The effect of filter bandwidth on the multifocal visual evoked cortical potential

Chisholm JA, Evans AL, Keating D, Parks S

Introduction

There remains considerable diversity in the technical details of multifocal visual evoked cortical potential (mfVECP) recording. Filter bandwidth is one such variable. In recent studies, reference has been made to local optimisation of the filter bandwidths, but there has been no detailed discussion of their effect on the mfVECP waveforms. This ongoing study aims to formalise the impact of removing high and low frequency components from the raw EEG signal prior to cross-correlation.

Methods

10 normal healthy volunteers underwent monocular mfVECP testing using a custom designed multifocal electrophysiology system. A dartboard pattern stimulus with 60 elements, each containing a 4x4 checkerboard pattern, was used and was presented using the back-projection technique at a frame rate of 75Hz. A 15-bit m-sequence was used to control the pattern reversal of the stimulus, resulting in a recording time of approx 8 minutes per run.

Signals were recorded using four commonly employed midline electrode placements including the standard VEP mid-occipital arrangement 1, 2. A forehead electrode served as ground. Ag/AgC1 electrodes were used and impedances were below 5kΩ EEG signals were passed through a hardware bandpass of 0.1 to 100Hz, amplified by a gain of 100K and were sampled at 1200Hz.

After recording, the raw EEG signal was software filtered using custom designed software. Digital Filter Design Package (DFDP) Version 1.1 (Atlanta Signal Processors Inc) was used to calculate the coefficients used in the filtering program. Software filtered data was then cross-correlated as usual.

Results

Early results indicate that narrowing the bandpass from 0.1 to 100Hz to 3 to 30Hz removes noise and results in small changes to the amplitude and latency of waveforms. More detailed analysis will be presented.

References

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The influence of stimulus presentation time on the multifocal ERG response.

David Keating, Gillian Ainslie, Stuart Parks, Donald Smith and Aled Evans

Purpose: The multifocal ERG response is a composite response formed by a number of different contributing frequencies. The purpose of this study is to examine how the first order response and the contributing sub-components are affected by the stimulation frequency (frame rate).

Methods: Both CRT and LCD devices operate at a fixed frame rate of 75Hz. By using a custom built p.c. based multifocal system driving an LED stimulator it is possible to vary the frame rate with a resolution of 1 msec. Six normal healthy volunteers performed a 61 element multifocal ERG and an m-sequence driven global ERG. A 15 bit m-sequence was used for the multifocal response and a 12 bit for the global response. For the global response, separate recordings were obtained at the following stimulation frequencies: 10 Hz, 14 Hz, 24 Hz, 34 Hz, 45 Hz, 56 Hz, 67Hz, 77 Hz,, 91 Hz, 111 Hz, 143 Hz, 200 Hz, 333 Hz and 500Hz.. Full cross correlation and a selective cross correlation was performed to recover the first order and the response sub-components.

Results: In general, the responses demonstrate the high pass filter characteristics of the retinal architecture. Response amplitude decreases as stimulation frequency increases and waveform shape becomes closer to the standard Ganzfeld ERG as stimulation frequency is decreased. Sub-component analysis shows which pulse trains dominate the response and also give an insight into the origin of the so-called 'induced components' of the multifocal ERG.

Conclusions: There are many factors to consider when choosing a stimulation frequency. High frequencies offer fast recording times which could be important for pediatric applications (a full 12 bit m-sequence can be delivered in 8 secs at a frame rate of 500 Hz) and slower frequencies offer preservation of standard ERG waveform shapes at the expense of longer recording times and the loss of non-linear contributions to the response.

mfERG with scanning laser stimulation and concurrent view of retinal structures

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Purpose: To stimulate mfERGs and image the macula simultaneously using a Heidelberg Retina Angiograph (HRA) and to compare the results to those obtained in the same subjects using CRT stimulation.

