theories of emmetropisation, refractive screening, clinical prescribing, and the evaluation of infants in treatment trials.

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◆ **Screening for amblyopia with a hand-held autorefractor in pre-school children: automated data interpretation with the aid of a neural network system**

M F Angi, M Sturaro, M Pandin¶, G Didoné¶ (Padua University Eye Clinic, Padua, Italy; ¶ USL, 15 Veneto, Italy)

It is difficult to identify amblyopia on the basis of visual acuity measurement in pre-school children, owing to the high incidence of uncooperative and false-positive cases. A portable autorefractor with an automatic neural network system may provide a useful screening test to detect amblyogenic

errors objectively. Manifest refraction was measured in 138 consecutive children, ranging in age from 3 to 5 years, who had never had optical correction before. The Nikon Retionmax hand-held and Canon R-30 autorefractors were used. Heterophorias and stereopsis were also evaluated by means of a cover-test and Lang stereotest. The children were then summoned for a complete ophthalmic evaluation, including visual acuity measurement with an HOTV chart, cycloplegic refractometry, and fundus examination. The relative weight of manifest refraction, heterophorias, and stereopsis on visual acuity were analysed by the neural network, which evaluated the relationships associated with the variables described. The predictive capacity of the neural network with respect to visual acuity and the identification of cases at risk of amblyopia is discussed.

VISION AND CHILD DEVELOPMENT/REHABILITATION

◆ **The role of vision in the development of goal-directed movements**

H Bloch (Laboratoire de Psycho-Biologie du Developpement EPHE – CNRS, Paris, France)

Many data have shown that, from the very beginning of life, infant motor activity is not simply reflexive. There is also growing evidence that perception – action relations contribute to the development of kinematic mechanisms and to the organisation of body displacements. We have investigated the role of visual perception in the development of hand movements towards external reachable objects. This development includes some successive stages, as approach or prereaching arm – hand movements, reaching, forceful grip, fine grip, and manual exploration. Several series of experiments conducted with neonates and 2 – 7-month-olds show that a first constraint against a perception – action coupling is the discontinuous, fragmented aspect of both hand movement and visual fixation. From birth to the second month, however, directional adjustments of the hand towards the target occur only under visual fixation. Moreover, the longer the fixations, the less segmented is the hand movement. Reduced peripheral vision increases the random directionality of the hand, increasing also the noise into the postural frame. Central vision is active in form processing, as shown by the differences which affect the hand movement to different forms. The relation between vision and hand movement does not develop linearly. Both seem to become more narrow from birth to the second month: visual fixation lasts much more, and, at the same time, the hand approach movement is more and more rapid, with a more constant direction and it ends closer to the target. At the third month, the latency of the hand movement increases, and its frequency decreases, as if the gaze inhibited the hand. In the 4th month, reaching begins to be performed regularly, and vision plays a different role on the movements of the right and left hands, as shown by different timings. At around 6 – 7 months of age, intermodal organisation between vision and hand haptic exploration gives a check character to vision from touch. Discussion focuses on the driving role of vision in the organisation of hand action and on its cognitive importance for building goal stability through movement.

◆ **Early motor characteristics of infants with ROP**

G Cioni, H Prechtl¶, C Einspieler¶, H Engele# (Stella Maris Scientific Institute, INPE University of Pisa, Pisa, Italy; ¶ Institute of Physiology, University of Graz, Graz, Austria; # Department of Paediatrics, University of Graz, Graz, Austria)

Blind infants have been reported to show a normal acquisition or a slight delay in postural development and a greater delay in locomotion. Very little information is available on the motor features of these subjects in their first weeks of life. The aim of the present study is to investigate the function of vision for early motor development and the possible motor consequences of blindness on the onset of motor and postural control. 6 preterm infants (gestational age 26 – 29 weeks, birth weight 650 – 1100 g), functionally blind because of ROP degree 4 – 5, were studied. Serial videorecordings (with off-line assessment of spontaneous and elicited movement patterns), ultrasound examination of the brain, and neurological examinations were carried out until about 6 months of corrected age. None of the infants showed severe cranial ultrasound abnormalities or signs of neurological impairment until the last check, carried out at the second year of life. The results of early motor observation were compared with those of another group of 6 preterm infants, matched for gestational age, birth weight, and ultrasound findings. All blind cases showed a delay in head and trunk control; when they were able to control their head, or while kept seated by the examiner, wiggling ataxic-like movements were observed. None of them showed normal 'fidgety' movements, which are small, circular movements, involving the whole body, occurring in normal infants during the age of 6 to 20 weeks post-term. Such motor abnormalities were not observed in the matched controls. These results seem to indicate an active role of vision on different aspects of motor development in the first weeks of life.

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◆ **Developmental problems in blind infants with and without associated handicaps**
E Fazzi, J Lanners, A Martini, G Lanzi (Department of Child Neuropsychiatry, IRCCS C Mondino, University of Pavia, Pavia, Italy; Early Intervention Center for Visually Handicapped Children, R Hollman Foundation, Cannero Riviera, Italy; Stella Maris Scientific Institute, INPE, University of Pisa, Italy)

The goal of the study was to assess early neuromotor and cognitive development in 20 congenitally blind or severely visually impaired children, 9 without (B) and 11 with associated handicaps (B-H) in order to develop a strategy for early intervention in visually impaired children. The mean age of first observation was 11.4 months (range: 4 – 30 months). The mean follow-up duration was 16.9 months (range: 3 – 36 months). Assessment included developmental history, neurological examination, video recording of spontaneous activity and administration of the Reynell – Zinkin scales, and neuroradiological and neurophysiological investigations. All B children walked independently (mean age 19.8 months) and 55.5% crawled (mean age 15 months); B-H subjects displayed absence of almost all neuromotor functions, except one who walked at 20 months. All the B and just one (9%) of the B-H children developed satisfactory fine motor abilities. 'Reaching to sound' at distance was achieved by all B children, but in the B-H group by only two subjects at a median age of 19.5 months. Stereotyped motor behaviours, as for example eye pressing, poking, and head banging, were present in all B children and in 45.9% of the B-H subjects. Thus strategies to help posturo-motor development, 'reaching to sound', and to reduce mannerisms appear to be central in early intervention on B children. Postural items testifying to neuromuscular maturation as regards control of the head and trunk are slightly delayed in children who are only blind compared with sighted children. In accordance with other authors, mobility items which normally follow each postural achievement were found to be delayed in children who are only blind. The onset of self-initiated mobility in children who are only blind was related to the demonstration of each child's ability to reach out and take an object presented by sound clue alone. Compared with children who are only blind, blind children who also have related handicaps show a more marked motor delay in postural items and an even more marked delay in dynamic and locomotor items which hardly any child is able to achieve.
[Supported by Italian Ministry of Health.]

◆ **Dynamic patterns in early language development: the role of visual information**
A Peltzer-Karpf, R Zangl, U Hasiba, S Friehs (Department of Language Development, Graz University, Heinrichstrasse 36, A 8010 Graz, Austria)

We examined early perceptual skills and language development against the background of developmental neurobiology and the dynamics of pattern formation, particularly the interplay of neural growth and the extension of focus in the organisation of the input. We present the first results of a project assessing the early stages of cognitive and linguistic development in sight-impaired and congenitally blind infants (age $\geqslant$ 12 months). The data are juxtaposed to the results of a recent long-term study on the dynamics of pattern formation in sighted children (age range: 1.5 – 3 years). The data ascertained so far prove that the visual and the cognitive/linguistic systems share common principles (eg in the search for coherence) and yet display specific evolutionary patterns. In both domains the following sequence could be ascertained: salience, configuration, size, orientation. There are, however, some drawbacks in the case of visually impaired children: (1) they lack criteria for deciding whether a particular constellation of features is likely to constitute a figure; (2) they show differences in the ranking of salient features and the structuring of categories; and (3) they evince problems with semantic fields pertaining to the visual domain and in general with spatial language and cognition. In the context of the overall cognitive and linguistic development it is particularly important to note that the different time scales in the development of systems suggest a link between spurts of brain growth and the dynamics of scene segmentation and pattern formation. This implies that the current functional capacity of the underlying neuronal circuitry sets the pace for the intake and organisation of information, and that the specification of neural processing correlates with the eventual fine-graining of the holistic scene segmentation and the gross contours favoured in early childhood.
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◆ **Restitution of visual function in cerebrally blind children**
R Werth, S F Bucher, K Seelos (Institute for Social Pediatrics, University of Munich, Heiglhofstrasse 63, D 81377 Munich, Germany)

Areas of the visual field which were blind owing to post-chiasmatic cerebral lesions caused by perinatal asphyxia were systematically stimulated with light in 17 children aged between 1 and 7 years. The extension of the functional visual fields and functional luminance difference thresholds were measured with a specially designed arc perimeter. Recovery of visual functions was

found in 12 of these children within a training period of 12 weeks even when blindness had persisted for at least 1 year. 38 children who were also blind owing to perinatal asphyxia and who did not receive visual field training served as controls. They did not recover within 1 year. In additional experiments, it was shown that the widening of the visual field during training, which we interpreted as a sign of the development of visual functions, was not an effect of scattering of light. These results support the assumption that systematic stimulation with light may facilitate the development of visual functions in cerebrally blind children. We further investigated by functional MRI whether brain tissue in the area of the damaged striate cortex of 2 children who recovered from blindness could still be activated by light stimuli. In both children, vital brain tissue in the area of the visual cortex contralateral to the blind visual hemifield was activated by light. Spared tissue in the striate and extrastriate visual cortex and underlying white matter may be the anatomical basis for the recovery of vision in children suffering from cerebral blindness.

◆ **Intervention during the first year**

L Hyvärinen, U Hirvonen, M Tammikallio (Department of Biomedicine, Section of Physiology, University of Helsinki, SF 00014 Helsinki, Finland)

During the first year of life, problems in the use of vision vary. An infant may be totally unaware of vision and therefore needs stimulation to become aware of it. Hand regard may not develop without training and thus require specific play situations. Delay in the development of accommodation affects the child's eye contact and may lead to dangerous misinterpretations of the child's mental capabilities. Some of these children have had the diagnosis of infantile autism. Infants with extrafoveal fixation of gaze need support in developing communication. The training is more that of the caretakers who must learn to understand that the infant is looking at the adult person's eyes when he/she seems to look at the hairline or higher. Video documentation of the communication situation often demonstrates to the parents that the infant does interact. Differentiation of eye movements from head movements may not develop without training, which can be included in the child's physiotherapy. A diagnosis between half-field loss and attentional deficits is impossible during the first year and therefore training of the nonfunctioning part of the visual field is important because attentional deficits are often overcome by training. In children who have had problems in the development of accommodation, inward squint often develops a few weeks after accommodation starts to function. In these cases prevention of amblyopia by training the squinting eye and careful compensation with the use of overcorrection may prevent esotropia from becoming constant. Development of vision-related spatial concepts and the use of vision in orientation can be supported early by using properly designed playmats and small boxes where the child can experiment with spaces of his/her size. Vision training can be taught to the child's physiotherapist or occupational therapist, later to the speech therapist, who can be instrumental in helping the child to develop picture perception and communication despite the loss of many important cues. Since the child's visual functions change, develop or sometimes deteriorate, good communication between all persons who take care of the child is essential.

POSTERS

EYE MOVEMENTS

◆ **Features of nystagmus in congenital achromatopsia**

R Salati, R Magni, P Mazzone, F Polenghi (Istituto Scientifico 'E Medea', Bosiso Parini (Lc) Settore di Ricerca in Neuro-oftalmologia)

We studied the features of nystagmus in patients with congenital achromatopsia. 10 subjects, aged from 5 to 23 years, underwent a complete ophthalmological examination, VEP, ERG, and electronystagmography. A control group of 14 subjects, aged 6 to 15 years, with congenital idiopathic nystagmus was studied with the same criteria. We found that sensory nystagmus in congenital achromatopsia is characterised by high-frequency low-amplitude oscillations. Electronystagmography allows differentiation of it from the idiopathic form of congenital nystagmus.

◆ **Dynamics of spontaneous nystagmus in children with unilateral and bilateral congenital cataracts**

E Sergienko (Institute of Psychology, Russian Academy of Sciences, Moscow)

We studied the dynamics of spontaneous nystagmus in children with congenital cataracts. Spontaneous nystagmus was observed in different situations such as awake, asleep, visual and auditory tasks, and under functional trial tasks: light, strobic lights and full darkness. We studied children, aged from 4 months to 5 years, before surgery, shortly after surgery, and after optical correction for 3 years. The children had congenital bilateral cataracts (12 subjects, total 40 observations)

or unilateral cataracts (12 subjects, 6 with cataracts of the right eye and 6 of the left eye, total 18 observations). Spontaneous nystagmus (stereotypes of the optomotor system) was observed in 30% of children with unilateral cataracts and 100% of children with bilateral cataracts. Spontaneous nystagmus occurred in children with bilateral cataracts for some time after the treatment. It could be induced by functional load (complex tasks, mental and physical fatigue, load on the visual system, and so on). Children with unilateral cataracts usually had latent spontaneous nystagmus after surgery and treatment. It could appear with intensive visual stimulation or in the dark. The occurrence of spontaneous nystagmus under increasing visual demands supports the viewpoint that the stereotypes have a functional role in the regulation of behaviour to provide the optimal level of arousal. Our data point to an early sensitive period in the development of the optomotor system. The absence of the normal sensory input to the visual system leads to the formation of stereotyped eye movements that do not include goal-directed actions.

