Clinical Norms for Visual-Evoked Potential Testing
FSUCO Electro-Diagnostic Laboratory

Senior Research Project:
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Abstract: The purpose of this study was to develop clinical norms, with regard to VEP testing, for the FSUCO Electro-Diagnostics Laboratory. Ten randomly selected subjects were tested with reversing checkerboard patterns of various sizes. Serial testing was performed monocularly and in random order. The results were analyzed for amplitude, latency and variability. The efficacy of VEP testing for investigating the visual pathway for evidence of occult insult is well documented. Development of these norms will allow the use of this technique for clinical decision making in selected cases.

Materials and Methods: Serial testing of twenty eyes using reversing checkerboard patterns in random order was performed using the following protocols, devices and materials.

Materials/Devices;

1. "Venus" version 3.4, copyright 1991, Neuroscientific software package, testing/display/analysis

2. "Venus" model 1020 stimulus generator, Neuroscientific

3. AST Premium 286 computer and keyboard

4. Princeton "Ultra 14" color monitor

5. Mitsubishi model HL 6615 TK high resolution color monitor, stimulus display

6. Grass P511K High Performance Pre-Amplifier, signal enhancement

7. Grass EZM5 Electrode Impedance Meter

8. Grass grounded dipole gold cup scalp electrodes

9. Miscellaneous- surgical adhesive tape, alcohol wipes, tape measure, electrode gel (various),

Methods; The following is a brief outline of the methods used in gathering and analyzing the data. For an exhaustive discussion of the recording and analysis protocols the reader is encouraged to refer to the addendum entitled "Clinical Protocols".

Recording Data, The patient was seated 1.5M from the stimulus monitor in a darkened room. Evoked potentials were recorded through scalp electrodes placed on sites selected and prepared as described in the addendum. Serial recordings of evoked potential responses to six sizes of

reversing checkerboards presented in random order were made of each eye in ten subjects. Results were stored as raw data and analyzed further upon completion of testing. Subjects were given instructions as to appropriate fixation and were directed to remain quiet for the duration of each test. Pertinent stimulus parameters appear in Table 1.

Analysis, Each of the recordings was analyzed using the "Venus" system. Amplitude (response magnitude) and latency (time from stimulus to response) were determined for each subject, in each eye, for each stimulus size. The data was collated by eye for each check size and analyzed for means, standard deviations and normal ranges. In addition, intrasubject variability was assessed for both amplitude and latency using linear regression.

Subject selection, Each of the subjects was an Optometry student at Ferris State University College of Optometry. They ranged in age from 23 to 34 years and were equally divided among males and females. All were determined to have a minimum visual acuity of 20/20 by Snellen chart and no evidence of visual field defect or ocular disease.

Table 1: Stimulus Parameters (reversing checkerboard square wave gratings @ 1.5 M)

Stimulus	Subtense	Snellen Equivalent (approx.)
4 check	122 MOA	20/2400
8 check	61 MOA	20/1200
16 check	30.5 MOA	20/600
32 check	15.25 MOA	20/300
64 check	7.6 MOA	20/150
128 check	3.8 MOA	20/75

Reversal rate = 1.37 Hz Sampling rate = 2.74 Hz
Test duration = 60 secs. Data points/test = 363

Results: Tabular and graphical representation of the collected data.

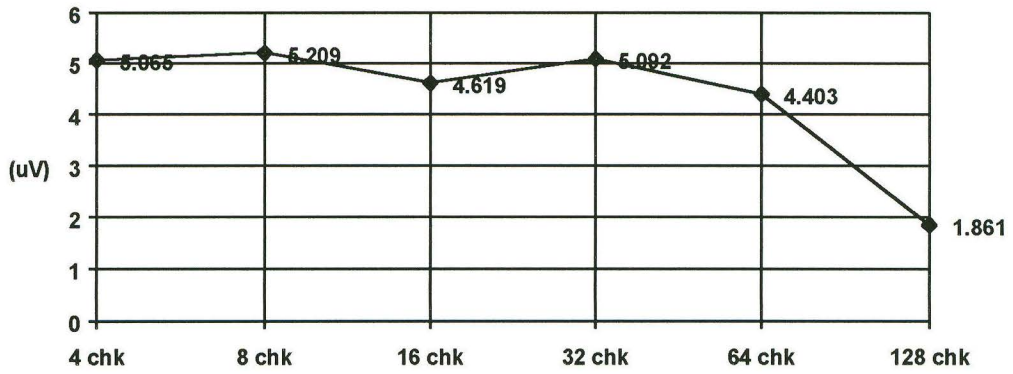
Table 2: Amplitude (uV) vs. Check Size

Stimulus	mean	standard deviation	normal range
4 check	5.065	2.069	0.927-9.203
8 check	5.209	1.952	1.305-9.113
16 check	4.619	1.706	1.207-8.031
32 check	5.092	1.631	1.830-8.354
64 check	4.403	2.502	0-9.407
128 check	1.861	0.944	0-3.749