Methods: The Roland Consult 'Retiscan' system was used to control mfERG stimulation using either CRT or HRA. The Retiscan also performs response acquisition and data analysis for each mode of stimulation. The CRT stimulated at a rate of 60Hz with simulated white light whereas the HRA stimulated at a rate of 20.4Hz using a 514nm laser. Imaging of the macula before, during and after the mfERG stimulation period was achieved by reflectance of the 795nm laser of the HRA. 19 unscaled segments over an area of 20° radius were stimulated by each method in the same subjects.

Results: Images show how the stimulated area was chosen and maintained during mfERG stimulation with the HRA. Response waveforms show similarities between HRA and CRT stimulation. Some differences are probably explained by the relatively slow stimulation rate of the HRA and its monochromatic stimulus.

Conclusion: Simultaneous retinal imaging and mfERG recording has previously been performed using the HRA in cats and normal human subjects (Seeliger *et al*. 1998; Seeliger *et al.* 2000). mfERGs can be used to identify areas of retinal dysfunction in age related macular degeneration (Palmowski *et al.* 2002) and other causes of local dysfunction. Simultaneous mfERG stimulation and retinal imaging may allow a more precise assessment in patients who find it difficult to fixate or cases that require investigation of a specific extra-foveal region.

Comparison of Multifocal ERG, Pattern ERG and Psychophysical Measures of Rod and Cone Function in Patients with Retinitis Pigmentosa and Abnormal Fundus Autofluorescence

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Purpose: To assess the functional significance of macular abnormalities visible in fundus autofluorescence images of patients with RP in relation to multi-focal and pattern ERGs (mfERG, PERG).

Methods: Patients with a clinical diagnosis of RP were selected according to 3 criteria: a clinical diagnosis of retinitis pigmentosa (rod-cone dystrophy) confirmed by ISCEV-standard ERGs; normal visual acuity; and an abnormal high density ring on fundus autofluorescence imaging (AF). AF imaging of lipofuscin at the level of the RPE was performed using a confocal scanning laser ophthalmoscope (modified Zeiss). mfERG, PERG, photopic and scotopic fine matrix mapping (FMM) were also performed. High density AF rings were compared with the spatial extent of mfERG preservation. PERG P50 was compared with the summed responses associated with the central 1, 7, 19 and 61 mfERG stimulus elements.

Results: The eccentricity at which the mean mf ERG N1 and P1 components were reduced to 33% of the central response showed high correlation with the radius of the ring of high density (r=0.78 and 0.67). There was high correlation between PERG P50 amplitude and the sum of the mf ERG components: correlation with P1 was greatest for the summed responses associated with the central 7 and 19 mfERG stimulus elements (r=0.65 and 0.69). FMM across the high density ring revealed a severe loss of photopic sensitivity concordant with the PERG and mfERG abnormalities. Scotopic sensitivity loss encroached upon central areas.

Conclusions: Both the mfERG and PERG P50 suggest relative preservation of photopic macular function within the AF ring, consistent with the photopic sensitivity losses demonstrated by FMM. Pattern ERG and multi focal ERG amplitudes correlate over central retinal areas.

Multifocal VEP Detects Small Localized Paracentral Visual Field Defects in Retinal and Neural Disease.

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Purpose
To demonstrate circumscript damage of electrophysiological conduction in a patient group with unilateral or bilateral paracentral small visual field defects.

Patients and Methods
mfVEP (VERIS dart board 60, single channel in the midline, recording time 7 min 17 sec) was applied in a group of patients with perimacular retinal disease or neural disease, accompanied by a sharply confined paracentral visual field scotoma. An amplitude criterion was applied for an estimation of the local functional loss. The signals from both eyes were analysed in order to identify local damage. An additional mfERG was recorded in the retinal cases.

Results
Localized defects of mfVEP signals could be detected in a part of both retinal and neural cases which were in good accordance with the visual field defects. In retinal cases, localized retinal mfERG abnormalities were in accordance with the mfVEP signal abnormalities.