◆ **Eye – head coordination as an anticipatory adjustment to the target in infants 2 to 6 months old**
I Carchon, S Chevalier (Laboratoire de Psycho-Biologie du Développement, 41 rue Gay-Lussac, F 75005 Paris, France)

Visual pursuit of a mobile object has to be adjusted to some parameters of the target movement. In order to establish if and how such an adjustment can be performed by young infants, we have compared the performance of infants 2, 4, and 6 months old in the tracking of a periodic constant-velocity saw movement. Parameters of oculomotor functioning were monitored by electro-oculography in conjunction with video recording, and parameters of cephalic movement were obtained from a digital video system. The results show an increasing pursuit duration in infants 2 – 4 months old, but a decreasing one in infants 4 – 6 months old. Head movements increase both in frequency and amplitude between the ages of 2 and 4 months, then decrease from 4 to 6 months. Such a decreasing evolution appears to be quantitatively related to the direction of the target. This surprising decrease observed both in eye and head movements can be related to the shift of direction which is anticipated from 4 months of age, and more clearly at 6 months of age. Such an anticipation suggests how closely the eyes and the head are coordinated from the age of 4 months.

DEVELOPMENT OF VISION

◆ **Developmental changes in infant responses to visual cueing in the first 6 months of life**
P R Butcher, A F Kalverboer (Experimental Clinical Psychology, University of Groningen, 9712 TS Groningen, The Netherlands)

Covert visual attention mechanisms play a central role in the regulation of adult looking behaviour. Little is known about the development of these mechanisms. We report the results of a longitudinal investigation in infants of one indicator of covert visual attention—responses to visual cues. 12 infants carried out a looking task at 2-weekly intervals from 6 weeks to 6 months of age. A brightly coloured moving pattern was presented on a monitor. When the infant fixated the pattern, a 100 ms cue was presented 10 deg to the left or to the right. When the cue disappeared, the central pattern reappeared. After an interval of 900 ms the central pattern disappeared and bilateral targets appeared simultaneously 10 deg to the right and to the left. The performance of 6 of the 12 infants has been analysed. The 6-week-olds looked significantly more frequently to the just cued target. The preference for the cued target decreased gradually from 8 weeks of age, and by 20 weeks of age, most infants showed a preference for the uncued target. There were considerable interindividual differences in the strength of preferences, and the age at which the preference for the uncued target emerged. We conclude that (i) the early preference for the cued location suggests that covert visual attentional mechanisms are functioning at 6 weeks of age; (ii) the tendency to inhibition of a return of visual attention to a just attended location emerges in all infants, but at different ages; (iii) factors such as motor preferences or hemispheric differences in intensity of arousal may have as powerful an impact on looking behaviour as covert visual attentional mechanisms.

◆ **A longitudinal assessment of stereoacuity development**
C D O'Dell (Department of Psychology, Indiana University Northwest, Gary, IN 46408, USA)

Several studies of human infants have documented improvements in stereoacuity. To date, most studies of stereoacuity development have used line stereograms which assess local stereopsis. There is only one longitudinal study of stereoacuity development, reported by Held et al in 1980. The study reported here contributes to the growing body of knowledge in the field with a longitudinal evaluation of global stereoacuity development with the aid of random-dot stereograms. A forced-choice preferential looking technique was used to assess the development of stereoacuity in 14 infants: 8 males and 6 females. Random-dot stereograms produced by Stereo Optical Inc.

were presented in pairs behind polarising filters to achieve crossed binocular disparity. One stereogram of the pair contained a vertical bar stereofigure, the other did not. Infants were tested with disparities ranging from 1760 to 22 s arc. Measurements began at 2 months of age to assess age of onset of stereopsis and continued weekly for several months to record the developmental progression of stereoacuity. The mean age for onset of stereopsis was 105 days (or 15 weeks) (SD = 13.5 days). The average age at which the infants had attained stereoacuity of at least 22 s arc was 161.5 days (23 weeks) (SD = 38.8 days). Performance fell to chance levels when infants who responded to small binocular disparities viewed stereograms during two control conditions: horizontal disparity presentation and uncrossed polarising filters.

◆ **Effects of contrast change: a means of studying the transition between pattern onset reversal and offset VEP components**

F S Shawkat, T Kriss (Department of Ophthalmology, Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

The relationship between the VEP components to half-field stimulation was studied by tracing the transition from onset/offset mode to the reversal mode by way of a series of contrast change steps. Pattern VEPs were recorded in 15 subjects from 3 transoccipital electrodes referred to a midfrontal electrode. The checkerboard stimulus was presented in the left half-field of the screen. Three checksizes were studied (12, 50, and 80 min arc). Eight contrast conditions for each checksize were recorded. Each condition consisted of the alternation of a constant high-contrast checkerboard (A) with a second checkerboard (B) in which the contrast was systematically changed. Checkerboard B was initially of identical spatial phase to A, but contrast was reduced systematically until B was a uniform grey field (onset/offset). In subsequent steps checkerboard B was of opposite spatial phase and contrast was systematically increased until B was of equal high contrast (full reversal). Occipital VEPs ipsilateral and contralateral to the stimulated half-field were recorded. All ipsilateral and contralateral onset (CI, CII, CIII, and P105) and offset (N85, P110, N165, and N115) components, and reversal P100 significantly enhanced with increasing contrast. The extent of amplitude change with contrast appeared to be the greatest for offset, followed by onset and then reversal. Pattern-offset components could be traced through to the reversal components (ipsilateral offset N85-P110-N165 became reversal N80-P100-N145, and contralateral offset N115 became reversal N105). Onset CI and CII could be traced through to reversal P100 and N145, respectively. When small, 12 min arc, checks were used, onset Co could be traced through to reversal N80 component. The contralateral onset P105 component did not have a comparable component in the reversal mode. Offset and reversal components are closely associated which suggests that they may be mediated by similar physiological mechanisms. Onset and reversal components differ in morphology but the onset CI appears comparable to the reversal P100 component. Onset Co and reversal N80 components appear analogous and have a predominant macular contribution as they are conspicuous to small checksize stimulation.

◆ **Spectral power and time-frequency distributions of beat VEPs**

P West, C M Harris, A Kriss (Department of Ophthalmology, Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

The 'beat VEP', obtained when each eye is simultaneously stimulated at a different frequency, is considered to measure binocular interaction and has been used to study visual development. We find beat VEPs are not robust and report here on the use of analysis techniques to elucidate the origins of these inconsistencies. 6 subjects with normal stereoscopic vision were tested. Sinusoidally modulated luminance stimuli were independently presented to each eye, 6 different and 4 identical frequency pairs were used. Fast Fourier transforms (FFT) (resolution 0.004 Hz) were performed on data acquired for 256 s for each experimental condition. Responses at the fundamental stimulating frequency, and the first-order (sum and difference) cross-modulation product (CMP) frequencies were measured. In addition, time–frequency distributions of instantaneous amplitude were calculated. Not all subjects showed responses at the cross-modulation product frequencies. There was no systematic intertrial and intersubject consistency in response trends. The time–frequency distributions revealed that the instantaneous amplitude of the fundamental and CMP responses varied with time; and indeed were sometimes undetectable for long periods. There was no correlation between the instantaneous amplitude of the fundamental stimulus and that of the first-order CMP. Initial results with single-frequency stimuli suggest that there is a significant inverse relationship between instantaneous alpha-band amplitude, and the total amplitude of the fundamental and harmonics. We conclude that conventional Fourier techniques alone may not be appropriate for analysing sustained responses. Variations in the instantaneous amplitude can result in spurious measurements as FFTs only quantify the average amplitude of frequency components over the analysis period. Endogenous factors most likely associated with

subject attentiveness appear to contribute to changes of the amplitude of the response. These results have implications not only in the use of luminance steady-state VEPs, but may also be relevant to other forms of visual stimulation.

◆ **A comparison of logarithmic and Snellen-based visual acuity charts in a paediatric population**
A J Simmers, L S Gray, K Spowart¶ (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, UK; ¶ Department of Community Health, Ruchill Hospital, Glasgow, UK)
The single optotype format of the Sheridan–Gardiner test (SGT) has over the years been accepted as the method of acuity measurement in both pre-school-age and early-school-age children. It has, however, several disadvantages, the most salient being the irregular progression of letter size, truncation of the measuring scale and lack of contour interaction. A new linear visual acuity chart (Glasgow Acuity Cards; GACs) has been developed for paediatric use which incorporates several design features used in adult test charts to improve the sensitivity of visual acuity measurements. The aim of the present study was to establish normal values of unaided visual acuity for GACs, on the basis of a regular logarithmic progression of letter size, and to compare this test with the more traditional SGT based on the irregular Snellen progression of letter size. 702 children with a mean age of 5.4 $\pm$ 0.3 years were recruited with parental consent from local primary schools. Unaided visual acuity was measured monocularly with both the SGT and the GACs. The SGT was scored as the smallest line where a majority of letters were correctly identified, whereas the GACs were scored per letter. Each subject was encouraged to guess until no further letters were read correctly. Visual acuity scores from the SGT were converted to logMAR to allow a direct comparison of the two scoring systems. Unaided visual acuity was found to be 0.10 ($\pm$0.08) log units for the GACs and $-$0.13 ($\pm$0.07) log units for the SGT. However, the distribution of visual acuity scores was found to be non-normal for the SGT, with scores tending to fall at or close to the mean value. Comparison of GACs and SGT revealed a bias in the mean difference between acuity scores. SGT produced a higher or better score than GACs (mean difference 0.2 log units). The 95% confidence limits for an interocular difference in unaided visual acuity was $\pm$0.08 log units for the GACs; however, the distribution of the interocular differences for the SGT shows a leptokurtic form with most of the values being zero. Confidence limits for both unaided visual acuity and interocular differences in acuity cannot be accurately determined for the SGT owing to the non-normal distribution of visual acuity scores. Consequently, the use of single optotype tests may well conceal a true interocular difference and also tend to overestimate a child's visual acuity, because of the irregular progression of letter sizes and the coarse scale of the SGT. These problems can be overcome by using a test with a regular logarithmic progression of letter size, such as the GACs, which can be scored per letter.

◆ **Analysis of visual function with visual evoked potentials and Teller acuity cards in premature and full-term infants**
G Ruberto¶, W Misefari¶, B Marenzi¶, P E Bianchi¶, S Compiano¶, N Mastricci#, E Fazzi§, A Cavallini§, A Luparia§, R Da Rold§, R Guagliano¶, G Chirico#
(¶ Clinica Oculistica, # Patologia Neonatale, IRCCS San Matteo, Pavia, Italy; § Divisione di Neuropsichiatria Infantile, IRCCS Istituto Neurologico, C Mondino, Pavia, Italy)
A longitudinal prospective study has been conducted at the Neonatal Intensive Care Unit of the Policlinico San Matteo, Pavia between July and December 1996. 37 premature (mean age 33.24 weeks) and 8 full-term infants were studied by VEPs, with a flash rate of 0.5, 10, and 30 Hz (Oz referenced to Fz, analysis time 350 ms). Age at follow-up was 40 $\pm$ 2 weeks, 1 month, and 3 months (protocol-expected controls are 6, 9, and 12 months). Subjects with abnormal neonatal cranial ultrasound were rejected. The selected subjects had normal visual findings. Visual performance was tested with Teller acuity cards (TACs). P100 latencies were similar for full-term and premature infants at stages 1 and 2, but full-term infants showed significantly shorter latencies at stage 3 (follow-up at 3 months). 30 Hz harmonic amplitude showed no significant differences between the two groups considered at any stage, but the 10 Hz response showed an increase after the 45th week. TAC means in pre-term infants are 0.60 and 2.41 cycles deg^{-1} for 40 weeks and 3 months later, respectively, while for full-term infants they are 0.45 and 2.14 cycles deg^{-1}. Our data suggest therefore that acuity and physiological function may not have a simultaneous development rate.

