

The natural visual acuities of 15 adult persons were predicted on the basis of changes in visual evoked potentials (VEP's) to flashed patterns of various sized dots. An objective method was used to quantify the VEP's, based on the minimum-sized stimulus that would elicit a pattern VEP—the VEP pattern threshold. This measure was highly correlated with recognition and resolution measures of perceptual visual acuity (r's as high as 0.89). The regression equation between the VEP measures and predicted perceptual measures of acuity enabled the objective estimation of perceptual acuity to within ±0.29 decimal units.

There are a number of advantages to using pattern visual evoked potentials (VEP's) to assess visual characteristics. Most importantly, VEP techniques do not require a perceptual judgment or behavioral response on the part of the subject or patient as do traditional subjective methods, and they do not require a perceptual judgment on the part of the investigator as do some objective techniques (e.g., retinoscopy). Although VEP's have been used to estimate the visual acuity of both animals and human infants, the validity of these VEP measures as estimates of the more traditional psychophysical measures of visual acuity has not been established either quantitatively or conclusively. Only one study was found which systematically estimated visual acuity, but a correlation coefficient or standard error of the estimate was not reported. In the present study, VEP estimates of visual acuity were found to be highly correlated with psychophysically measured word recognition acuity and pattern resolution.

Method

Subjects. Fifteen volunteers with binocular visual acuities ranging from 2.2 (20/9) to 0.05 (20/400) served as subjects. Most of the subjects were selected from a population of undergraduate students on the basis of their response to a visual questionnaire. Data were collected with uncorrected vision.

Visual acuity. Natural visual acuities were measured monocularly and binocularly with a Jaeger recognition acuity test and with a pattern-resolution measure. The Jaeger card was used because it could be observed at the same viewing distance employed to obtain VEP's (0.81 m.). Pattern-resolution acuity was obtained during the experiment by having subjects classify each stimulus as either "diffuse" or "pattern" by pressing one of two switches held in their right hand. The dot sizes being discriminated were sufficiently small to enable their use as a measure of pattern resolution. Both Jaeger and pattern-resolution measures of perceptual acuity were expressed in decimal units (1/minute of arc). This unit was selected because it expands the high visual acuity end of the scale and resulted in a better linear relationship.

Visual stimuli. Evoked potentials were elicited by a binocularly viewed 10 μsec. light flash (Grass Model PS-2 Photo-stimulator) which back-illuminated black and white transparency slides (contrast = 0.9) once every 600 msec. The space-average luminance of all stimulus flashes was 4.2 log units above threshold for the experimental conditions. These flashes momentarily appeared in a relatively dark window (1.8 mL) surrounded by a constantly illuminated white field (25.0 mL). The display was 0.81 m. in front of the subject and subtended 4.3 by 5.9 degrees.

The stimulus transparencies consisted of a diffuse stimulus and a series of patterns containing white dots on a black background (individual dots subtending 0.75, 1.5, 3.1, 4.4, 6.7, 8.8, and 39 minutes of arc). The distance between dots was approximately the same as the dot diameter.
Fig. 1. A, Evoked potentials to diffuse and dot-pattern flashes of three subjects with relatively good (D. B.), average (M. L.), and poor (M. W.) visual acuity. , Jaeger acuity threshold; D, perceptual resolution of the dots; asterisk, smallest dot size giving a significant pattern VEP (VEP-PT, see text). Lowest tracings represent variance analysis, the peaks of which define the latencies at which amplitude measures were taken (N120 and P220). Dotted lines indicate amplitude from baseline. B, Same as A but with diffuse VEP subtracted from the VEP's to dots. The presence of a difference potential indicates the dots were resolved electrophysiologically.

SUBJECTS

A  

D. B.  

M. L.  

M. W.  

DOT SIZE (mm)  

DOT SIZE (mm)  

LATENCY (sec)  

VEP - VEP diffuse  

VEP - VEP diffuse  

VEP - VEP diffuse  

in each pattern. These dot sizes were chosen because they fell in the range of most subjects' perceptual visual-acuity threshold. Dot patterns, rather than checkerboard ones, were used in this experiment because the perception of such patterns would be less influenced by cylindrical refractive errors.

Procedure. The eight stimuli were presented in a quasi-random order (AAADDGGBBBEE HHHCCCGFFFF) until each had been presented 64 times. Stimuli were presented in blocks of three to give the subject time to make a discrimination as to whether pattern or diffuse light was perceived. This procedure was repeated one or two times, depending on the consistency of the subjects' data. The subjects were instructed to fixate a point 1 cm. below the top center of the display and to stop the stimulus train with a button if they had difficulty in maintaining fixation or accommodation.