Conclusions
mfVEP helped to detect localized paracentral dysfunction on places of the visual field where the patients reported a circumscript subjective depression of sensitivity. There were limitations of mfVEP application: Due to high variabilities of the mfVEP, signal interpretation was delicate, mainly if only a single channel was used. Furthermore, localized visual field defects may have been present also in cases with diffuse retinal or neural defect resulting in a generalized bioelectrical signal depression.

Interpretation of Visual evoked potentials in sick children

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The interpretation of visual evoked potentials (VEPs) in sick children relies on knowledge of environmental, physiologic and pathological factors all of which can affect the results.
Environmental factors are most problematic in the intensive care wards or with infants visiting the department in incubators where ventilators and automated drips can evoke artifacts despite attempts to remove them from the recordings.
Physiological considerations include the state and age of the child/infant. In the very young the EEG is dominated by theta activity that can become time locked in to the evoked potentials. The EEG is also modulated by state of arousal, consisting of high amplitude slow wave activity when drowsy. In addition in a child who has been crying the EEG consist of slow activity as a result of hyperventilation.

It is very common for clinicians to expect some kind of measure of visual function in reports. This becomes problematic in a large population of children who may have suffered some kind of prenatal insult, are ex-premature children or with structural abnormalities, for example in children with craniosynostosis. In these cases it is common to report poor vision levels as the VEP can be degraded, have atypical morphology or even be absent. It will be discussed what additional recordings can be carried out to assist determining vision levels in these children

Full-field skin ERGs are comparable, after scaling, with corneal ERGs in normal adults and children.

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Full field ERGs were recorded in healthy children (age 5-14 years) and adults at two centres (Boston, USA and Cambridge, UK) to compare responses obtained with either corneal contact or skin electrodes. Rod, mixed rod-cone and cone responses (ISCEV Standard, 1999) and rod b-wave S-R functions were recorded in 34 adults and 14 children with a Burian-Allen (BA) electrode, 26 adults with a Gold Foil (GF) electrode and 11 adults and 17 children with an electrode on the skin. The aim of the study was to determine whether reliable ERGs can be recorded with skin electrodes.

With computer averaging all standard rod and cone ERGs could be measured with skin electrodes and response waveforms were comparable with those obtained in the same centre using the GF electrode. Rod and cone responses were approximately one quarter of the amplitude of responses recorded to the same stimuli with GF electrodes. Skin ERGs from adults and children did not differ significantly. The skin ERGs were scaled to match the response obtained with a GF electrode to allow comparison of group variance and this did not differ significantly for any response for either adults or children.

GF and scaled skin electrode rod and cone b-waves and the mixed rod–cone b-wave did not differ significantly in amplitude from the responses recorded with the BA electrode for either adults or children. The rod a-wave was significantly smaller and the cone a-wave significantly larger with the BA electrode, which may be due to stimulus differences between the two centres. There were only slight differences of b-wave peak latencies. Group variances were significantly greater for the BA responses.

Corneal and skin rod ERGs can be recorded over the same intensity range extending to 5 log units below ISCEV Standard flash energy. The Naka-Rushton function was fit to each b-wave S-R data set. Vmax was comparable for GF and BA responses but these were four times the size of the skin responses; values for adult and children did not differ significantly. Log k for the Boston data was significantly more sensitive than the Cambridge data.

These results show that ERGs recorded with skin electrodes are comparable, after amplitude scaling, with corneal ERGs. They suggest that a protocol using skin electrodes in the unsedated child may give valid data for clinical diagnosis when responses cannot be obtained with corneal electrodes.

Testing for Motion artifacts in steady state Vernier VEP measurements.