◆ **Refractive development following pre-term birth**

K J Saunders, A J Shepherd, D L McCulloch (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, UK; and The Royal Hospital for Sick Children, Glasgow, UK)

The aim of the present study was to examine the changes in refractive state between birth and 6 months of age in a group of pre-term infants compared to infants born at term. Healthy pre-term infants without ROP ($n = 40$, gestational age 28 – 35 weeks) were tested within 5 days of birth and re-tested at term age ($n = 34$) and at 6 months corrected age ($n = 23$). A cohort of healthy full-term infants were also tested within 5 days of birth ($n = 39$) and again at 6 months of age ($n = 17$). Refractive error was assessed by cycloplegic retinoscopy (0.5% cyclopentolate HCl). Pre-term infants were significantly more myopic, anisometropic, and astigmatic at birth than infants born at term (ANOVA $p < 0.05$). Pre-term infants demonstrated more variability in astigmatic axes than full-term infants whose astigmatism was predominantly with the rule (chi-square $p < 0.05$). By term age pre-term infants had shown a significant reduction in astigmatism and anisometropia (repeat measures ANOVA $p < 0.05$). They remained more myopic than those born at term (ANOVA $p < 0.05$), but anisometropia and astigmatism had reduced to levels not significantly different from those in full-term infants. Astigmatic errors were predominantly with the rule in both groups. By 6 months corrected age myopia had significantly reduced in the pre-term group (repeated measures ANOVA $p < 0.05$) and at this age pre-term and full-term children's refractive statuses were statistically indistinguishable. Thus, in the absence of clinically diagnosed ROP, pre-term infants are born more myopic, astigmatic, and anisometropic than children born at term. Astigmatism is more variable in axis. By term age, astigmatic and anisometropic errors have reduced significantly in the pre-term group and do not differ significantly from the control group. However, it is not until 6 months corrected age that spherical errors in the pre-term group equate with those in the control group.

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◆ **Development of the pattern-reversal VEP in pre-term and full-term infants**

A J Shepherd, K J Saunders, D L McCulloch (Department of Vision Sciences, Glasgow Caledonian University, Glasgow, UK; and The Royal Hospital for Sick Children, Glasgow, UK)

The aim of the present longitudinal study was to examine the development of pattern-reversal visual evoked potentials (PRVEPs) in a group of high-risk and low-risk pre-term, and full-term infants in the first year of life. Pre-term infants (gestational age 26 – 35 weeks) and full-term infants (gestational age 38 – 43 weeks) were tested at the corrected age of 3 months (pre-term $n = 29$, full-term $n = 19$), and re-tested at 6 months (pre-term $n = 33$, full-term $n = 16$), and at 12 months (pre-term $n = 21$, full-term $n = 3$). For each age group, pre-term infants were divided into high risk (3/12: $n = 4$, 6/12: $n = 4$, 12/12: $n = 0$) or low risk according to the presence and severity of cranial ultrasound abnormalities including intraventricular haemorrhages, ventricular dilation, and periventricular echogenicity. PRVEPs were recorded from an occipital electrode to a range of check sizes. Starting at 120 min arc checks, patterns were presented in a staircase manner until a threshold was reached or until cooperation was lost. For all check sizes the PRVEP matured between 3, 6 and 12 months in both the pre-term and full-term groups. The prominent P100 component became consistently earlier as the infants age increased (ANOVA $p < 0.005$). No significant differences were found between the PRVEPs of the low-risk pre-term group and the full-term group at 3, 6, or 12 months of age (ANOVAs $p > 0.1$). Some PRVEP abnormalities were found in infants in the high-risk pre-term group at all ages. (This group is currently too small for valid statistical comparisons). The PRVEP was found to mature at the same rate in both pre-term and full-term infants during the first year of life when age is corrected for prematurity. The presence of an abnormal cranial ultrasound appears to increase the risk of a delayed or abnormal PRVEP.

[Supported by SOHHD, Chief Scientists Office grant K/RED4/C265.]

◆ **Electro-oculography of binocular and monocular viewing of moving isoluminant stimuli in 3-month-old infants**

B Lia¶, J O Phillips¶#, D V Finocchio¶#, D Y Teller¶# (Departments of ¶ Psychology and # Physiology/Biophysics, University of Washington, Seattle, WA 98195, USA)

Direct observation of OKN-like directionally appropriate eye movement (DEM) is used in studies of infant colour vision. Such observational measures have indicated a surprising temporalward bias for monocular viewing of moving isoluminant stimuli, rather than the nasalward bias seen with luminance-modulated stimuli We are obtaining eye-movement records characterising DEM elicited in infants by isoluminant stimuli under both binocular and monocular viewing conditions.

EOG recordings were made of 3-month-old infants viewing either isoluminant (red/green; 25% rms cone contrast) or luminance-modulated (either 100% or 25% contrast) sine-wave gratings on a video monitor (40 deg s^{-1}, 0.25 cycles deg^{-1}, 53 deg $\times$ 40 deg field). Small-field OKN (stare OKN) is readily elicited by 100% contrast luminance stimuli. 25% luminance contrast also commonly elicits robust OKN (slow-phase gain 0.8). When OKN-like responses are observed for isoluminant stimuli, slow-phase gain is much reduced (0.3), as reported for adults. Slow-phase eye movement of long excursion with infrequent fast phases (pursuit OKN) was more often observed. Eye-movement patterns sometimes lack measurable smooth eye-movement characteristic of the slow phase of OKN, yet exhibit staircases of several small saccades directed opposite to target motion that alternate rhythmically with large saccades in the direction of target motion. Such asymmetries could still provide directional cues for an observer to judge DEM. Under monocular viewing, the normal nasalward bias is observed for OKN in response to luminance-modulated stimuli. For isoluminant stimuli, low-gain stare OKN responses were observed for nasalward motion, interspersed with episodes of pursuit OKN. The response to temporalward motion differs in that long-excursion slow phases (pursuit OKN) predominate. These latter eye movements may be more readily scored as DEM.

When OKN is elicited from infants by isoluminant red/green stimuli, it is weaker than that elicited by luminance-modulated stimuli of equivalent rms cone contrast. Some eye-movement patterns which provide sufficient cues for observers to judge DEM accurately may be of a form that cannot be regarded as OKN. The temporalward bias for monocular viewing of isoluminant stimuli reported for DEM measures may arise from greater salience of the long-duration slow phases predominant for temporalward motion relative to nasalward motion.

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◆ **Visual performance based on motion contrast: a new technique for assessing the development of dynamic vision**

M Schrauf, E R Wist (Institut für Physiologische Psychologie II, Heinrich-Heine-Universität Düsseldorf, D 40225 Düsseldorf, Germany)

The development of dynamic visual performance was investigated in a sample of about 400 healthy males and females between the ages of 4 and 19 years. A test was used in which a computer-generated random-dot kinematogram containing a Landolt ring target became briefly visible when the pixels defining it moved coherently while those of the background remained stationary. Motion contrast was varied in terms of the percentage of moving pixels within the ring (100%, 50%, 30%, 20%) (Wist et al, 1996 *Pflügers Archiv* **431** 14). Subjects verbally reported one of four gap locations (left, right, upper, lower). At the same time we measured visual acuity based on static luminance contrast (conventional Landolt test). Results of the motion contrast test show a clear developmental trend with age (4 to 13 years) with performance improving at all motion contrast levels. Maximal performance was reached at the age of 14 years as compared to a norm group of about 800 subjects (age span: 20 to 29 years). No correlation was found between dynamic and static measures of performance. There was a tendency for females to perform better than males. Furthermore, performance with 50% motion contrast both for females and for males decreased at the ages of 10 to 11 and 12 to 13 years, respectively, suggesting a performance loss during puberty. The MS-Windows version of this test of dynamic vision requires about 5 min, and the task is simple enough even for 4 year olds to carry out.

CLINICAL STUDIES (NEUROLOGY)

◆ **Visual and psychomotor development with emphasis on visual perception in at-risk neonates at 5.5 years of age**

B M van den Hout, P Stiers¶, M Haers¶, R Vanderkelen¶, D van der Linden#, D Wittebol-Post#, S Aleman, A Jennekens, O van Nieuwenhuizen, E Vandenbussche¶, P Eken‡, L S de Vries‡ (Pediatric Neurology, Wilhelmina Children's Hospital, Utrecht, The Netherlands; ¶ Laboratory of Neuropsychology, Leuven, Belgium; # Ophthalmology, Academic Hospital, Utrecht, The Netherlands; ‡ Neonatology, Wilhelmina Children's Hospital, Utrecht, The Netherlands)

The aim of the study was to gain insight into the natural course of visual and visuo-perceptual development in children with perinatal haemorrhagic-ischaemic brain lesions and the impact of these lesions on long-term psychomotor and cognitive (visuo-perceptual) development. A cohort of 65 at-risk neonates with haemorrhagic-ischaemic brain lesions on cranial ultrasound had been prospectively followed during 18 months with regard to visual acuity (acuity card procedure) and neurocognitive development (Griffiths Developmental Assessment scales). The cohort was examined again at the age of 5.5 years. The methods employed were as follows. (1) Assessment of visual perception with the L94 (a screening battery, comprising seven tasks, developed to evaluate

visual perceptual abilities). Correction for cognitive levels in the patient group was performed. Control data for the L94 were gathered in a group of 210 children (age range 2.5 – 6.0 years, equally divided among 14 age groups). (2) Orthoptic and ophthalmological assessment. (3) Neurodevelopmental assessment (Movement Assessment Battery for children). (4) Neurocognitive assessment (mean age 5.61 years, McCarthy developmental scales).
[This study was supported by 'Praeventiefonds', grant 2814061, 's-Gravenhage, The Netherlands.]

◆ **Magnetic resonance imaging of brain structure in two young cases of Williams syndrome**
E Mercuri¶#, M Rutherford#, G Bydder§, S Countrell§, F Cowan#, J Atkinson¶, O Braddick¶ (¶ Visual Development Unit, University College London, London WC1E 6BT, UK; # Department of Paediatrics, and § Robert Steiner MRI Unit, Royal Postgraduate Medical School, Hammersmith Hospital, London W12 0NN, UK)
Results of magnetic resonance imaging of the brain are reported for two Williams syndrome (WS) children aged 3 and 2.5 years. Two abnormal features were common to both cases. (i) As has been reported for some older WS cases, the cerebellar tonsils were unusually shaped, with an ectopic protrusion below the foramen magnum (a mild form of Chiari I malformation). (ii) Although the overall myelination of the brain was grossly adequate for their age, abnormal signal was detected in the white matter, involving the centrum semiovale and the superior aspects of the frontal and parietal lobes bilaterally. This may represent a defect in myelination of tracts of cortical association fibres. Fuller understanding of the functional anatomy may help us to understand the disorder of neural development which underlies the cognitive and perceptuomotor deficits in WS.

◆ **Divergent visual development in three children with treated congenital cataract**
M Abrahamsson, A Sjöström, J Sjöstrand (Department of Ophthalmology, Göteborg University, Göteborg, Sweden)
In a cohort of 108 children with congenital cataract born during the eighties in the western part of Sweden, 22 were defined as total and bilateral cases. 3 of these children showed a visual development that differed not only from the other bilateral, total cases but from all the other cases with bilateral congenital cataract. The visual acuity of these 3 children was for a long period of time stabilised at a low acuity level. At approximately 7 years of age their acuity started to increase and there was a continuous increase from that age. The increase was 2.5, 2.8, and 3.0 octaves, respectively, for the three children between 7 and 11 – 14 years of age. These data indicate that the visual system retains its plasticity over a very long period of time and that this must be taken into consideration in the design of treatment and follow-up for these children. The causes for this change in visual acuity in comparatively old children need to be studied much further in order to obtain a reasonable explanation for the phenomenon.
[Supported by Swedish Medical Research Council (grant 0226).]

◆ **Visual outcome at one year of pre-term infants with periventricular leukomalacia**
B Fazzi, L Bartalena¶, A Boldrini¶, G Cioni, M Coluccini, J Van Hof-van Duin# (Stella Maris Scientific Institute, INPE University of Pisa, Pisa, Italy; ¶ Neonatal Intensive Care Unit, University of Pisa, Pisa, Italy; # Faculty of Human Movement Sciences, Free University Amsterdam, Amsterdam, The Netherlands)
Various defects of the visual function have been reported in pre-term infants, mainly retinopathy of prematurity (ROP), but also cerebral visual impairment, ie a visual loss due to a disturbance of posterior visual pathways. The aims of the present research were (1) to study frequency and characteristics of cerebral visual impairment in pre-term infants suffering from periventricular leukomalacia (PVL), a brain lesion which might involve areas important for visual perception; (2) to try to correlate the visual deficit with the severity of brain lesions, as revealed by brain ultrasound and magnetic resonance imaging (MRI). Visual outcome at 1 year of corrected age was investigated in 14 preterm infants affected by severe cystic PVL and another 34 with moderate PVL (prolonged periventricular echodensities). All infants with ocular abnormalities were excluded. Visual acuity, visual field, eye alignment, fixation and following, OKN, and visual threat were tested. A high incidence of cerebral visual impairment, consisting mainly of low visual acuity, severe oculomotor disorders and reduced visual field was found in infants with severe PVL. Visual defects were less frequent and less severe in the moderate PVL group. The results of neuroimaging, and especially of MRI, indicate lesions at the level of optic radiations as the main anatomical substrate of the visual impairment. All infants with PVL need a visual follow-up, the results of which are important for visual and motor rehabilitation of these cases and their daily care.
[Supported by grant RC 2/95 of the Italian Ministry of Health.]

