Human electroretinogram near the absolute threshold of vision

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With total visual field stimulation and the aid of a computer of average transients, the ERG can be recorded with stimulus intensities approaching the absolute visual threshold. At these low intensities, the predominant feature of the ERG is a corneal negative potential.

Traditional studies of the animal and human electroretinogram (ERG) indicate that the stimulus intensity necessary to evoke a minimal ERG from the dark adapted retina is well above the absolute threshold of vision; these studies also show that the ERG response at threshold consists of the b-wave only, and the a-wave appears at suprathreshold intensities.

Recent work on the toad, rat, cat, monkey, and human, however, demonstrates that it is possible to obtain an ERG with very dim stimuli, approaching the absolute threshold of vision. Some of these investigations have shown that the threshold ERG consists of a corneal negative potential with the b-wave appearing at suprathreshold intensities.

The amplitude of the ERG is small when caused by stimuli of very low intensity, so that it is difficult to record and interpret ERGs with stimuli near the absolute threshold of vision. The purpose of our study was to enhance and utilize these very small potentials by modifying the traditional recording apparatus. Our two modifications included a stimulus which filled the subject's entire visual field and a computer of average transients which summed the ERG responses. Neither of these techniques is by any means new, but to our knowledge they have not been used together before to study characteristics of the human ERG near the absolute threshold of vision.

The recording of such small evoked potentials near threshold are not only of value in extending the range over which vision can be studied by the ERG but also permits a more direct comparison of objective with subjective measurements of visual function.

Methods

ERG's were recorded with a modified Burian-Allen electrode from normal volunteer college students. The pupil was dilated with a 10 per cent solution of phenylephrine hydrochloride (Neoephrine). Before the insertion of the contact lens electrode, the subject was seated in a light and electrically shielded cage and adapted to dim red illumination. The cornea was anesthetized with proparacaine hydrochloride (Ophthalmine); electrical contact of the electrode with the cornea was facilitated with a 1 per cent solution of methyl cellulose. The ERG was amplified by a Tektronix 122 preamplifier with a frequency response from 0.8 to 1.0 kc., displayed...
on an oscilloscope, and photographed. The stimulus flash was presented with a ganzfeld spheroidal integrating sphere constructed by Dr. R. D. Gunkel. The ganzfeld was designed to present uniform illumination to the entire field of vision; in this way maximum summation was achieved at the cornea of the small potentials elicited with dim stimuli. The inner surface of the ganzfeld was coated with a matt white paint similar to those paints made specifically for integrating spheres by the National Bureau of Standards. The stimulus was obtained from a Grass stroboscope built into the upper portion of the sphere and recessed behind the subject's visual field.

The duration of the stroboscope's flash was 10 μsec; the maximum brightness within the ganzfeld was approximately 13 photopic nits (candela per square meter). The intensity of this stimulus could be reduced in steps by placing neutral density filters before the stroboscope. The subject sat with his chin so supported that he looked into the center of the sphere as shown in Fig. 1.

The absolute threshold of vision was determined for each subject with the contact lens electrode in place. The luminance of the stimulus at visual threshold was assumed to be 10^-5 photopic nits. This assumption has been based on the fact that the best estimates of the absolute threshold of vision show a range extending from 0.4 × 10^-6 to 0.2 × 10^-5 photopic nits in normal young observers when determined statistically (50 per cent frequency of seeing) with a 47 degree, white light stimulus of 15 seconds duration and binocular viewing. Our stimuli were much shorter and threshold was taken at the point where each subject could see the stimulus 100 per cent of the time. Therefore our light levels at subjective threshold (averaged for 6 subjects) were assumed to be somewhat higher than the absolute visibility threshold and the approximate value of 1 × 10^-5 nits was assumed.