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Purpose

Vernier acuity measured by steady-state sweep visual evoked potential (SSVEP) involves stimulus modulation between alignment and misalignment and yields vernier acuity (first harmonic response) and motion acuity (second harmonic) in normal subjects. The potential exists for patients with motion asymmetry (MA) eg. early onset esotropia, to produce motion responses which masquerade as a vernier response at the first harmonic.
The purpose of this study was to determine the extent to which a motion asymmetric response is likely to contaminate vernier acuity measurements in patients.

Methods

Each eye of 11 subjects with documented early onset esotropia was tested. VEP responses to horizontal and vertical orientations were investigated.
The first experiment involved a 'provocation test' to detect and measure MA using 80% contrast sine-wave gratings (2 cycles per degree), modulated at 6 and 10 Hz. The second experiment involved a 'penetration test' to detect if MA carriers produced a significant first harmonic response to a motion-only version of the vernier acuity paradigm. This motion control consisted of an 80% contrast square-wave grating (2 cycles per degree), the bars alternating at a fixed temporal frequency between symmetric periodic vernier offsets of increasing magnitude. In the third experiment vernier acuity was measured with the bars alternating between collinear and offset states. First harmonic responses in the motion control condition thus serve as an indicator of the potential for MA to contaminate vernier response measurements.

Results

All 11 subjects demonstrated MA as calculated by an Asymmetry Index (n = 10), and as demonstrated by the 'bowtie' configuration on inter-ocular polar plot comparison (n = 4).
Two subjects penetrated to produce a valid first harmonic response in the motion control paradigm.

Conclusions

Vernier acuity measured with offset gratings appears to be a reliable method of measuring true vernier acuity in that the potential for asymmetric motion responses contaminating the vernier response is small, however caution must be exercised in the interpretation of Vernier thresholds when the subject 'penetrates' on the motion control stimulus.

Improved success in paediatric acuity assessment

Alison M Mackay[1], Michael S Bradnam[1], Ruth Hamilton[1], Gordon N Dutton[2], John Dudgeon[2] and Katherine M Spowart[3].

Purpose: To establish the success rate and outcome of a new automated acuity assessment based on the real-time analysis of steady-state visual evoked potentials (step_VEP). To compare the step_VEP with transient VEPs (t-VEPs) and subjective methods of estimating acuity.

Methods: Both VEP assessments presented checkerboard stimuli of 100% contrast and mean luminance of 60cdm^{-2}. The t-VEP and step_VEP stimuli reversed at rates of 1.1/second and 7.8/second respectively. t-VEP stimuli were presented from large to small in octave increments until a response could no longer be recorded or until the patients attention was lost. The step_VEP analysed steady-state responses in real time and presented stimuli using a successive approximation paradigm until a threshold was established.

Independent groups of 107 and 111 paediatric patients underwent acuity assessment by t-VEPs and the step_VEP respectively. 183 of these 218 patents also underwent subjective acuity assessment by an orthoptist. Each individual assessment was graded prospectively as being successful or incomplete. The whole group was then used to calculate success rate for each technique. A z-test for independent proportions established the significance of the difference in success rate between techniques.

For the children who successfully completed both VEP and subjective assessments on the same day, N=50 and N=55 for t-VEPs and step_VEP respectively, test outcomes were compared using regression analysis, Bland-Altman plots and expressing the range of subjective acuities corresponding to each VEP critical check size.

A sub-group of 66 patients also received assessment by a developmental paediatrician. The effect of developmental factors on success rate and test agreement was investigated using repeated Kruskal-Wallis tests. The effect of main diagnosis on these factors was investigated using McNemar and Binomial tests.

Results: Step_VEPs had a success rate of 83% compared to 67% for t-VEPs and 74% for subjective assessments. These differences were statistically significant (p=0.007, p=0.000).

Agreement with subjective tests was closer for the step_VEP than t-VEPs (0.41 LogMAR vs. 1.04 LogMAR); the step VEP also had much narrower 95% confidence intervals around the mean agreement than t-VEPs and narrower ranges of subjective acuities corresponding to each critical check size.