◆ **Accelerating slow phases in epileptic nystagmus: implications for congenital nystagmus**

M R Harwood¶, S Boyd#, K Chong§, I Russell-Eggitt¶, C M Harris¶ (Departments of ¶Ophthalmology, #Neurophysiology, and §Radiology, Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

Attempts to understand congenital nystagmus (CN) have focused on the almost unique accelerating nature of the slow phases. Acquired nystagmus with horizontally accelerating slow phases (ASP) is extraordinarily rare. We report such a case associated with cortical epileptic nystagmus (EN), which has profound implications for modelling CN. Eye movements were recorded before, during, and after an episode of EN in an 8-year-old girl with a 2-week history of partial seizures. There was no previous history of any nystagmus in her or her family. Dc-EOG was used to record gaze stability, saccades, smooth pursuit, VOR suppression, and vestibular and optokinetic nystagmus. Neurological investigations were normal but neuroimaging revealed a subtle low-density area in the left visual cortex. EEG demonstrated a clear cortical focus in the same region. Inter-ictal eye movements were normal with steady fixation in all points of gaze. The onset of seizures was accompanied by the start of the right-beating horizontal conjugate nystagmus. There were no other outward signs of the seizure and the girl remained conscious, but experienced oscillopsia. In contrast to all previously reported cases of EN, the slow phases showed marked, consistent acceleration of up to 600 deg s^{-2}, and reaching velocities of 200 deg s^{-1}, typically over a 60 – 70 deg range. The quick phases reset the eyes to 40 deg in right gaze as well as resetting the velocity to zero. EN ceased after anti-convulsant treatment. The resetting of eye position and velocity clearly indicates involvement of cortical position control in the underlying mechanism of the ASP. All previous models of CN have involved velocity control. In the light of this case we believe this is no longer tenable.

◆ **Saccadic strategies in hemianopic children**

L E Mezey, F S Shawkat, A Kriss, P West, C Timms, D Taylor, C M Harris (Department of Ophthalmology, Great Ormond Street Hospital for Sick Children, London, WC1N 3JH, UK)

We studied the saccadic eye-movement strategies seen in children with homonymous hemianopia (HH) and attempted to reconcile the findings with simulations concerning saccadic flight time and total time-to-fixation. Saccadic eye movements were recorded in 10 children (aged 6 – 16 years) with HH with the use of dc-EOG. HH was diagnosed with perimetry and/or pattern VEPs. Saccades were elicited to red LEDs at amplitudes of 10 or 20 deg, randomised to the left or right of the central fixation target in a no-gap paradigm. Children with cerebellar symptoms, ocular motor apraxia, or basal ganglia disease were excluded. All children made multiple hypometric saccades into their blind field whereas saccades into their preserved field were mostly normometric. 9 children made occasional hypermetric saccades, though into both the blind and preserved hemifields. One child showed more consistent hypermetria into the blind field, but with an equal tendency to make multiple hypometric saccades. Although hypermetria has been described as a compensatory strategy in adults with HH, we have found little support for this in children. Computer simulations suggest that the optimal strategy to minimise either saccadic flight time or total time-to-fixation depends on whether the subject holds an expectation of target location. With no expectation hypometria is optimal. With a strong expectation hypermetria may become optimal. Despite non-randomisation of target amplitude, allowing the buildup of an expectation of target position, the children in this study paradoxically did not adopt hypermetria as a consistent compensatory strategy.

◆ **Transportation component in prehension movement: role of visual feedback in congenital and acquired motor disorders**

F Posteraro (Stella Maris Scientific Institute, INPE University of Pisa, Pisa, Italy)

The acceleration of wrist during grasping movements, executed with or without vision, has a typical profile with a re-acceleration peak located earlier when the subject can see both the object and the hand (visual-feedback condition) than in no-visual-feedback condition where the subject cannot see the hand during grasping. It has been reported earlier that prehension movement executed in visual-feedback condition tends to have longer duration than movement executed in no-visual-feedback condition. This pattern shows that visual feedback is incorporated into the motor program and that additional time is needed to process visual information. By computerised movement analysis system (ELITE) we studied the acceleration profile of a wrist during prehension in 10 children (aged 7 – 12 years) with congenital (cerebral palsy) or acquired (brain injury) movement disorders involving upper limbs. All subjects showed normal cognitive performance and did not suffer psychiatric illnesses. Each subject performed a single grasping movement either in visual-feedback condition or in no-visual-feedback condition. All children with cerebral palsy showed a change in the acceleration profile of a wrist with the re-acceleration peak located

earlier in no-visual-feedback condition than in visual-feedback condition. Some children with acquired motor disorder showed a normal pattern, others showed a pathological pattern. MRI revealed white-matter damage in all children with cerebral palsy and in children with acquired motor disorders who showed a change in the acceleration pattern. Children with acquired motor disorder who showed a normal acceleration profile had no white-matter damage. The study confirms that visual information processed in the posterior areas of the brain is transferred to the anterior areas by white-matter bundles and these bundles take part in motor programming. When white matter is damaged, this information cannot be transferred correctly and this could be responsible for motor programming disorders.

◆ **Visual orientation and detection in infants with leukomalacia**

J Provasi, C Blain-Lacau, H Bloch (Laboratoire de Psycho-Biologie du Développement, EPHE, CNRS, 75005 Paris, France)

The great advances in neonatal research have been accompanied by an increase in perceptual and motor diseases. Some are caused by brain pathology, for example leukomalacia which affects the parietal region and is thought to cause visuo-motor defects. The aim of our study was to determine any specific behavioural features of pre-term infants born with periventricular leukomalacia. Subjects were submitted successively to a visual orientation and a visual detection task. In the first task a form made by 8 diodes was lit 30° on the right or on the left, randomly. At least two trials on each side were performed. The latency and the direction of the eyes and the head were observed. In the second task (detection), first a central attention target flashed until the infant fixed it. Then a peripheral target appeared randomly at 10°, 20°, or 30° on the right or on the left. Each target was lit for 10 s. At least two trials for each target position and side were performed. The latency, the direction, and the pointing and its duration were observed. Eye movements were recorded both by EOG and by video images. Head movements were coded into X and Y coordinates from video images. Data analyses were performed with a digital transformation in an interfaced computer program. A group of 9 premature infants with leukomalacia was compared with a group of 16 healthy premature infants. Infants were born between 28 and 35 weeks gestational age. The mean birth weight was 1580 g. Subjects were tested between 37 and 48 weeks gestational age. The number of responses in the two tasks was high in the two groups: there was no global difference. Infants with leukomalacia, however, showed a lateral asymmetry which was not present in the normal group: the orientation frequency was less to the right than to the left and was performed more frequently without a proper fixation of the target. In the detection task, the mean latency was longer and the detection less frequent on the right than on the left. This effect is particularly important for target positions at 10° and 20°. Because detection involved control of the head in pathological as well as in normal infants, the lateral asymmetry suggests that the main difficulty for infants with leukomalacia lies in the control of the head movement. Lesions designated as leukomalacia are not homogeneous. In our study sample, 7 infants showed EEG and ETF abnormalities, 1 had only abnormal EEG and 1 only abnormal ETF at the first examination after birth. Such differences were not reflected in the behavioural criteria we used in our experiment, suggesting that effects of very early leukomalacia may be transitory. But, if the main effect resides in the motor control of head and eyes, the tasks may be inappropriate.

◆ **The visual and kinesthetic space in children with cerebral palsy: reaching movement analysis and rehabilitative considerations**

P Puccini, I Breghi, R Tavella (Recovery and Functional Rehabilitation Division, Pisa Hospital, Pisa, Italy)

Through a study of the development of reaching movement made at the Pisa Hospital on children 4–8 months old, some mechanisms of this function have been hypothesised to provide better understanding of the development of perceptuo-motor coordination. The skill alterations in children with cerebral palsy were analysed, to build a hypothesis about their abnormal information processing and problem solving. Tests for the localisation and identification of visual and kinesthetic informations ('where' and 'what' space) and tests for transmodal operations are being proposed. The following aspects are being examined: (1) How do the children establish visual–kinesthetic coordination? (2) What kind of visual exploration is altered? (3) Is the kinesthetic knowledge altered? (4) Do the visual and kinesthetic coordinates converge in children with cerebral palsy? (5) What is the problem in the cognitive organisation? The answers to these questions can give some insight into the relationship between motor and cognitive skills. They can also be useful for rehabilitative programming.

◆ **Paradoxical monocular OKN asymmetry in an achiasmic acallosal child**

C M Harris, A Kriss, R J Leitch, D Thompson, K Chong, D Taylor, I Russell-Eggitt (Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

It is well known that the monocular OKN response in young infants is asymmetrical, with a poorer response in the naso-temporal direction of the viewing eye. This asymmetry gradually diminishes in the first few postnatal months, but may persist in both eyes in the presence of early-onset uniocular visual deficits, such as strabismus, cataract, etc. It is also well known that lateralised damage of one parieto-occipito-temporal cortex can reduce or abolish OKN for stimulus motion towards the side of the lesion, whichever eye is viewing. We report for the first time a child who exhibited a paradoxical monocular OKN asymmetry in which the response was poorer in the temporo-nasal direction of the eye. This child had presented with a midline craniofacial cleft and see-saw nystagmus. Neuroimaging revealed absent decussation at the chiasm and absent corpus callosum. We propose that this paradoxical OKN asymmetry reflects the anomalous retino-cortical pathways. Horizontal slow eye movements are driven predominantly by ipsilateral cortex, which normally receives ipsiversive motion information from the contralateral eye via the chiasm and from the contralateral cortex via the corpus callosum. In the absence of both structures, temporo-nasal visual motion information presented to one eye cannot be accessed by the contralateral cortex.

◆ **Visual perception and performance intelligence in cerebral visual impairment due to neonatal brain damage**

P Stiers¶#, P De Cock¶, E Vandenbussche# (¶ Centre for Developmental Disabilities, University Hospital, B-3000 Leuven, Belgium; # Laboratory for Neuropsychology, Katholieke Universiteit Leuven, B-3000 Leuven, Belgium)

We investigated whether impaired performance on visual perceptual (VP) and performance intelligence (PI) tasks, which are strongly associated in neonatally brain-damaged children (Ito et al, 1996 *Developmental Medicine and Child Neurology,* **38,** 496 – 502), reflect separate deficits. With this aim, the performance of 22 neonatally brain-damaged children with cerebral visual impairment (CVI) and 16 mentally retarded (MR) children with no CVI indications was studied on a visual object recognition task (the De Vos task), in relation to intelligence data available from clinical records. First, we investigated whether deficits occurred that are specific to the VP domain. This is the case if performance on the De Vos task is weaker than can be expected from the child's PI level. This is established by comparing the child's De Vos score to that of normal children of an age corresponding to the child's PI age. According to the above criterion, 16 CVI children (73%) were specifically VP-impaired, compared to only three MR children (19%). Secondly, we investigated whether this VP deficit affects performance on intelligence tests. We found that the ratio of performance to verbal intelligence was significantly lower in VP-impaired children (14 WPPSI forms, 8 VP vs 6 nVP: $F_{1,12} = 10.7$, $p = 0.0035$). On the other hand, no larger performance subtest scatter was found in VP-impaired children (29 SON forms, 16 VP vs 13 nVP: $F_{1,27} < 1$), nor did they show a different subtest profile (group × subtest interaction: $F_{4,108} < 1$). These results show that neonatal brain damage can give rise to deficits that are visual perceptual in nature, even though these deficits seem to go together with reduced PI. If this PI reduction were a mere performance reduction due to VP impairment, one would expect some PI subtests to be more vulnerable, or at least an increase in subtest scatter. Since this was not found it might reflect a separate impairment.