Average VEP's. The surface EEG was derived from a 9 mm. Grass gold-cup scalp electrode placed 2.5 cm. above the inion on the midline (Oz) referenced to the right earlobe (A2). VEPs were amplified, averaged, and quantified with a DataCom signal-averaging system.

Results. To identify those latencies of the VEP most sensitive to the nature of pattern in the light flashes, a variance-analysis procedure was employed (Fig. 1). The variation due to changes in check size was greatest at two points in time after the light flash: one between 115 and 140 msec. (N120) and the other between 185 and 240 msec. (P220), depending on the subject. The peak of the variance curves defined the latency at which VEP amplitude was measured in reference to the computer-determined "zero-voltage" baseline. If the subject's vision was so poor that no peak appeared in the standard deviation function, the amplitude measures were taken at the average latency of the other subjects.

The pattern threshold for VEP's was estimated by determining the smallest pattern element which elicited a VEP significantly different in amplitude from that to diffuse light (p <0.001, one-tailed test). This criterion (using Z tests) had to be shown for two consecutive dot sizes. The VEP pattern thresholds for N120 and P220 will be referred to as VEP-PTN120 and VEP-PTP220, respectively.

The results are illustrated for three subjects in Fig. 1. To aid visual inspection of the effects of pattern on the flashed-pattern VEP's, difference potentials were derived by subtracting the diffuse VEP from the pattern VEP's (Fig. 1). Significant deviation from a horizontal straight line in these difference potentials indicates the dot size was at or above the VEP-PT.

The second measure of perceptual visual acuity, the smallest dot size that could be perceptually resolved (resolution acuity), was relatively poorly correlated with both VEP-PTN120 and VEP-PTP220.
The multiple-regression equation based on both of these relationships accounted for only 38 percent of the variance in resolution acuity (equation 4, Table 1).

In many situations it is impractical to use the quantitative procedure described above to estimate visual acuity on the basis of VEP's. An alternate procedure was investigated wherein the VEP waveforms to the different dot sizes were carefully inspected and a subjective judgment was made by the experimenter as to the smallest dot size that elicited a VEP reliably different from the VEP to the diffuse light flash. These judgments, which were made blindly and independently by both authors, will be referred to as the visual-inspection VEP pattern thresholds (VEP-PTvi). Since the VEP-PTvi judgments made by the authors were highly correlated (r = 0.81), they were averaged.

The VEP-PTvi estimates of visual acuity were highly correlated with both Jaeger acuity scores and resolution acuity (r = 0.86 and 0.89, respectively; p < 0.001; df = 14). These correlations are reflected in Fig. 3, A and B, and in regression equations 5 and 6. The standard error of the estimate for predicting Jaeger acuity scores and resolution acuity was 0.44 and 0.29, respectively.

Discussion. The results of the present experiments indicate that both Jaeger recognition and dot-resolution measures of perceptual visual acuity were highly correlated with VEP estimates of visual acuity. The highest simple correlation obtained was between the smallest dot sizes that could be resolved perceptually and electrophysiologically (VEP-PTvi), the latter being determined by visual inspection of VEP data. This relationship accounted for 79 percent of the variability in pattern resolution. Such relatively high accuracy of prediction may be attributed to the greater sensitivity and generality of the visual inspection as compared to these quantitative measures of changes in pattern VEP waveform and to the fact that both perceptual and VEP measures of visual acuity were to the same stimuli (dots) and were taken at the same time. It may be noted that VEP-PTvi was not only the most accurate but also the fastest and simplest estimate of perceptual acuity. It was made on-line in less than 5 min.

The next highest correlations were multiple correlations taking into account both VEP measures. They established the fact that perceptual visual acuity may be estimated totally objectively on the basis of VEP's without any behavioral response from the subject or interpretive observations from the experimenter. The increased predictive ability of multiple correlations implies that the N120 and P220 measures of VEP amplitude vary independently and may therefore reflect different aspects of pattern-information processing.
PT’s between 11 and 27 minutes have been used to estimate visual acuities between 20/220 and 20/600 in infants less than 1 month of age. If the adult regression equation (6) may be used to standardize the VEP estimates of acuity in these infants, their VEP-PT’s may reflect acuities between 20/77 (0.26) and 20/133 (0.15). Such underestimation might simply indicate that different criteria were used to establish the perceptual acuity as compared to VEP-PT’s, or it could indicate these two acuity thresholds reflect different, but interrelated, underlying processes.

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REFERENCES