The degree of motor impairment and intellectual impairment was shown to influence the success of subjective assessments but not VEP assessments. The success rate improvement of the step_VEP over t-VEPs was larger in the vision clinic group, specifically in patients with learning difficulties.

Conclusion: Children with a wide range of ophthalmological and developmental difficulties are referred for VEP acuity assessment. Our study showed that the step_VEP was more likely to provide a successful acuity assessment than t-VEPs or subjective techniques in this general population. The chance of step_VEP success relative to subjective success increases with the degree of intellectual or motor impairment.

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Intensity response functions in the photopic ERG: B-wave implicit time produces a hill and flicker phase produces a valley

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The luminance response function for amplitude of the photopic b-wave peaks for moderately bright stimuli then declines for brighter flashes. This well recognised feature is referred to as the photopic hill.

The aims of our current research are

- To replicate the phenomenon of the photopic hill and extend the range to include high intensity flash stimuli.
- To investigate the intensity response function for photopic flicker stimuli
- To examine the effects of background illumination on the photopic a and b waves.

Using ISCEV standard recording conditions and full field flash stimulation, ERGs were recorded to an intensity series of white flashes from below threshold to 3.16 log cd•s/m^2 on two photopic backgrounds corresponding to the higher and lower levels within the ISCEV standard range. Sinusoidally modulated flicker stimuli (30Hz.) were presented on similar backgrounds up to a maximum of 1.48 log cd•s/m^2. For both background levels, the a-wave amplitudes demonstrated the expected saturating functions. The b-wave amplitudes demonstrated the photopic hill, which was more pronounced on the brighter background level. An associated change in b-wave implicit time was also demonstrated: maximum b-wave implicit time occurred for flashes around 1.6 log cd•s/m^2 with shorter implicit times for flashes above and below that level. Flicker ERG amplitudes demonstrated saturating functions. Flicker phase produced a minimum for moderate flash intensities, a feature that could be called the photopic valley. These findings may have implications for interpreting results of standard clinical recordings of the photopic flash and flicker ERGs and may be important for understanding the source of the photopic b-wave and flicker ERG.

Visual evoked potentials elicited by first and second-order modulations of noise

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Vision is sensitive to first-order luminance patterns (gratings, checkerboards) as well as to second-order modulations of carrier contrast. Some studies have suggested that these two types of visual information are processed by different pathways. The first-order pathway consists of linear filters that are sensitive to luminance modulations. The second-order pathway consists of early linear filters, followed by a non-linear stage and then proceeded by linear filters tuned to the spatial frequency of the modulating signal. This final linear stage extracts the signal from the second-order patterns. The existence of additional stages in the second-order pathway may result in slower responses to contrast modulations compared to the responses to luminance modulations.

We recorded onset visual evoked potentials (VEPs) to first- and second-order modulations of dynamic binary noise. The electroencephalograph signals were recorded from three electrodes attached to the observer's scalp at Oz, O3 and O4 according to the 10-20 International system. The data were used to calculate the Laplacian responses by a 3-point Laplacian operator. The Laplacian responses to 0.5-c/deg luminance gratings in the absence and presence of noise were positive with a latency of about 130 ms. For luminance modulations of 4 c/deg, the Laplacian responses were negative with a latency of about 100 ms. The early components of the Laplacian responses to contrast modulated noise of both low and higher spatial frequencies had a negative polarity with a latency of about 200 ms.

Additionally, we carried out multiple channel recording of VEPs to second-order patterns which were presented in the upper, lower, left and/or right parts of the visual field. The Laplacian responses to contrast modulations of both 0.5 and 4 c/deg showed a reversal in amplitude between stimulation of lower and upper as well as between left and right parts of the visual field. Bearing the cruciform model of the primary visual cortex in mind, these findings suggest that the generators of the responses to second-order modulations are likely to be localised in the striate cortex. The longer latency of these responses may be due to the presence of additional stages in the second-order pathway. These stages could be associated with neural structures located either within the primary visual cortex or within extrastriate cortex which activate striate neurones via backward connections.