◆ **CNS damage and visual outcome at 4 – 7 years in very premature infants**

R Caputo, G Rapisardi¶, M Paternoster¶, L Campa, P Bonucci, E Scarano¶, S Frosini, G P Donzelli¶, R Frosini (Department of Ophthalmology; ¶ NICU, Department of Pediatrics, University of Florence, Florence, Italy)

We studied the correlation between site, severity, and kind of hypoxic-ischemic or haemorrhagic CNS insult and later visual function development in high-risk pre-term infants. From 1st January 1988 to 1st January 1992, 152 infants with a gestational age (GA) of 30 weeks and/or a birth weight (BW) of 1500 g were discharged from the NICU of A Meyer Children's Hospital, Florence, Italy. 104 of them (68%) were reassessed by experienced ophthalmologists at 4 – 7 years of age (mean ± SD = 5.2 ± 1 years). The infants had a mean BW of 1192 ± 261 g (range 650 – 1950 g) and a mean GA of 29.7 ± 2.7 weeks (range 25 – 37 weeks); 67% were AGA. On the basis of the CNS parenchymal damage, neonatal cerebral US was classified as: normal, with mild to moderate, or severe damage. The site (frontal, parietal, occipital, temporal; right, left, bilateral) and the kind (hypoxic-ischemic or haemorrhagic) of the lesion were also considered. The presence of abnormalities in ocular motility (AbMot), refraction (AbRef), fundus (AbFun), visual acuity (AbVis), stereopsis (AbSter), and the presence of anisometropia and amblyopia were assessed by the ophthalmologist. 56% of the children showed 1 and 32.7% showed 2 ophthalmological abnor-

malities. Their presence was significantly correlated with CNS parenchymal damage ($p < 0.05$), but not with GA, BW, % AGA, presence of occipital lesion, or kind of lesion ($p > 0.05$). AbMot and AbFon were correlated with the severity of the CNS insult ($p < 0.05$). The left hemisphere was more often affected by CNS insult than the right one (44.8% vs 10.5%); the left eye was affected twice as much as the right by AbMot, whereas the AbRef was mainly bilateral (70%). Assessment of neonatal CNS damage by US had a prognostic value for later visual development, particularly for abnormalities of the ocular motility and the fundus.

◆ **Dyslexia as a brain dysfunction**

O Alves da Silva, G Serrano (Santa Maria Hospital, Lisbon, Portugal)

Dyslexia is much more than a reading disability. Wrong sound perception, dyslalia, and writing disability, among others, have been mentioned as symptoms accompanying dyslexia. This kind of symptoms does not seem to match very well with the classical concepts pointing to a limited brain lesion like excess of neural tissue or migration of cortical brain cells. The failure to cure dyslexic people by treating their reading disabilities is in accordance with our concept that dyslexia forms part of a widespread body syndrome. On the basis of our large clinical experience, we show that organic factors are not important in the majority of the cases of dyslexia. Common dyslexia is one of the symptoms of a faulty body proprioception syndrome. Electrophysiological mapping of the brain shows high absolute power levels at low brain frequencies. The treatment we have been using for some twenty years now to solve the proprioceptive disorders is also able to normalise the brain electrophysiological map and to treat the dyslexia. After the treatment children can read easily, but for scientific purposes we have decided to compare their Rey tests before and after the treatment and also their writing and drawing abilities. These tests show very significant improvements after the treatment which are in accordance with our clinical evaluation concerning the raising of their abilities. We analyse in detail 62 dyslexic children randomly selected from our clinical archives. This analysis shows the reasons why we believe dyslexic people have good reasons to smile nowadays.

◆ **Reading with and without eye movements in normal and disabled readers**

C Casco, L Battelli¶, A Vestri§ (Dipartimento di Psicologia Generale, Università di Padova, Padua, Italy; ¶ Dipartimento di Psicologia, Università de Trieste, Trieste, Italy; § Dipartimento di Psicologia dello Sviluppo e della Socializzazione, Università di Padova, Padua, Italy)

It has been shown earlier that programming and execution of saccadic eye movements impose an upper limit on conventional reading rate. Indeed, reading rate with conventional page presentation (250 ms per word) becomes faster when text is presented sequentially one word at the time at the same location in the visual field (60 ms per word) so as to abolish eye movements. We attempted to distinguish between two sets of factors contributing to saccadic latency in reading: oculomotor (programming and execution of eye movements) and visuomotor factors (stimulus localisation and decision processes involved in selecting the saccade target). We also investigated how each of these factors contributes to reduce reading speed in disabled readers. We compared reading time per chunk in 9 normal (mean age 12 ± 1 years) and 9 disabled readers (mean age 11.5 ± 5 years) when text was presented in chunks either contiguous (moving window, MW) or at the same location (rapid serial visual presentation, RSVP). Only the MW involves eye movements. In both modes, chunk length varied within blocks according to 3 levels: 8 – 13, 14 – 18, and 19 – 30 words. Results show that in both groups reading speed is slower in MW mode than in RSVP mode ($p = 0.001$). However, this difference is less than what it would be predicted by the oculomotor hypothesis. The mean difference in reading speed between MW and RSVP is equal to 28.4 ms for normal readers and 271.6 ms for disabled readers. The greater difference in disabled readers suggests that reading speed in this group is affected by oculomotor factors. Moreover, this suggests that oculomotor factors cannot explain saccadic latency by themselves. Second, reading time significantly increases ($p = 0.001$) with chunk length, but more in the two largest chunks for both normal and disabled readers, suggesting that visual factors involved in saccadic programming play an important role in reducing reading speed in disabled more than in normal readers. These visual factors are introduced when the chunk length is larger than the perceptual span.

◆ **The electrophysiological findings in 3 children with delayed visual maturation**

M Kraemer, A Sjöstrom (Children's Eye Department, East Hospital, Göteborg University, Göteborg, Sweden)

We investigated children with delayed visual maturation (DVM) by electrophysiology and looked for models to explain the physiological background. Three cases of DVM with different backgrounds were investigated by ophthalmological routine examination and flash visual evoked response (FVEP). The first case was a boy with nystagmus. The FVEP revealed an immature response with marked increase in latency of the identifiable potentials at 3 months of age. At 4 months of

age, he started to give responsive smiling and the FVEP response was normalised. The second case was a girl with immature FVEP response at 3 months of age, and along with the responsive smiling and raised visual interest at 4.5 months of age the FVEP developed. The third case was a prematurely born boy with severe perinatal and postnatal complications such as intraventricular haemorrhage (IVH), periventricular leucomalacia (PVL), and retinopathy of prematurity (ROP). At 8 months of age he gave no eye contact nor responsive smiling and the FVEP response was abnormal with no identifiable potentials. At 14 months of age he was acting visually normally and the FVEP showed a marked development, although still prolonged latencies of N1 and P1. It has earlier been shown that in the normal neonatal development of the FVEP the short latency complex starting with a negativity at approximately 60 – 70 ms (N1) emerges at 4 – 6 weeks of postnatal life when the child starts to give responsive smiling and shows raised visual interest. In accordance with animal experimental research and human studies, the immature unspecific response of the FVEP may reflect mainly subcortically mediated activity and the specific short latency complex response may represent the cortical activity mediated via the specific retino-geniculo-striatal pathway. Since the FVEP develops in the same way in the children with DVM, the physiological background to DVM can be partly understood. The results show that (i) the FVEP response is abnormal in children with DVM, (ii) the improvement of vision in DVM can be measured with FVEP, and (iii) the physiological basis for DVM may be discussed in terms of early subcortically mediated vision with visual unresponsiveness and later retino-geniculo-cortically mediated vision when improvement of visual function has occurred.

CLINICAL STUDIES (OPHTHALMOLOGY)

◆ **Electrophysiological assessment of the visual potential of young children with coloboma**
A Kriss, D Callender, D Thompson, I Russell-Eggitt, D Taylor (Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

It can be difficult to gauge the visual acuity of colobomatous eyes in pre-verbal children—this is particularly problematic when the optic nerve is involved. Visual electrophysiological assessment was made to assess its efficacy in gauging acuity and in indicating visual outcome. Flash ERGs and VEPs to flash and pattern reversal stimulation were recorded in 15 young patients with retino-choroidal, optic-nerve, or macular coloboma. Patients generally tended to have well-preserved mixed cone – rod ERGs. Although they were often smaller than average, they were within normal amplitude limits despite what appeared to be substantial retinal defects. Alterations in the amplitude and latency of pattern and flash VEPs were good indicators of the extent of macular and/or optic nerve involvement in coloboma. Pattern VEPs, in particular, reflected well the degree of preserved vision from colobomatous eyes. We conclude that visual electrophysiology can provide clinically useful information when assessing young, pre-verbal children with coloboma.

◆ **The importance of VEP assessment in craniofacial dyostosis**
A Kriss, J Walker, D Thompson, I Russell-Eggitt, R Hayward, B Jones (Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

Our aim was to assess the value of electrophysiological monitoring in visually assessing young patients with congenital craniofacial conditions, most of whom are prone to progressive visual dysfunction due to raised intracranial pressure and optic nerve compression. The craniofacial conditions in which visual function can be markedly affected are Apert's, Crouzon's, and Pfeiffer's syndromes; all three are associated with shallow orbits, proptosis, and recessed maxillae and nasal bridges. Flash ERGs and VEPs to flash and pattern reversal stimulation were recorded in 18 young patients presenting with craniofacial dysostosis. Flash ERGs were normal; however, VEPs were generally significantly attenuated and degraded from an early stage. VEP testing could sometimes be accomplished when clinical acuity testing was unsatisfactory. Regular monitoring by means of pattern and flash VEPs provided early indications of visual pathway compromise. We find that VEP monitoring provides a useful early indication of post-retinal visual pathway dysfunction, and is especially valuable when dealing with very young craniofacial dysostosis children unable, or unwilling, to undergo conventional clinical acuity testing.

◆ **The role of visual evoked potentials in monitoring low-grade gliomas of optic pathways**
D Riva, C Pantaleoni, V Saletti, C Ciano, W Scaioli¶, M.R Balestrini¶, S D'Arrigo, C Tebaldi (Division of Developmental Neurology and ¶ Division of Neurophysiopathology, Istituto Nazionale Neurologico, 20133 Milano, Italy)

The use of visual evoked potentials (VEPs) for monitoring low-grade gliomas of optic pathway has been examined. The treatment of low-grade gliomas in children with and without NF1 is still subject to debate. While a 'wait and see' attitude is adopted if the tumor and the visual functioning are stable, the increase of the lesion dimensions and the deterioration of visual functioning can

independently indicate the need for treatment. We evaluated visual functions of 12 children with optic gliomas using visual evoked potentials, MRI, and assessment of visual acuity. The results indicate that deterioration of VEPs has a good correlation only with a severe but not a slight visual worsening and poor correlation with an increase of the lesion size. These results provide evidence that VEPs can be used as a screening test in children with NF1 suspected to have an optic glioma as an alternative to routine neuroimaging, but that this test is not recommended as a very sensitive tool in monitoring visual worsening in small steps.

◆ **Photorefraction in 1-year-old children with the MTI-photoscreener**

A Rydberg, J Ygge (Department of Ophthalmology, Karolinska Institute, Huddinge University Hospital, 141 86 Huddinge, Sweden)

It is important to detect subnormal vision early in life. Monocular visual acuity screening in Sweden is performed on a general basis at 4 years of age. The aim of this study was to investigate whether the MTI-photoscreener could be used as a screening method for detecting refractive errors, strabismus, and other abnormalities of the visual system in even younger children. 50 children were included in the study. The age range was 10 – 14 months. An orthoptic investigation was performed including cover test, ocular movements, convergence, the 20 prism fusion test, the Lang stereotest, and preferential looking (the acuity card procedure). Photos were taken with the MTI-photoscreener (1 – 4 photos per child, mean 1.8). A complete ophthalmological investigation including cycloplegic refraction, and examination of fundi and media was performed. The polaroids from the MTI-photoscreener were analysed without knowledge of the result of retinoscopy. No constant manifest strabismus was found. 1 child had an intermittent exotropia for distance. The ocular movements and convergence near point were normal in all children. All but 6 children did cooperate with the Lang stereotest and showed normal response. 50% of the children did not cooperate with the prism fusion test; most of those who did had normal response. All but 7 children did cooperate with the preferential looking method binocularly and they all had normal grating acuity (3 – 15 cycles deg^{-1}). The refractive errors measured by retinoscopy were within normal limits in most of the children. None of the 50 children had any abnormality of the fundi and media. The results obtained with the MTI-photoscreener were normal in most children. In 4 children the results from the photos would have been difficult to judge. No major abnormalities were found. The usefulness of the MTI-photoscreener as a screening method cannot be predicted from the results of this study. Our general feeling, however, is that the test is easy to use and the children cooperated very well. The test is probably not reliable enough to be used as a screening method for a normal population of children at this age. Too many false positives would be referred, and some higher refractive errors and other abnormalities would be missed. We have now extended this study to adults with multihandicap and will later look at multihandicapped children. These groups might benefit from screening with the MTI-photoscreener.

