

VISUAL ASSESSMENT USING THE VISUAL EVOKED RESPONSE

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INTRODUCTION

While the visual evoked potential is of intrinsic scientific interest, its great appeal to many is that it can be used to determine objectively the status of the visual system. Significant capability in this regard is hardly a decade old and even now is continuing to improve. Certain assumptions have been tacitly made in employing this measure. It is well to trace the development of the evoked potential for visual assessment of its origin, examining along the way the accuracy of the assessment and the evidence on which it is based. We will consider two aspects of visual assessment, the determination of the refractive state of the eye, and visual acuity.

EVOKED POTENTIAL MEASUREMENT OF EYE REFRACTION

Although Spehlmann was the first to use patterned targets systematically for an evoked response /1/, and Rietveld et. al. studied form responses /2/, Harter and White were the pioneers who developed evoked potentials for the determination of the spherical refractive state of the eye /3, 4/. They illustrated that retinal image sharpness gave specific responses in the evoked potential recorded from the occipital area. These responses occurred first around 90 to 100 msec after the onset of the stimulus and second around 180 to 200 msec. By using lenses to change the vergence of the rays, increasing or decreasing blur, they demonstrated that one could find the optimal spherical lens for maximum retinal image sharpness by the visual evoked response. With the sharpest retinal image the first wave at around 100 msec was minimized, that is, made most negative, and the other at about 200 msec was maximized. Their stimulus consisted of discrete flashes of a checkerboard image at a rate of about one per second. This is called transient or flashed mode of stimulation. Both Rietveld et. al. /2/ and White /5/, apparently independently, subtracted the flash response from the checkerboard response. If one, ideally, assumes linearity of the responses, subtraction of the flash response from the checkerboard response would subtract the flash evoked potential from the flash plus form evoked potential, leaving only the form evoked potential. The assumption is apparently at least partly correct because this seems to improve the results.

A few years later Millodot and Riggs /6/ presented another method of determining the refractive state of the eye by the use of continuous, steady-state, or antiphase, stimulation at 6 or 7 1/2 Hz or 12 or 15 alternations per sec. The polarized checkerboard squares were sinusoidally modulated in antiphase by a rotating Polaroid filter and presented the subject with alternating form at constant average retinal illumination. The important advantage

of this method was that the response was primarily a matter of form changes rather than diffuse light flashes. Presumably, then, the response mirrored image sharpness which is a function of refractive changes rather than merely the change in retinal illumination. Accuracy appeared to be within 0.25D. Incidentally, Millodot and Riggs also obtained evoked responses from the retina by means of electroretinographic recording from the cornea of the eye, but the retinal responses were not as sharp and clear as those from the brain where the macula area is heavily represented. Neither Millodot and Riggs, nor Harter and White reported any attempt to treat astigmatic refractive errors. Duffy and Rengstorff /7/ used a refined form of the Harter and White transient stimulation method. Instead of presenting a checkerboard by flashes alone, they presented a 50 msec duration flashed checkerboard stimulus alternately with a 50 msec diffuse flash stimulus. The interstimulus interval was varied in an apparently random way from 3/4 second to 2 1/2 second in order to minimize alpha rhythm entrainment or ringing. Duffy and Rengstorff also showed that a grating could be used to determine the astigmatic axis. Ludlam and Meyers /8/ show the stability of the VEP refraction from month to month. They also illustrated the need for first using coarse dioptic steps, 0.50 to 2D ("broad scan") to find a rough estimate of the refractive error. Then they used a smaller range in this region of 0.25D steps ("fine scan") to obtain the refractive state within 0.25D. A similar procedure with a grating target was used for the cylinder which was measured to within 0.50D with  $\pm 10$  degrees for the axis. Ideally a complete refraction could be performed in 20 minutes.

McCormack and Marg /9/ attempted to use meridional refractometry principles with visual evoked potentials to determine the refractive state of the eye. While they found a similar sensitivity for the spherical correction of 0.25D in favorable subjects, those with a high signal to noise ratio, the cylindrical sensitivity was at best  $\pm 0.50$  but as poor as  $\pm 1.50D$ . The importance of using latency as well as amplitude as a measure of retinal image sharpness was emphasized.