Using the PERG to detect early glaucoma damage

Professor Michael Bach

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Raised intraocular pressure (IOP) is a major risk factor for glaucoma, but only approximately 1% of patients with pressure of 25 mmHg or above develop the condition each year. Sizable retinal ganglion cell loss occurs prior to a manifest visual field defect, and it would therefore be of considerable benefit to identify those patients with elevated IOP at risk of field defect **prior** to the occurrence of the visual field loss.

Electrophysiology offers a wide spectrum of tools to assess visual pathway function: ERG, EOG, PERG, mfERG, VEP, motion-VEP, and mfVEP. All of these have been reported to be sensitive to glaucomatous damage, usually by comparing a group of patients with advanced glaucoma to a group of normal subjects. However, we need measures that allow accurate diagnosis and management in **individual** patients and in early stages.

The pattern electroretinogram (PERG), a direct indicator of retinal ganglion cell function, is markedly affected by glaucoma. However, its high interindividual variability seems to hamper application to detection of early glaucoma. I will demonstrate that the ratio of the amplitude to two widely different check sizes (0.8° and 16°) reduces variability, revealing a clinically useful sensitivity of the 0.8° checksize response to early glaucoma damage. This has been utilized in a 10-year prospective study of ocular hypertensives (122 eyes of 69 patients), some of whom now have developed manifest glaucoma. Incipient damage in these patients appeared in the PERG about 2 years earlier than by visual testing.

While PERG recording appears too exacting for screening purposes, I suggest using it to "tip the scale" when qualms remain after considering IOP, visual fields, morphology and family history. If so, it appears highly advantageous to use the 2-dimensional approach alluded to above.

THE GOOD, THE BAD AND THE MAYBE: A Practical Guide to Normative Data

Prof Daphne L. McCulloch,
Vision Sciences, Glasgow Caledonian University

ISCEV recommends that each clinical electrophysiology laboratory establish or confirm normal values for its own equipment, patient population and protocols. This requires a substantial commitment whenever a laboratory is established or new equipment is acquired. It is reasonable for most laboratories to acquire reliable norms for co-operative adults using ISCEV standard tests and any non-standard tests in routine use. In some laboratories, normative data will be acquired for special populations.

However, clinical populations will vary from the normative group in age and ability to co-operate and a variety of other factors (pigmentation, pupil diameter etc.). It would be grossly impractical and actually detrimental to clinical practice to restrict clinical testing to populations and protocols for which reliable local norms are available. This session will provide an overview of the standard normative ranges and some practical approaches to interpreting ERG and VEP data with judicious application of published data and interpolation.

The Multifocal ERG in Clinical Practice

Mr Stuart Parks
Tennent institute of Ophthalmology, Gartnavel General Hospital, Glasgow

The Multifocal Electroretinogram (mfERG) is a relatively new objective technique for mapping retinal function. Although it is applied in a similar manner as the conventional Electroretinogram (ERG) it offers advances in the spatial and temporal information it can provide. Unique mathematical sequences are used to provide rapid aperiodic stimulation of the visual system. The composite response is the result of stimulation at multiple frequencies and reflects photoadaptive non-linear processes within the retina. In addition, the nature of these mathematical driving sequences allows multiple areas of the visual field to be stimulated simultaneously but independently. The technique offers potential to provide unique objective information on the integrity and function of the visual system. This presentation covers the basic principles of the technique, including recording procedures, stimulus considerations, data acquisition and analysis and common factors that may influence the quality and interpretation of results.

(Keynote Lecture)

The Multifocal ERG and VEP

Professor Colin Barber

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Electrophysiology, which offers the opportunity for functional examination of the visual system, has made a valuable contribution to the understanding of vision and visual disorders. But its full usefulness, particularly in clinical examination, is hampered; paradoxically by the very richness of the data recorded. Simultaneous signals from various classes of cells and different parts of the visual field are confounded, reducing its sensitivity for detection of malfunction in specific kinds of cells, or localised areas of the visual field.