◆ **Infant vision: first steps in Romania**

C Vladutiu (Opthalmological Clinic of the Medical University, Cluj, Romania)

220 children between 7 months and 3 years of age have been investigated for the first time in Romania in a systematic manner, for a high visual risk (striking strabismus, nystagmus, absence of fixation or follow-up reflex, family history of strabismus and/or amblyopia). Strabismus was confirmed in 173 children (constant convergent strabismus—140; divergent strabismus—6; vertical deviations—7; convergent intermittent strabismus—20). Visual acuity was measured by visuodisk (preferential vision)—50 patients; image test (Rosano – Weiss)—7; Snellen 'E'—34. The visual capacity was assessed by alternating fixation. Amblyopia was diagnosed in 100 children (40%). The examination of optokinetic nystagmus showed congenital strabismus in 70 children and essential strabismus in 75. The conservative treatment of strabismus consisted of optical correction, occlusion, penalisation, and sectorisation. Only 40 of the children (16%) have followed the indications. An improvement of the visual acuity could be observed in 34 of these patients (85%); isoacuity was restored in 24 (60%); 10 (25%) improved significantly. Ocular deviation disappeared in 4 children (10%) and diminished in 11 (27%). Surgical correction was necessary in 30 children. It is concluded that early detection and treatment of strabismus and amblyopia are sine qua non conditions for positive results.

◆ **A preliminary analysis of visual acuity in infants followed up from the second Cambridge infant vision screening programme**

S Anker, J Atkinson, O Braddick, D Ehrlich, T Hartley, J Wade (Visual Development Unit, University College London, London WC1E 6BT, UK)

We report early findings in the development of visual acuity in a cohort of infants generated from a total population of infants screened at 8 months of age as part of the Second Cambridge Infant Vision Screening Programme. The screened infants were invited to attend the Unit for further

investigation if they showed large lags of accommodation on videorefraction ($\geqslant +1.5$ D), or a difference of focusing between each eye (>1 D). A further group of infants were recruited as controls; they were able to focus well and were not strabismic. Half the infants who were significantly hyperopic ($\geqslant +3.5$ D) at 10 months were given a partial spectacle correction to correct their spherical hyperopia. Interim results are reported as the study is ongoing. Each child has been followed up regularly at 4 – 6 monthly intervals from the age of 8 – 10 months. The visual acuity was measured at 12 – 15 months by automated forced-choice preferential looking, and then again at 36 – 39 months by single-letter matching with the use of the Cambridge Crowded Cards. The infants were tested binocularly at 12 – 15 months, with and without spectacles if prescribed, and monocularly at the later age. In tests at 12 – 15 months no significant differences were found between the binocular acuity of the controls, the untreated hyperopes or the hyperopes (not including anisometropes) wearing a spectacle correction (t-test, $p > 0.05$). The interim results reported concern the acuity measures made on the control group, the non-prescribed group, and the spectacle wearers at 36 – 39 months. These preliminary results indicate that preferential looking may not be a sensitive indicator of the effects of moderate refractive errors on development of acuity in normal infants.
[This work is supported by the Medical Research Council of Great Britain.]

◆ **Decomposition of infant refractive measures**
D Ehrlich, A Rudenski¶ (Visual Development Unit, University College London, London WC1E 6BT, UK; ¶ Addenbrookes Hospital, Cambridge, UK)

Clinically, refraction is described by a sphere, a cylinder (positive or negative notation), and an axis. The sphere is not independent, but is the mean spherical equivalent power (MSE) plus or minus half the astigmatism. We consider the importance of decomposition into primary independent components and how this improves our understanding of infant refractive changes with age. (1) Astigmatic refractive error is considered as a sinusoidal distortion superimposed on a mean refractive error. This decomposition creates independent primary components of MSE—astigmatism 'amplitude' and axis. Mathematically, the astigmatic sinusoidal wave 'amplitude' represents half the peak-to-trough magnitude (the traditional astigmatism magnitude). Physiologically this is appropriate too, because as regards relative defocus effects, cylindrical blur is approximately half that of spherical blur. (2) Astigmatism can be split into oblique C45 and horizontal C180 components, with the latter component being negative for WTR and positive for ATR astigmatism. This is useful for studying astigmatism in isolation. (3) The overwhelming skewness of the distribution of astigmatism may require nonparametric analysis. (4) Analysis of anisometropia requires special care if MSE and cylinder differences and their relationships are to be evaluated. We describe use of a root-mean-square difference as a measure of separation. It is defined by integrating over any angular interval which is in an integral multiple of radians. It is interesting to note that the square of this measure of separation can be decomposed into two components. The first is the square of the difference in MSE, while the second is related to the square of the cylinder components and a term which takes into account the angular separation of their axes. This overall measure of separation and the way it easily separates into components is likely to improve our understanding of anisometropia and the mechanisms at work in its natural history in infants. Understanding of infant emmetropisation processes, as well as other infant refractive issues, is assisted by decomposition of refractive measures into their true mathematical and physiologically primary components. We also present a method of measuring the separation between two sets of refractive values which may be helpful in investigating anisometropia, both the overall effect and its MSE and cylinder components.

◆ **The refractive components in binocularity disturbances**
L Lindberg, H Erkkilä (Department of Ophthalmology, Helsinki University Central Hospital, FIN-00290 Helsinki, Finland)

It is known that squint interferes with refraction during the first decade of life. The general view is that the squint is secondary to a refraction anomaly. A novel approach is to ponder whether the refractive power of the developing eye can be affected by disturbed binocularity. Growth of the axial length is considered to be a determinant in the process of emmetropisation, which tends to counteract the hyperopia of the newborn period. Do the squinting eyes, ie disturbed binocularity have some abnormal features indicating disturbance of emmetropisation? This study was made on 160 patients between 3.1 and 76.7 years of age who were operated on for strabismus. The measurements of the axial length, anterior chamber depth, lens thickness and vitreous chamber were done in lying position with a-scan ultrasound, whilst refraction and keratometry were measured in cycloplegia with an autorefracto-keratometer. We evaluated the refractive components both in normal and strabismic eyes, in strabismic subtypes and amblyopic eyes. The results and conclusions are discussed.
[Supported by Silmäsäätiö and Clinical Research Institute of the Helsinki University Central Hospital.]

◆ **Infants with defects of basic visual functions retard in red/green, but not in yellow/blue discriminations**

A A Nevskaya, V M Bondarko, L I Leushina (Pavlov Institute of Physiology, Russian Academy of Sciences, Nab. Makarova 6, 199034 St Petersburg, Russia; Early Intervention Institute, ul. Chaikovskogo 73, 199053 St Petersburg, Russia)

Colour discrimination was investigated in two groups of infants aged 4 – 14 months: healthy (250 subjects) and those with slight defects of basic visual functions (the risk group—80 subjects showing instability of binocular fixation, slightly reduced visual acuity, or restricted visual fields, etc). A toy moving in front of an infant disappeared behind a screen and reappeared after 2 – 3 s on the other side. Sometimes when the toy was not seen the experimenter replaced it with a new one differing only in colour: yellow/blue or red/green. The form and size of the toy remained constant. The emotional reaction of surprise showed whether the infant could discriminate these pairs of colours. The brightness of each stimulus was slightly varied to make sure that the infant reacted to colour change but not to brightness changes. About 75% of healthy 4 – 5-month-olds showed good expressive reactions to replacing of blue and yellow, and practically all children discriminated these colours at 7 – 8 months. The discrimination of red and green develops slower. About 75% of the children discriminated the red/green pair at 6 – 7 months, and only at 12 months practically all children showed good reactions to the red/green replacement. There were no children who discriminated the red/green pair but not the yellow/blue pair. The mean difference between the number of children discriminating these two pairs was 7.6%. The infants in the risk group were as good as their healthy age-mates in the yellow/blue discrimination, but their results were substantially worse in the red/green discrimination. The mean difference between these pair discriminations was 17.0%. The reasons for the retardation of chromatic discrimination in the risk group are discussed.

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◆ **ROP at NICU, A Meyer Children's Hospital (1987-1995): incidence, associated factors and visual outcome**

G Rapisardi, R Caputo¶, M Paternoster, L Campa¶, M L Cioni, E Scarano, R Frosini¶, G P Donzelli (NICU, Department of Pediatrics, and ¶ Department of Ophthalmology, University of Florence, Florence, Italy)

During the period from 1 January 1987 to 31 December 1995, a total of 361 infants with a gestational age (GA) <32 weeks were discharged alive from the NICU, Department of Pediatrics, A Meyer Children's Hospital, University of Florence. All the survivors were regularly examined by two experienced ophthalmologists, starting from the third or fourth postnatal week and then repeatedly at least every two weeks until retinal vascularisation was completed. 76 cases of ROP were diagnosed (49 ROP I, 23 ROP II, 3 ROP III, 1 ROP IV), in infants with a mean birth weight (BW) of 1016 $\pm$ 293 g (range 450 – 1940 g) and a mean GA of 27.8 $\pm$ 2.5 weeks (range 24 – 32 weeks). The total ROP incidence in the survivors was 23.7% in VLBWIs (BW <1500 g) and 47.8% in ELBWIs (BW <1000 g). Severe ROP (grade III and IV) was uncommon: 1.3% in VLBWIs and 3.3% in ELBWIs. As the risk of ROP is highest in infants at the highest risk of dying, the cumulative percentage of total ROP and death was also computed, which was 42.4% for VLBWIs and 68.6% for ELBWIs (25.8% and 41.8% for severe ROP, respectively). All infants with ROP showed a spontaneous resolution, except 3 cases in which cryotherapy was used. The distribution of ROP by GA showed a sharp decrease after 27 weeks. Mean $\pm$ SD postconceptional age (PCA) at ROP onset was 35.2 $\pm$ 2.1 weeks (range 31 – 41 weeks), mean PCA at ROP resolution was 41.2 $\pm$ 3.1 weeks (range 35 – 53 weeks), and mean duration was 6 $\pm$ 2.3 weeks (range 2 – 12 weeks). GA was the single most powerful factor associated with the occurrence of ROP. Compared to a control group of 125 infants not affected by ROP, which did not differ by GA and BW, infants with ROP $>$ II were more likely to need more days of artificial ventilation and oxygen therapy and to be affected by a severe intracranial haemorrhage (grade III and IV by Papile) ($p < 0.05$). They also showed a worse neurodevelopmental outcome and a higher incidence of myopia and strabismus at follow-up ($p < 0.05$). Thus we can conclude that in our unit the incidence of ROP is low and the large majority regress spontaneously. The most important factors associated with it are GA, CNS haemorrhagic disease, duration of artificial ventilation, and oxygen therapy.

◆ **Crowding in grating acuity of normal and amblyopic children**

M Irwin, M J Moseley¶, A R Fielder¶ (Academic Unit of Ophthalmology, University of Birmingham, Birmingham B15 2TT, UK; ¶ Academic Unit of Ophthalmology, Imperial College of Science, Technology and Medicine, London SW7 2AZ, UK)

Grating acuity overestimates letter acuity in some children with amblyopia. One reason may be the lack of crowding elements in typical grating targets. We investigated the influence of crowding on the grating acuity of normal and amblyopic children. Subjects were children diagnosed with amblyopia (interocular acuity difference, IAD > 0.1 log units) and children with normal vision ($\geqslant 6/6$ in preferred eye, with spectacle correction if worn). Acuity was measured monocularly with the use of 3 cycle high-contrast monochromatic grating targets oriented vertically or horizontally, which were either (i) isolated; (ii) contour-surrounded (with four flanking bars at a separation of 2.5 cycles—equivalent to inter-letter spacing on a logMAR chart); or (iii) crowded (flanked by four competing gratings, at 2.5 cycle separation). Thresholds were estimated by the method of limits with minimum target step size of 0.1 log units. The patient group was tested in each eye. Distance letter acuity was also measured with the aid of a logMAR chart. 24 amblyopic (13 with strabismus, 4 with anisometropia, 7 with both; mean age 5.6 years, SD 1.4 years) and 49 normal (mean age 5.8 years, SD 1.0 years) children were tested. There was no statistically significant difference between contour-surrounded and isolated grating acuity in either group. On average, crowding (ie crowded − isolated logMAR grating acuity) was 0.1 log units in the patient group ($p < 0.005$, amblyopic eye) and 0.05 log units in the normal group ($p < 0.001$). 20 of the 24 patients with amblyopia showed normal crowding in both eyes (within confidence limits of crowding of the normal children). The remaining patients, who all had strabismus, showed abnormal crowding in the amblyopic eye (range: 0.4 to 1.1 log units), and one of these also had abnormal crowding in the fellow eye (0.4 log units). In the patient group, letter acuity of the amblyopic eye was overestimated by grating acuity measured both with isolated and with contour-surrounded grating targets (least squares linear regression, slopes 0.36 and 0.57, respectively), but agreed well with crowded grating acuity (slope 1.00). Letter IAD was underestimated by all grating targets, but showed best agreement with crowded grating IAD (slope 0.85). We conclude that grating acuity in normal and amblyopic children is reduced when targets are flanked by competing gratings at a 2.5 cycle separation. In children with amblyopia, grating acuity measured with crowded rather than isolated or contour-surrounded targets better predicts letter acuity and IAD.

