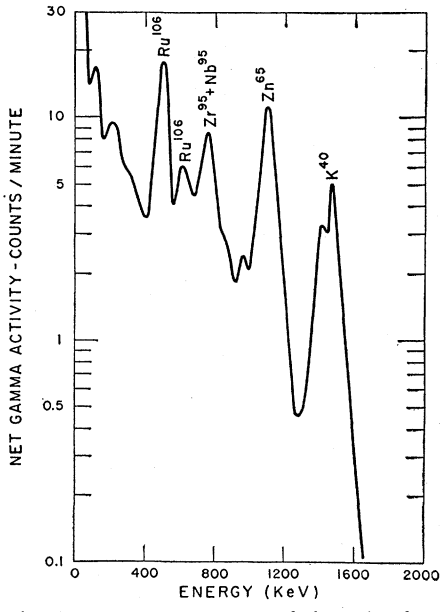

Fig. 1. Gamma spectrum of the ash of an oyster sample harvested from Chesapeake Bay.

served in foods raised in this country." Investigations made in our laboratory have revealed the presence of this radionuclide in a wide variety of foods of different origin, although at levels considerably lower than those observed in the samples collected downstream from the Hanford project.

A number of food samples purchased on the Cincinnati market have been analyzed for a variety of radionuclides, including Zn^{65}, during the past year. The gamma spectra of the ash of large samples of these foods, ranging up to 3 kg, have been determined with a heavily shielded 4- by 4-in. NaI crystal and a 100-channel pulse-height analyzer (*2*). With this instrumentation the efficiency of counting Zn^{65} was approximately 11 percent, and the sensitivity was of the order of 1 $\mu\mu$c in the ash.

The gamma spectrum of the ash of an oyster sample harvested from Chesapeake Bay is shown in Fig. 1; this curve reveals the presence of Zn^{65} in addition to some of the fission products and the naturally occurring K^{40}. The results of Zn^{65} analyses on a number of different food samples are summarized in Table 1, demonstrating the presence of this radionuclide in a wide variety of foods. The higher levels of Zn^{65} in oysters, as compared to other foods, is not unexpected in view of the findings of Chipman *et al.* (3), who demonstrated experimentally the capacity of this organism to concentrate Zn^{65} at levels many times higher than the level in the surrounding water.

The extent of nuclear operations, including the use of isotopes, in the Chesapeake Bay area seems entirely inadequate to account for the presence of the levels of Zn^{65} observed in oysters. Similarly, there are no obvious sources of the Zn^{65} found in the other foods; of these, some were grown in the Cincinnati area, while the rest were obtained from diverse parts of the United States. Therefore, it may be assumed that this radionuclide, which has been found in large amounts in samples taken near the Pacific proving grounds (*4*), must have been deposited on the East Coast and throughout the United States from high-altitude fallout.

The concentrations of Zn^{65} observed in these foods cannot be considered to constitute a radiological health hazard, since the maximum permissible concentration for this radionuclide is 6×10^6 $\mu\mu$c per liter of water or kilogram of food (wet weight) (*5*).

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2 July 1959

Subthreshold Retinal Integration Shown in Low Contrast Flicker Measurements

Abstract. Evidence of facilitation of response has been found in psychometrically determined critical fusion frequencies to flicker at low contrast. Spatial summation is denied by the distribution form of the data. Temporal summation within a determined time limit is supported. This may be mediated through association cells at the bipolar-ganglion synapse.

The use of low-contrast flicker measurement to assess retinal function was proposed in 1958 (*1*). Flicker refers to the perceptual response to a rapidly alternating dark and bright stimulus. In the present study (*2*) we alternated two nearly equally bright foveal stimuli in a circular area 1° in diameter on a 50° surround at 5 percent contrast above and below the 60 cd/m² background. Originally, for experimental convenience, the stimuli were presented in random order in two ranges, from 22 to 34 and from 30 to 46 per second.

The perceptual response fails when the rate increases across a threshold, called the critical flicker frequency. This visual response is analogous and may be identical to the scintillation found in a weakly irradiated phosphor. It is random in nature and may represent a chance distribution of the responses of individual foveal cones. Our results have been expressed in terms of the duration of half of the stimulus cycle, being therefore shorter as the rate of flicker increases. For example, 40 flickers per second equals a half cycle of 12.5 msec. Data are reported for each eye separately for 172 subjects for approximately 112 trials per eye, or a total of 38,324 trials. This volume of data is sufficient for discrimination between various distribution forms (*3*). The data were analyzed as probability functions of perception of the flicker against the temporal duration of the brighter half of the alternation (Fig. 1).

The two ranges show considerable difference in response, although the rates of alternation and all other conditions were the same where the ranges overlap. Attempts to fit these two curves with normal or Gaussian frequencies by the methods of probit analysis and least squares were unsuccessful (*4*). The best fitting normal distributions showed chi-squared equal to 11.23 and 84.75 for the seven centralmost points for the slower and faster ranges respectively. The probabilities of fit are interpreted as 8 percent and less than 0.0001 percent.