**Results**

Fig. 2 shows three series of ERG's from 3 normal subjects. The stimulus intensity is decreased from above downward. The dimmest intensity was about 2.3 log units above the subjective threshold of vision. All stimuli were presented with the ganzfeld. These responses were photographed from the oscilloscope screen without the use of a computer of average transients. Each tracing in Fig. 2 is two or three ERG's which were superimposed to accentuate the significant response characteristics. The amplified gain was increased with decreasing stimulus intensity; therefore, amplitudes may not be directly compared as shown in Fig. 2, which is presented only to illustrate how the shape of the responses changes as the stimulus intensity decreases. From the brightest intensity to about 0.1 nit the b-wave decreased in amplitude, and with stimuli below about 0.02 nit a corneal negative potential is the dominant feature of the ERG. The amplitude of this negative potential increases slightly with stimuli of lower intensity; then decreases to a threshold in this figure of about 0.002 nit, approximately 2.3 log units above the subjective threshold of vision. Because of individual variation in responses, because of the small potentials involved, and because the leading edge of the negative potential has a slow time course, it is difficult to describe precisely the relationship of light intensity to amplitude and latency of response. In Figs. 3 and 4, nevertheless, these data are presented as a summary of the ERG's from 5 subjects. Corneal negative potentials have been called a-waves and positive ones b-waves in these figures.
Fig. 2. Changes in the ERG response with stimulus intensity for three dark-adapted subjects. Each column represents the responses of one subject and each tracing is the oscillograph of 2 or 3 ERG responses to the same stimulus superimposed. The brightness expressed in log nits of the stimuli is the same for each horizontal row of responses and progressively decreases from above downward in the following manner: 1.5, 1.2, 0.9, 0.6, 0.3, -0.3, -0.7, -1.0, -1.3, -1.7, -2, -2.3, -2.7. The hatched lines indicate the time of the light flash. The horizontal calibration is 0.1 second. The vertical calibration is 0.105 mv. for the upper 6 responses of the first two columns and the upper 4 responses of the third column, is 0.025 mv. for the lower 6 responses of the first, the lower 5 responses of the second and the lower 7 responses of the third column, and is 0.05 mv. for the remaining.
Fig. 3. Relationship of ERG amplitude to stimulus intensity. Filled circles represent a-wave; open circles represent b-wave. Five subjects were used to obtain these data. Arrows mark absolute visual threshold for 6 subjects. Log 7 relative intensity represents approximately 25 nits.

Fig. 4. Relationship of ERG latency to stimulus intensity. Filled circles represent a-wave; open circles represent b-wave. Five subjects were used to obtain these data. Log 7 relative intensity represents approximately 25 nits.

Fig. 5 shows ERG's of a single subject caused by very dim stimuli and summed on a computer of average transients. In this way we were able to demonstrate a threshold for the negative component of the ERG only 0.60 log units above this subject's threshold of vision.

We emphasize that it requires subjects who are well accustomed to the wearing of a corneal ERG electrode and who are comfortable with the testing procedure in order to obtain a base line "quiet" enough to measure the small potential elicited with dim stimuli.

Discussion

By using a ganzfeld stimulus ERG's were found about 1.5 log units above the subjective threshold of vision; by adding a computer of average transients to the recording apparatus this value can be lowered to only about 0.6 log unit above the absolute threshold of vision. The threshold ERG, either with or without a computer of average transients, is a corneal negative potential; the suprathreshold ERG remains a predominantly negative potential up to a stimulus intensity of about 0.02 nit, about 3.3 log units above the absolute threshold of vision, when it becomes largely obscured by the corneal positive b-wave. It is our impression that the leading edge of the corneal negative potential forms the a-wave and the corneal negative potential of
the threshold ERG is Granit's PIII component. Arden and Brown reached similar conclusions regarding the threshold local ERG which they recorded from the cat retina.

Since the a-wave and Granit's PIII component are generally agreed to arise from the outer plexiform layer of the retina, low intensity ganzfeld stimulation provides a direct method of viewing human outer plexiform activity unobscured by the b-wave. Further work, especially with well-defined human and animal retinal lesions, will determine the role of this corneal negative potential as an additional monitor of retinal function.

REFERENCES
4. Ripps, H.: Personal communication.