Table 3: Latency (msecs.) vs. Check Size

Stimulus	mean	standard deviation	normal range
4 check	113.775	6.493	100.789-126.761
8 check	109.531	4.779	99.973-119.089
16 check	109.666	5.348	98.970-120.362
32 check	114.688	6.899	100.890-128.486
64 check	123.910	6.444	111.022-136.798
128 check	139.009	14.736	109.537-168.481

Chart 1. Amplitude vs. Check Size



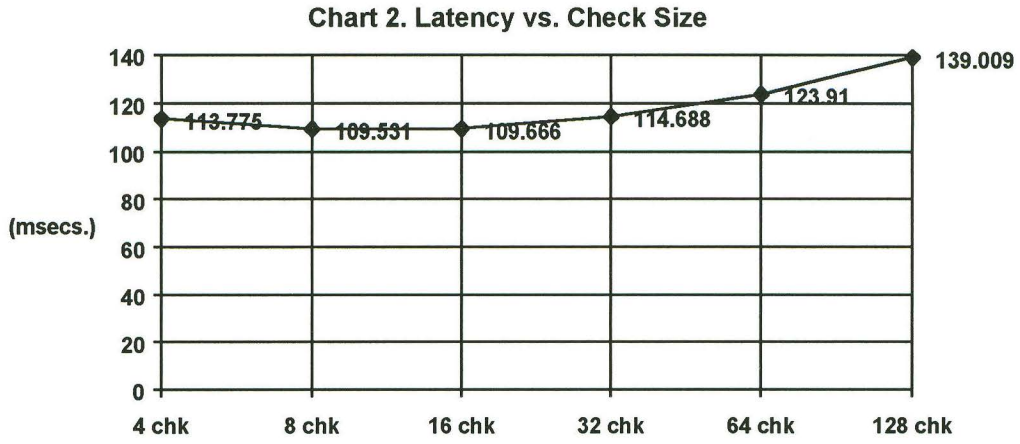


Table 4: Coefficient of Correlation, OD vs. OS

Stimulus	"r" (amp)	"r" (lat)
4 check	+ 0.9462	+ 0.8486
8 check	+ 0.9663	+ 0.4480
16 check	+ 0.9428	+ 0.7429
32 check	+ 0.8723	+ 0.3194
64 check	+ 0.8159	+ 0.8720
128 check	+ 0.7463	+ 0.6799

These data reveal that amplitude is stable over the range of target size excepting the smallest check when the amplitude may be expected to decrease significantly. Latency demonstrates an interesting pattern of minimal implicit times in the middle of the target size range with significant delays noted at both the largest and smallest checks. Inter-subject variability is minimized for both amplitude and latency in the mid range of check sizes as demonstrated by smaller standard deviations and tighter normal ranges for 8 and 16 check stimuli. Intra-subject variability as assessed by the Pearson "r" test indicates a high degree of correlation between eyes as regards amplitude. The correlation between eyes as regards latency is less well defined but still statistically significant over much of the target size range.

Discussion: Visual-evoked potentials have long been recognized as a valuable diagnostic tool for objective investigation of the visual pathway. Occult insult as a result of demyelination, compression or biochemical derangement may be revealed by VEP testing before subjective testing such as perimetry can detect it, making evoked potentials a powerful diagnostic tool in several important disease states such as Multiple Sclerosis. In addition, functional deficits such as amblyopia, dyslexia and learning disabilities can also affect the VEP waveforms in characteristic ways, making evoked potential testing a valuable objective measure for monitoring the efficacy of remediation efforts such as patching and vision therapy. Further, cortical magnification of the macular area results in VEP waveforms that are predominated by macular activity, making evoked potentials a very sensitive objective test of macular functional integrity. Monitoring progressive maculopathies and assessment of visual acuity in non-responsive patients are only two of a myriad of possible uses which capitalize on the comparative over-representation of macular information contained in a VEP.