An ingenious method devised by Regan /10/ was proposed as a fast, clinically useful method of determining the refractive state by fast Fourier transforms of the evoked potential. With the use of a quadrature circuit, Regan proposed to determine the refractive state by a rapid and continuous meridional method. At approximately 18 seconds per trial of each cylinder and sphere, the complete refractive state could be determined to a number of lenses or powers within a few minutes. Using more sophisticated electronic equipment, Bostrom, Keller and Marg /11/ were not able to get sufficient reliability to make this method into a useful clinical tool despite its clinical attractiveness and theoretical advantages.

The current status of visual evoked potentials as a means of determining the objective refractive

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state of the eye has become clear. There is no doubt that a refractive measurement can be made using evoked potentials. There is a place for these measurements when better methods cannot be used. However, in general, it takes more time and is less accurate than subjective methods. It has perhaps the same order of accuracy as objective methods of refraction such as retinoscopy, manual or automated, for the spherical component but probably less for the cylinder. Its value lies in those instances where the subjective method is not possible because of difficulty in communication between the examiner and the patient, or because of malingering. The method, however, has the additional advantage that it also determines the patency of the visual pathways and can be also used to measure visual acuity objectively.

#### EVOKED POTENTIAL MEASUREMENT OF VISUAL ACUITY

Campbell and Maffei in 1970 /12/ showed the relationship between psychophysical and evoked potential thresholds of contrast sensitivity. Campbell and Kulikowski in 1972 /13/ demonstrated the relationship between seeing and not seeing and the visual evoked potential by having the subject direct the signal into two separate memory banks, one when the target was seen, the other when the target was not seen. While the target was visible at near threshold levels there was a clear evoked potential. Without it being visible there was not.

Berkley and Watkins in 1973 /14/ showed the relationship between grating size or resolution and the amplitude of the visual evoked potential in cats. They extrapolated stripe size in cycles per degree to the zero amplitude evoked potential baseline. R. D. Freeman and Thibos' /15/ data illustrated that the decrement in evoked potentials paralleled the decrement in visual acuity in meridional amblyopia (1973). Freeman and Marg /16/, using essentially the Berkley and Watkins approach, extrapolated the grating resolution of kittens and found that adult values occurred by about the third month of life. This turns out to be the same as the duration of the kitten's sensitive period to occlusion. Marg, Freeman, Peltzman and Goldstein /17/ and also Marg and Freeman /18/ modified this method for use in infants. They found that adult acuity, defined as 20/20, occurs between the fourth and sixth month of age in normal, healthy human babies.

The evidence for the relationship between visual evoked potential resolution and psychophysical visual acuity requires further examination. We have compared psychophysical acuity measured with Snellen letters to visual evoked potential resolution responses elicited with gratings. Figure 1 shows this relationship for eleven subjects with normal acuity and nine subjects with abnormally poor acuity because of some visual problems. The correlation between Snellen chart visual acuity (expressed in cycles per degree) and visual evoked potential resolution shows a Pearsonian correlation of 0.72 at the 0.001 level. For clinical purposes the visual evoked potential resolution and Snellen chart acuity are essentially equivalent, since the two agree to within one line on the Snellen chart. This is within the ordinary limits of clinical accuracy, a difference amounting to about ten cycles per degree.

Using an antiphase, steady-state checkerboard stimulator, Grall et. al. compared the evoked potential response with a subjective response to this target /19/. They found that the evoked potential method agreed with psychophysical measurements within two tenths of a decimal unit. This corresponds to six cycles per degree. Plotting these limits on our graph it can be seen that almost all of our subjects fell within these lines. However, some of those with abnormal vision fell beyond these limits. We conclude, therefore, that the results of Grall et. al. on normal subjects are in good agreement with ours for normal subjects and slightly less so for those with pathological conditions of the eyes. Abnormally sighted eyes still have reasonable agreement between the evoked potential and the psychophysical results, but the latitude is probably closer to ten cycles per degree or a decimal value of .333. This corresponds to about one line for the normal and about two lines in the abnormal for the smaller letters on the standard Snellen visual acuity chart.