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◆ **The public health significance of the prevalent vision disorders of young children in the United States**

P Schmidt¶, E Ciner, L A Cyert, V Dobson, M Maguire, B Moore, D Orel-Bixler, J Schultz (Preschool Children's Vision Screening Study Group and ¶ Planning Center at The Ohio State University College of Optometry, Columbus, OH 43210-1240, USA)

Vision disorders occurring in early childhood account for vision loss which, if identified early, could be prevented. We critically reviewed the literature published between 1940 and 1995 reporting the prevalence rates of vision problems in young children in the United States and the screening methods used to detect them. We also conducted surveys of all 50 of the United States and the District of Columbia to identify the vision screening guidelines currently used for preschool children. Vision disorders were documented as the leading cause of handicapping conditions and the fourth most common disability in childhood in the United States. These vision disorders include amblyopia, strabismus, significant refractive errors, ocular disease, and colour vision deficits. For example, a total of 6 million Americans experience significant loss of vision owing to amblyopia, with an additional 75 000 3-year-olds developing amblyopia each year. It is now recognised that early detection and treatment of vision disorders is essential for preventing vision loss. 28 states recommend or require screening the vision of preschool children. Yet less than 15% of children below the age of 6 years receive eye or vision examinations and less than 25% of preschool children have their vision screened. The prevalent vision disorders in young children thus pose a significant threat to the health of young children and may preclude full participation in society. The significant vision disorders of early childhood, the prevalence rates, the negative associations, and the effectiveness of methods for their detection used in the United States are discussed.

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◆ **Clinical and electrophysiological assessment of Leber's congenital amaurosis**

B Stirn Kranjc¶, J Brecelj# (University Medical Center Ljubljana, ¶ University Eye Clinic, # University Clinic of Neurophysiology, Ljubljana, Slovenia)

Leber's congenital amaurosis (LCA) is a congenital rod–cone disorder, associated with very poor vision from birth. We report on a prospective clinical and neurophysiological study of 9 children with suspected LCA. Our main interest was to confirm the diagnosis (LCA might be overestimated or underdiagnosed, mostly because of an underlying systemic disorder, eg metabolic, Zellweger, Refsum, Joubert disorder, adrenoleukodystrophy) and to assess any progression of the disease. Thorough ophthalmological, paediatric, and neurological examinations were carried out at referral (children's age 3–13 months, mean age 7.6 months) and on several occasions at follow-up (2–6 years). Computed tomography of the head was performed. At least twice, electroretinograms (ERGs) were recorded with skin electrodes (placed on the lower eyelids) simultaneously with the visual evoked potentials (VEPs), recorded with three electrodes over the occipital cortex in alert children without pupil dilatation. Recordings were made to white, red, blue flashes and to pattern-reversal stimuli (age-matched controls were also tested). 9 children (5 boys and 4 girls) with negative family and perinatal history had nystagmus and very poor vision registered at referral. Their anterior eye segments were unremarkable, optic media clear. They were all slightly photophobic with sluggish pupils, 7 of them poked their eyes. They had mostly normal appearing fundi, or very mild attenuation of the retinal vessels and pigmentary changes. All were hyperopic. There was no severe neurodevelopmental delay. Only 1 child had some motor problems and seborrhoic dermatitis, another had small opening of foramen ovale. Neurometabolic disorders or syndromes associated with retinal dystrophy were excluded. There was no hearing loss. CT scan of the head was normal in 6 children, in 1 there was some enlargement of the ventricles, and slight atrophy of the brain in 2 cases. At first examination ERG was not recordable in 8 children, VEP to binocular stimulation could not be detected in 3, was delayed in 2, attenuated in 2, attenuated and delayed in 1 child. At the last examination the vision was still poor, but slightly improved from light perception to 0.01 and 0.04 in at least one eye in 6 of the children. Clinically some more pigmentary changes at the posterior pole were found. There were no changes in the somatic status. ERG and VEP recordings remained consistent with the diagnosis, only in 1 child with detected attenuated ERG to blue flash stimulation it is still open. We conclude that in LCA thorough clinical diagnosis is essential. Simultaneous recording of ERG and VEP with skin electrodes in alert children is acceptable before age of 1 year.

◆ **Monocular optokinetic symmetry in early onset esotropia**

C Timms, P West, F S Shawkat, M Harwood, C M Harris (Department of Ophthalmology, Great Ormond Street Hospital for Sick Children, London WC1N 3JH, UK)

It has long been assumed that the coincidence of maturation of both symmetrical monocular optokinetic nystagmus (MOKN) and binocular vision suggested a common underlying mechanism subserving these two functions. We have previously reported MOKN symmetry in patients with profound unilateral loss from birth. We investigated this relationship in a group of patients who had no demonstrable binocular vision and good vision in both eyes. 10 subjects with early-onset strabismus and an equal number of normals were studied in the age range 5 to 13 years. None of the patient group had more than 1 Snellen line difference between each eye. Binocular vision was assessed with Bagolini striated glasses, the Randot, and Lang stereotests. Monocular and bi-ocular OKN was elicited to a rotating full-field curtain at stimulus speeds of 25, 50, and 75 deg s^{-1} to the left and to the right. Horizontal eye movements were measured by DC electro-oculography, digitally recorded, and computer analysed. Slow phases were identified as lying between consecutive quick phases; each slow phase was tested by appropriate criteria for inclusion in the analysis. Slow-phase velocity distributions were calculated for each stimulus condition and an index of symmetry was calculated. MOKN responses were categorised as symmetrical, near-symmetrical, or asymmetrical. None of the subjects demonstrated stereopsis. Only 4 of the patients were categorised as having asymmetrical MOKN responses; of the remainder 3 were symmetrical and 2 near symmetrical. One patient showed a response difference between eyes, being symmetrical in the right eye and not in the left. There was no relationship between the index of symmetry and type of strabismus. Contrary to the generally accepted view, our patient group contained a significant number of individuals in whom MOKN symmetry was not related to their degree of binocular function. In these patients neither binocular vision nor stereopsis is a prerequisite for development of normal MOKN symmetry.

◆ **Assessment of impaired vision during the first year**
L Hyvärinen, U Hirvonen (Department of Biomedicine, Section of Physiology, University of Helsinki, Helsinki, Finland)

We use two parallel assessments of visually impaired children during the first year: the evaluation of the type and degree of the visual impairment and the assessment of functional vision. In the latter, we need to assess how much vision is available for the development of each particular function and in which areas the child needs to use other modalities for learning. In the assessment of vision for communication, we can use low-contrast pictures of a face. If the infant reacts only to intermediate and high contrasts at close distances, facial features of the mother need to be accentuated by make-up. Visually impaired infants may not develop accommodation and thus have problems in eye contact because they seem to look through the adult person. Accommodation is often difficult to measure during dynamic retinoscopy; the use of near correction may be an easier and more effective way of evaluating it. If the infant has central scotoma due to retinal or visual pathway lesion, or the retina is dragged temporally by scar tissue or upward because of coloboma, the child seems to look past or above the person, at whom he/she is trying to look at. The child's fixation behaviour needs to be well documented and reported to all persons involved with the infant's care. In the assessment of impaired vision for early intervention purposes we thus need to assess, during each follow-up visit: the visual sphere of the infant for objects of different sizes and contrasts, grating acuity, vision for communication with the use of low-contrast pictures of a face, oculomotor functions including accommodation and fixation behaviour, and observe whether the child has enough vision to learn hand regard, to bring hands to the midline, to grasp, to develop pincer grasp, and to develop vision-related spatial concepts and orientation in space. Vision is not an independent sensory function but an integral part of the development of a number of functions. Therefore the clinical evaluation and the functional assessment should cover all the developmental areas to provide useful information for the planning of the early intervention.

VISION AND CHILD DEVELOPMENT/REHABILITATION

◆ **Strategies of visual analysis in children with low vision**
I V Blinnikova (Laboratory of Cognitive Processes, Institute of Psychology, Russian Academy of Sciences, Yaroslavskaya 13, 129366 Moscow, Russia)

Four different tasks were used to investigate visual analysis strategies in low-vision children at different ages: set A and set AB of Raven's Coloured Progressive Matrices; maze tasks; and picture assembly tests. 48 low-vision children (age 6 – 12 years) performed these tasks twice, and their results were compared with those of normal-vision children (4 to 10 years old). Children with low vision were less successful in solving all the tasks, and needed more time for task performance. The results of low-vision children depended on the degree of the sight loss. Those with visual acuity from 2/100 to 4/100 performed set AB of Raven's test and picture assembly tests better than the two other tasks (in contradiction to results of other groups). Normal-vision children were more skilful in handling the experimental tasks, demanding the priority of holistic analysis of visual image (set A of Raven's test, maze tasks). Children with visual acuity between 5/100 to 8/100 demonstrated the same tendency but at the lower level of performance. The results show that heavy visual impairments lead to the changing of fragment/whole relation in the visual analysis. Low-vision children with visual acuity between 2/100 and 4/100 had difficulties with holistic analysis of visual image and therefore they used strategies of fragmentary visual analysis and achieved success in those tasks for which these strategies were adequate. However, a level of visual acuity over 4/100 ensured the use of holistic strategies of visual analysis. The differences in performance of the two types of tasks in low-vision children are maximum at about 9 years, and then begin to decrease. These data help to specify the training programmes for children with different level of vision loss.

◆ **Development of children's notion about the visual world in early infancy**
V M Bondarko, A A Nevskaya, L I Leushina (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg; Early Intervention Institute, ul. Chaikovskogo 73, 199053 St Petersburg, Russia)

The development of an infant's representation of the visual world was investigated on 800 infants (age 4 – 14 months). The age norms were established for such operations as prediction of movement direction; discrimination and recognition of object form, size, colour, and spatial position; and search for hidden objects. The prediction of movement direction starts at 4 – 5 months, and at 6 months practically all infants perform this operation. At 5 – 6 months about 80% of the infants notice size changes, but the proportion of infants showing surprise reactions to size changes diminishes at 9 – 10 months whereas the reaction to form changes increases. The result

may demonstrate the development of form recognition invariant to size. We also assessed basic visual functions: binocular fixation, eye movements, visual field, and visual acuity. Among the normal infant population, about 20%–25% showed some slight defects of basic visual functions. These infants showed poorer results than their normal age-mates in such tasks as search of a toy hidden under a cap, or prediction of movement, or object discrimination. The differences between the normal and risk groups remained, even when these groups were matched for developmental age (assessed by the KID scale of J B Reuter), so it was not caused by a general retardation. Even slight defects of the basic visual functions may influence unfavourably infant mental development. Detailed analysis shows that reduced visual acuity (non-attention to small visual objects such as crumbs 0.5–1 mm in diameter in the acuity test) was especially prognostic.
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◆ **The development of the magnocellular pathway in primary-school-age children**
G E Gordon, D L McCulloch, A H Herbert (Department of Vision Sciences, Glasgow Caledonian University, Glasgow G4 0BA, UK)

The aim of this study was to investigate the development of the magnocellular pathway in primary-school-age children. Steady state visual evoked potentials (SSVEPs) were recorded with the use of the Enfant system (Neuroscientific Corp, NY) from children aged 5 years ($n = 25$), 8 years ($n = 21$) and 11 years ($n = 21$) and young adults ($n = 20$). All subjects had good binocular vision and visual acuities better than 6/9 Snellen equivalent. Stimuli were low-spatial-frequency sinusoidal gratings (2.4 cycles deg^{-1}), modulated temporally at 24 reversals s^{-1} at a series of contrasts between 5% and 30%, presented for 16 s. These parameters were chosen in an attempt to obtain a signal which was primarily transmitted by cells of the magnocellular pathway. All children completed at least three contrasts: 20%, 10%, and 5% (two trials at each contrast). Active electrodes were on the central, right, and left occipital scalp. Signal-to-noise ratios (SNRs) were calculated from Fourier transforms of the SSVEPs. These were analysed for the best trial at the reversal rate and its first harmonic. The SNR of all age-groups improved with increasing contrast (MANOVA $p = 0.0005$). SNRs to all contrasts increased with age (MANOVA $p = 0.001$). The SNR of the 5-year-olds to the lower contrasts (5% to 10%) was not different from noise ($p > 0.1$). The VEPs of the 11-year-olds and the young adults were significant at all contrast levels. We conclude that the magnocellular pathway may not be mature at the age of 5 years but may continue to mature throughout the primary school years to reach adult levels at the age of 11 years.
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◆ **Holistic image recognition during perception of a limited number of elements in children with normal and low vision**
L P Grigorieva, M E Bernadskaya, I V Blinnikova, V V Svechnikov (Laboratory of Neuropsychophysiology, Institute of Special Education, Russian Academy of Education, ul. Pogodinskaya 8, GSP-3, Moscow, Russia)

Changes in holistic image recognition during the perception of a limited number of its elements were studied in 96 children with normal ($n = 48$) and low ($n = 48$) vision in relation to age (6–8, 9–10, and 11–12 years), to the degree of vision impairment (visual acuity 1%–10%), and after one-year visual perceptual training (VPT). A computer version of E Gollin's method was used for determining the percentage of the drawn part of the image at which its recognition as a whole image occurs. All visually handicapped children effectively recognised test images whose mnemonic standards were formed. Mean percentage of the drawn part of images at which their holistic recognition occurred decreased with age both in normal ($p < 0.001$) and in visually handicapped ($p < 0.01$) children. Mean percentage of the drawn part of images necessary for their holistic recognition was much higher in all groups of visually handicapped children than in groups of normal children of the same age ($p < 0.001$; $p < 0.01$). Differences between the mean scores in the groups of children with visual acuity of 1%–4% and 5%–10% were little significant ($p < 0.05$). Following VPT, mean percentage of the drawn part of images necessary for their holistic recognition considerably decreased in children with low vision ($p < 0.01$). We conclude that in children with normal and low vision, recognition of the whole image is based on a limited number of image elements. Recognition of the whole image gets better between the 6th and the 12th years of life, this probably being related to the ontogenetic maturation of the intracortical connections between the visual projection, inferior temporal, and posterior parietal areas.