In clinical use, the two parameters of a VEP recording which are of interest are amplitude (response magnitude) and latency (implicit time). Anatomical or biochemical derangement's will produce conduction deficits along the visual pathway resulting in prolonged latencies. Thus, Multiple Sclerosis, space-occupying lesions, ischemic atrophy, etc. will yield implicit times outside (greater than) the normal ranges. Conversely, functional deficits such as maculopathy, amblyopia, dyslexia, etc. will produce reduced amplitudes on VEP testing. Both measures must be carefully assessed for all patients tested, with consideration given to comparison to the norms and between each eye.

The data suggest that the most appropriate check sizes for testing fall in the mid range of those available. Both inter and intra subject variability are minimized for the 8 and 16 check experiments. Development of these normative tables allows the use of our device in the clinical setting presuming the testing conditions defined in this study are adhered to. Some interesting points for further consideration by other clinicians might be. What is the basis for the observed prolongation of latencies at the largest and smallest check sizes? Does a measurement which falls between 1 and 2 standard deviations from the established mean represent a "normal" response? Does the use of square wave gratings contaminate the result, or should sine wave gratings be used? How might variable contrast and or background conditions affect the

recordings? Are the response norms different for colored targets? Each of these questions and many others beg for answers. I hope that this study may provide a stepping stone for others to explore this fascinating aspect of visual physiology.

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Addendum:

Recording and Analysis Protocols

Visual-evoked potential testing may be used clinically in a variety of ways. Investigation for evidence of organic visual pathway disturbances, acuity/visual capacity assessment in non-responsive patients and determination of malingering are only a few of the possible uses. The VEP examines the functional integrity of the visual pathway by recording group potential electrical activity from the primary visual cortex in response to a visual stimulus. Multiple serial recordings are superimposed by the computer and averaged to eliminate "noise". This powerful tool can be invaluable if testing conditions are adequately controlled. Poor technique, however, yields little useful information. This addendum is intended to provide a standardized format for VEP testing in our clinic in order to facilitate the clinical use of this technology.

A. Patient Preparation; A thorough and sympathetic explanation of the process will greatly enhance the quality of the collected data. The equipment, procedure and expectations should be carefully reviewed with the patient and any caretakers present. The patient should be directed to fixate the center of the stimulus monitor at all times. No attempt to follow the motion of the pattern need be made. Appropriate fixation is crucial to the collection of usable data, and should be monitored continuously by the examiner. Loss of appropriate fixation should result in a pause in the recording process. Patients with motor control deficits may need assistance in maintaining fixation. This assistance may take the form of coaching, auditory stimuli such as a bell placed on the stimulus monitor, or even holding the patient's head in severe cases.

B. Equipment Preparation; The main computer, upper Grass amplifier, Venus stimulus generator and target monitor must be turned on one at a time. Select "run Venus" from the main menu and follow the appropriate menu choices (ie. "run", "analyze", etc.). Select the desired experiment from the following list.

1. Reversing checkerboards in order of descending size
   "chk0480a.exp"
   "8chk.exp"
   "p100a.exp" *primary screening test*

"chk3280a.exp"
"chk6480a.exp"
"ck12880a.exp"

C. Electrode Placement; This is the critical step in obtaining clean data. The ground electrode (brown lead) should be centered on the midline of the patient's forehead. Reference electrode (red lead) should be centered on the midline at the cranial apex. The active electrode (yellow lead) should be centered on the midline over the occipital pole (approx. 3cm above the inion). All electrode sites must first be cleaned with rubbing alcohol, followed by a mild debridement with an abrasive such as Nu-Prep. Application of the electrodes to their respective sites should be accomplished with liberal amounts of conductive paste. The ground electrode may be taped in position to avoid being dislodged. In addition the entire array may be taped to the patients shoulder to stabilize it. Impedance must be checked after electrode placement. Each lead must show less than 10 kohm. If impedance exceeds 10 kohm, the electrode must be removed and the site preparation steps repeated until acceptable impedance is achieved. The leads should now be attached to the computer interface as follows. Brown lead-green terminal, Red lead-blue terminal, Yellow lead-yellow terminal. Once this point is reached, testing may proceed. The patient should be seated 1.5M from the target monitored with the untested eye patched. Fixation instructions should be repeated before testing begins and fixation must be monitored throughout the testing process. At the conclusion of each test, save the data and note the raw data file number in the patient's chart.

D. Data Analysis; After saving the raw data, select "Analysis" from the menu and proceed to the appropriate data file. Cursors should be placed as follows, yellow cursor at the first major negativity/ purple cursor at the first major positivity. Amplitude is reflected as the distance between the cursors vertically. Latency is shown as the horizontal distance from time zero to the purple cursor. Comparison of the recorded values to the normative tables will reveal the relative functional integrity of the patient's visual pathway.