Many techniques have been devised over the years to improve the specificity of the responses recorded, the most recent and most promising being the multifocal technique developed by Sutter. This has been applied extensively to the recording of retinal signals (multifocal ERG) and, to a lesser extent, of cortical signals (multifocal VEP).

The multifocal technique comprises a unique stimulus and analysis method that permits virtually simultaneous recording of responses to stimulation of multiple small areas of the visual field. The number of such areas (stimulus elements) used is typically around 60, although it may be considerably more. They may be plain (for a flash stimulus, usually used for ERGs) or patterned (more useful for VEPs). The elements may be arranged as interlocking hexagons, as a "dartboard" shape or as a rectangular checkerboard. Regardless of the number or type of stimulus elements, the stimulation/recording process is the same: each element flashes on/off (or a patterned element may reverse) in a pseudo-random sequence known as an m-sequence. This sequence has special characteristics, including the very useful property that time-shifted versions of itself are orthogonal. Hence responses to each of the individual elements are independent of one another and may be derived by cross-correlation; also the non-linearities may be discriminated and displayed as separate kernels (waveforms) of the response.

Already this technique has led to important new insights into visual processing at retinal level, with the ability to separate contributions from different classes of retinal cells. The discovery of the optic nerve head component in the multifocal ERG (mfERG) is an outstanding example. At cortical level, the potential – and need – for signal dissection is even greater. A degree of spatial selectively is implicit in the VEP because of the way in which the visual field is represented on primary visual cortex, but confounding factors, notably the convolution of cortical surface, leads to a complex signal with great inter-subject variation. The multifocal VEP (mfVEP) can again provide component separation.

This lecture will briefly describe the multifocal technique and demonstrate the nature of the mfERG and mfVEP in normal subjects. Using work carried out in Nottingham, with some examples from the literature, it will review clinical applications and exemplar clinical cases. Finally, it will detail current research being carried out on the multifocal VEP and multifocal visually evoked magnetic field by the Nottingham group here at home and, collaboratively, in Okazaki and Helsinki.

(Instructional Lecture)

Paediatric Visual Electrodiagnostic Testing

Dr Dorothy Thompson
Tony Kriss Visual Electrophysiology Unit, Great Ormond Street Hospital for Children, London

There may be no fundal or other clinical clues why a baby does not fix or follow, or has unusual eye movements. For these infants the application of both ERGs and multi- channel VEPs in the same session can provide unique insight into the functional integrity of the visual pathway.

Yet infants and children can be one of the most challenging patient groups. The sight of a group of lively 'loud' toddlers in the waiting area can fill even the most seasoned scientist with trepidation. Paediatric test protocols have to be robust, but flexible so that the choice and order of protocol individually can be quickly tailored to suit the child's clinical presentation and co-operation. There are a few technical modifications, but mostly it is a team approach, built around patience, persistence and the ability to capture the data speedily.

Of course it is possible to perform infant ERGs to adult ISCEV standards under anaesthesia or sedation, but these have associated rare, but very serious, risks. And anaesthetic agents may affect the amplitude of the rod b-wave. Alternatively a child can be restrained, swaddled or strapped to a papoose board to carry out the tests. But it is possible to employ less invasive strategies to obtain valuable diagnostic information until a child is old enough to co-operate for unrestrained ISCEV ERGs. VEPs are more amenable to following ISCEV guidelines, but require alert children. Preferably more than one channel should be used and a range of pattern sizes and stimulation modes.

In this talk I will describe the philosophy and techniques that have evolved over a 10 year period in the Eye Dept of Great Ormond Street, based on 13,000 px recordings. I will use case studies to illustrate our approach to visual electrodiagnostic tests in a 'Brain and Eye' hospital, and I will highlight some of the pitfalls along the way.