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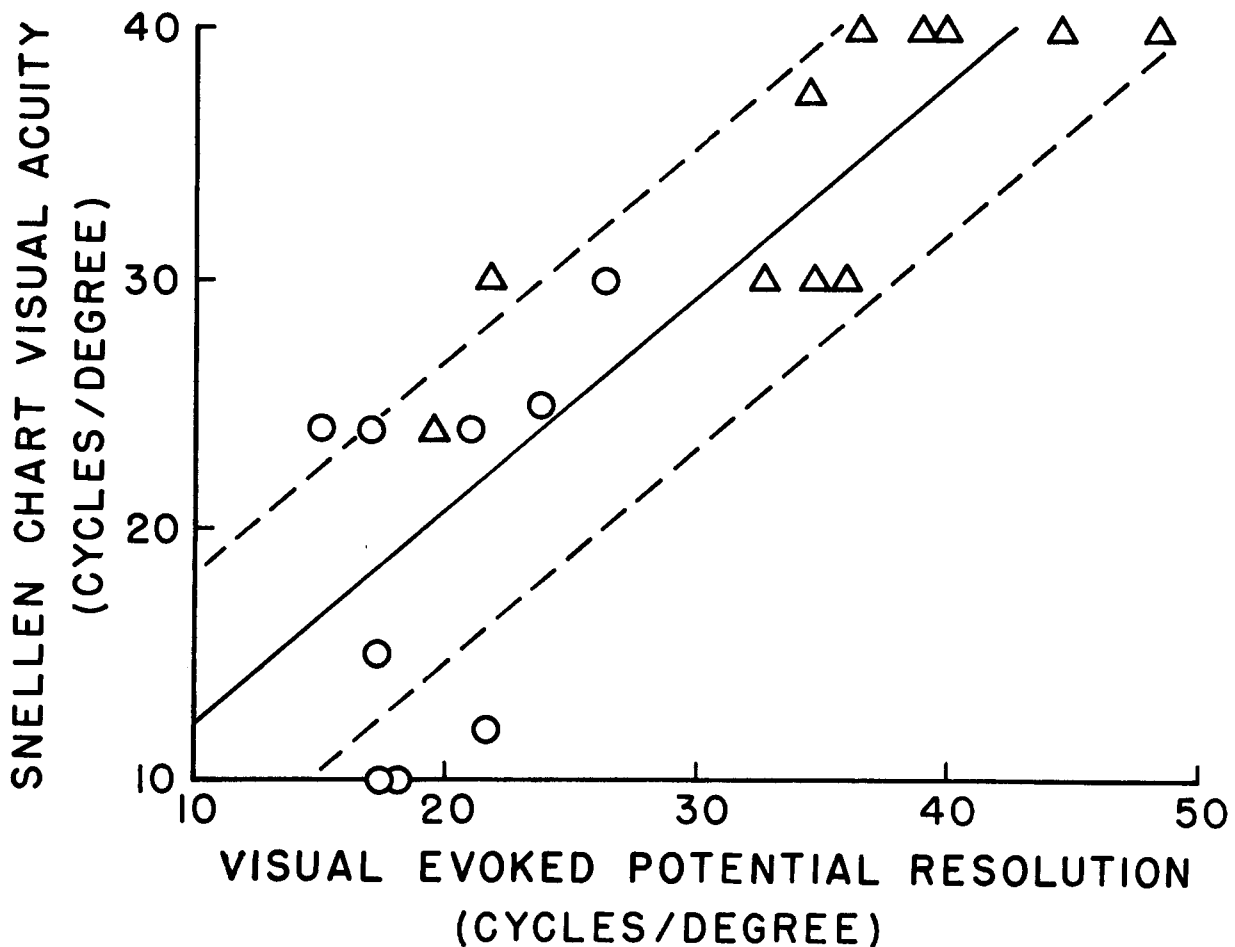


Figure 1. Triangles normal and circles pathological subjects. VEP resolutions are determined by linear extrapolation to zero potential.

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