◆ **Visuo-perceptual, visuo-spatial, and visuo-constructive ability in 11 – 12-year-old children with a birth weight < 2000 g**

M Haers, P Casaer¶, E Vandenbussche (Laboratory of Neuropsychology, K U Leuven, B-3000 Leuven, Belgium; ¶ Pediatrics, University Hospital Gasthuisberg, B-3000 Leuven, Belgium)

School-aged children with low birth weight (LBW) are often reported to show higher incidences of visuo-perceptual/motor difficulties than full-term controls. Subnormal task performance is found to be related to LBW (Waber and McCormick, 1995, *Journal of Pediatric Psychology* **20** 721 – 735) and being born small vs appropriate for gestational age (SGA/AGA) (Korkman et al, 1996, *Journal of Clinical and Experimental Neuropsychology* **18** 220 – 233). 93 LBW children (BW < 2000 g) aged 11 – 12 years, following mainstream education, were screened for school achievement, and for visuo-perceptual (judgement of line orientation test, JLO, Benton), visuo-spatial (road map test, RMT, Money), and visuo-constructive (developmental test for visuo-motor integration, VMI, Beery) skills. Children with school problems were also tested with the WISC-R intelligence test. 20 children had a BW < 1250 g, 25 between 1250 g and 1500 g, 17 between 1500 g and 1750 g, and 31 between 1750 g and 2000 g. 18 were SGA, 75 were AGA. We found mean performance on the visual tasks to be within normal limits. Visual performance was significantly related to performance on school achievement tests (one-way ANOVA). Children scoring below Pc25 on one or more of the achievement tests performed significantly worse on JLO, RMT, and VMI. This relationship is stronger than with WISC-R intelligence. We found no relationship between task performance and BW or SGA (one-way ANOVA). Reduced performance on visuo-perceptual, visuo-spatial, and visuo-constructive tasks in children with a BW < 2000 g is thus more strongly related to school achievement than to WISC-R intelligence, and is not related to BW or SGA. This finding is in line with high rates of school problems and grade retention in LBW children, and seems to indicate a pattern of functional impairments that is more generally shared by children with educational problems.

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◆ **Cognitive functioning in children with cerebral visual impairment: early development and outcome at 5 years of age**

B Bertuccelli, B Fazzi, G Cioni, J Van Hof-van Duin¶ (Stella Maris Scientific Institute, INPE University of Pisa, Pisa, Italy; ¶ Faculty of Human Movement Sciences, Free University Amsterdam, Amsterdam, The Netherlands)

The role of vision in motor, mental, and emotional development in the first period of life is essential for interaction with the environment, for controlling action, and to provide the main basis of mental representation. A high incidence of cerebral visual impairment (CVI), due to lesions of CNS involving the retrochiasmatic visual pathways and areas, has been recently reported in children with pre-perinatal encephalopathy. The aim of this retrospective study was to investigate early and pre-school cognitive development in children with CVI. So far we selected 14 children aged 5 years with pre-perinatal encephalopathy documented by neuroimaging (brain ultrasonography and/or magnetic resonance imaging) who were observed from the first period of life until pre-school age for their motor, visual, and cognitive development. In the first years, grating acuity was tested with Teller Acuity Cards, visual field by kinetic perimetry, ocular motility by Cover test, and the light reflex test for strabismus, optokinetic nystagmus, fixation, and following. In addition at the age of 5 years the Rotterdam C-chart was used to assess Landolt-C acuity, and the Lang and the Titmus test to evaluate binocular perception. Early cognitive development was assessed with the Uzgiris – Hunt scales and with the Griffiths scales; at the age of 5 years the Wechsler pre-school and primary scale of intelligence (WPPSI) was used. A wide range of visual defects was found in this group of children. Preliminary results show a correlation between visual and cognitive impairment, both early and at the age of 5 years. Children with early and pre-school normal grating acuity values and impaired Landolt-C acuity presented a normal or borderline cognitive development. Lower mental scores were obtained in children with impaired grating and Landolt-C acuity; in these cases cognitive level ranged between borderline and mild mental retardation. Moderate or severe mental retardation was always associated with severe CVI. At the WPPSI performance IQ was generally lower than verbal ability which was often spared. WPPSI scores correlated with CVI, irrespective of the severity of motor impairment.

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◆ **The results of visual acuity measurements conducted by Lea symbols far chart on pre-school children**

S V Kulikova (Uktomsky Institute of Physiology, St Petersburg State University, Universitetskaya nab. 7/9, 199034 St Petersburg, Early Intervention Institute, ul. Chaikovskogo 73, 191194 St Petersburg, Russia)

Standard visual acuity testing implies the application of line tests that contain symbols, letters, or numbers. Usually it is difficult for young children to work with such charts. Now Lea symbols visual acuity tests (L Hyvarinen et al 1980 *Acta Ophthalmologica* **58** 507), developed for children aged over 18 months, are available. 446 pre-school children were examined to determine success rates of visual acuity measurements conducted with Lea symbols far chart designed for screening, and to collect the data for preliminary calculation of age norms. Medical histories of most children were available. Of the visual acuity values measured, 152 binocular values and the same number of monocular values, obtained in children 2–6 years of age having normal vision, were selected for the calculation of age norms. Binocular visual acuity values were obtained in children as young as 18–23 months, but only 5% were successful during the primary examination. In children aged 24–29, 30–35, and 36 months and above the percentage success rates of binocular (monocular) measurements were respectively 49 (16), 75 (38), and 76 (67). To ensure the success of measurements it was very important to select a viewing distance convenient to the child, making it less than the standard one for younger children. Training material must be used also during examination to give the children opportunity to answer by pointing/matching. The developmental level requirements necessary for conducting successful measurements with Lea symbols far chart are discussed.

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◆ **The effect of premature birth on visual and developmental status at the age of 5 years**

R T Mackie¶, C A Brogan#, D L McCulloch¶ (¶ Department of Vision Sciences and # Department of Psychology, Glasgow Caledonian University, Glasgow G4 0BA, UK)

The aim of the present study was to compare the visual status of pre-term and full-term children at 5 years of age. The developmental status of the pre-term children was also determined and its relationship with the visual status investigated. Subjects were 38 children aged between 53 and 65 months who were born between 24 and 34 weeks gestation (mean 30.9 $\pm$ 2.1 weeks) and 24 age-matched controls born at term (mean 39.2 $\pm$ 1.3 weeks). Assessment was made of refractive status, binocular status, and visual acuity with the use of the Glasgow Acuity Cards, and pattern-onset visual evoked potentials (VEPs) were obtained. At a separate session, a subgroup of the pre-term children ($n = 24$) completed a Wechsler Preschool and Primary Scale of Intelligence Revised (WPPSI-R) and a Movement Assessment Battery test. The 2 groups of children exhibited similar visual clinical characteristics. The refractive error for each eye of the pre-term group was not significantly different from that of the full-term group (ANOVA $p > 0.05$) and the incidence of strabismus was similar (pre-term 18.4%; full-term 12.5%). However, the pre-term group had significantly smaller C1 amplitudes for all spatial frequencies (repeat measures ANOVA $p < 0.02$), and lower VEP and logMAR acuity thresholds than the full-term group. The pre-term group demonstrated age-appropriate IQ scores when age was corrected for prematurity (98.5 $\pm$ 16.5) but had lower IQ scores when chronological age was used (94.4 $\pm$ 15.1). 3 children (11.5%) had a definite motor impairment; 9 children (34.6%) had a borderline motor impairment and 14 children (53.8%) exhibited normal motor skills. Children with a definite motor impairment were more likely to have a significant refractive error ($p < 0.01$ Fisher PLSD) and smaller VEP amplitudes for all sizes of stimuli (repeat measures ANOVA $p < 0.05$) than other pre-term children. The remaining visual characteristics did not differ significantly between the motor skills categories. The children's IQ scores were not related to any of their visual characteristics. Thus we found that pre-term children differed from those born at full term only in subtle areas of visual function by 4–5 years of age. Visual status was related to motor competence but not to measured IQ scores.

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◆ **Helping reading with colour**

A J Wilkins (MRC Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, England)

About 20% of children aged 7–11 years report that pages of text glare, and the letters or words appear distorted, for example they wobble or blur. The perceptual distortions occur independently of the child's optometric status and are more frequently reported by children whose reading is poor, particularly after a prolonged period of reading. The distortions are not reported when the text is tinted by covering it with a coloured plastic overlay, provided the child has had the chance to compare a variety of colours and has selected a colour that gives optimal clarity.

With the selected colour, symptoms of asthenopia are greatly reduced and the speed of reading increases. The extent of the increase in speed can be used to predict whether the overlay will subsequently be used voluntarily in the classroom. Although each child expresses an idiosyncratic preference for certain hues, children almost equally frequently show an aversion to other hues, not necessarily those that are complementary. The beneficial effects of the optimally coloured overlay are not readily attributable to placebo effects, but may result from an influence of colour on the ease with which visual texture can be segregated. (Text resembles texture, particularly for those children unfamiliar with reading.) We have devised a simple test of the ability to segregate visual textures. Although the textures consist of contours that contrast only in brightness, the overall colour of the texture affects test performance, and does so in some observers more than in others. There are also individual differences between observers with respect to the optimal colour, and its specificity. The improvement in reading speed when the overlays are used is correlated significantly with the improvement in texture segregation. The texture segregation task is similar to reading in that it requires integration of information from successive fixations across a highly-contrasting texture, with a large consequential change in the contrast of the retinal image from one fixation to the next. By demonstrating colour specificity in such a task (one that does not involve reading) we have provided further evidence that there is a subset of children whose reading problems are visual and may be treated with colour.

◆ **The role of visual perceptual training in the cognitive development of visually handicapped children**

L P Grigorieva, M E Bernadskaya, I V Blinnikova, V V Svechnikov (Laboratory of Neuropsychophysiology, Institute of Special Education, Russian Academy of Education, ul. Pogodinskaya 8, GSP-3, Moscow, Russia)

We carried out an experimental verification of the systemic model of long-lasting visual perceptual training (VPT) intended for overcoming the consequences of sensory deprivation in 125 children aged 6 – 12 years with lesions in the retino-geniculostriate pathway and visual acuity from 1% to 10%. Psychophysiological methods were based on systematically repeated rhythmic ($f = 1$ Hz) on – off stimulation with light flashes, gratings, geometrical figures, or object images. Psychological methods were aimed at the formation of perceptual—cognitive operations. Control assessment following 3 – 4 years of VPT revealed: (i) an increase in the rate of correct recognition of sensory features (particularly of colour and shape of images of different size; $p < 0.01$; $p < 0.05$); (ii) a significant improvement in the constancy of black-and-white and coloured image perception; (iii) a considerable increase in the short-term visual memory ($p < 0.01$); (iv) a considerable development of visuo-operational thinking and visuo-imaginative thinking. Juxtaposition of the results obtained and morphological and neurophysiological data suggests that the cognitive development of children during VPT is based on the strengthening of intracortical integration of the visual projection and association areas which play a specific role in image recognition under the deficit of external visual information. The efficacy of the VPT systemic model, demonstrated in this study, makes it possible to recommend it for medical and psychopedagogical rehabilitation of visually handicapped children.