An attempt to fit the curves to log-normal functions indicated that the transformation log $(X-A)$ for X would be needed (*5*). The data for the slower range fit a log-normal distribution nicely, where $A = 0$, $X^2 = 2.91$, and $p = 82$ percent for the seven centralmost points. In the case of the faster range, the function can be described accurately only when $A = 11$ msec; then X^2 becomes 1.93 and $p = 92$ percent for the centralmost points. The differential area between the two curves (Fig. 1) is itself a log-normal curve, where $A = 0$ (Fig. 2).

In attempting to establish another relationship between the distributions for the slower and faster ranges, the slower range curve was expressed as a probability power function, such that $p^n = 1 - (1 - p)^n$. This function, shown where $n = 5$ (Fig. 2), fails to approach any chance of congruency with the faster range curve.

In discussing these results, we refer to Polyak's description of the neural structure of the retina (*6*). Polyak describes the cones, the bipolar cells, and the ganglion cells as the primary neural

chain. In order for the response of the photoreceptive cone to become an afferent nerve impulse, the response must pass both the cone-bipolar and the bipolar-ganglion synapse. Summation should occur through specialized bipolars (Polyak types "e" and "f") which extend their dendrites to several cones. This type of summation would be spatial, and stimulation of *any* cone might be transferred to a single ganglion cell. In this case, if we were to consider the slower range function as mediated by primary single cone chains, the multiple cone-bipolar responses should be expressed as the powers of the improbabilities, $(1-p)^n$, where n represents the number of cones so interrelated. Such an interpretation is denied by the data.

On the other hand, the effect of the association cells (Polyak type "l") could be one of facilitation at the bipolar-cone synapse, so that any response passing the cone-bipolar synapse would be more likely to pass the bipolar-ganglion synapse. The stimulus to the association cell, en route past the bipolar-ganglion synapse, could so affect the association cell as to cause it to reduce the synaptic resistances at other corresponding synapses. This effect would be limited in time and would fade out. The data indicate that the time of this temporal summation is near 11 msec for these specific experimental conditions.

Having allowed for the time interval, we find that the differential frequency curve for the facilitated function takes a log-normal form, where $A = 0$, as did the responses for the slower range.

A reason for the separation of the responses into two functions can be deduced from the nature of the two stimuli patterns. In both sets, time is a random variable within the range presented. The stimulus changes cross the threshold in either direction, from suprathreshold to threshold, and from subthreshold to threshold. The slower rates are more frequently above the threshold, and as such, serve to complete the neural discharges along the chain, thus decreasing any facilitation, since none is needed. On the other hand, the faster rates are more frequently below the threshold, thus increasing facilitation, and thereby increasing the probability of response.

In interpreting these findings in terms of visual behavior, we conclude that when the stimulus conditions approach threshold levels of intensity or extensity, the estimate of the threshold will be affected by summation, which may be temporal as well as spatial in nature. An uncontrolled criterion of response, and insufficient data, can serve to raise falsely the estimate of threshold, thus decreasing the opportunity to establish individual differences and hence decreasing the opportunity to determine the deleterious effects of dysfunction in pathology.

In the field of neuron theory, the results here presented provide interesting confirmation for the newer neuron doctrines described by Bullock (*7*).

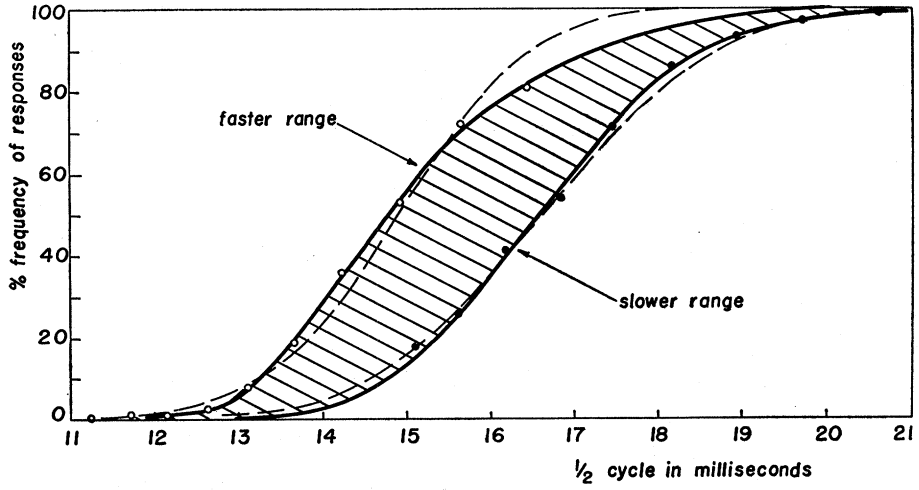

Fig. 1. Fitting of normal distributions to probability of response data summed for 38,324 trials on 344 eyes. The solid points represent the slower range, the open points the faster range. The broken lines are normal (Gaussian) curves fitted by the method of least squares. The heavy solid curves are log $(X-A)$ normal curves, which fit better. For the slower range the factor $A = 0$; for the faster range, $A = 11$ msec. The shaded area indicates a differential enhancement of the faster range responses over those of the slower range.

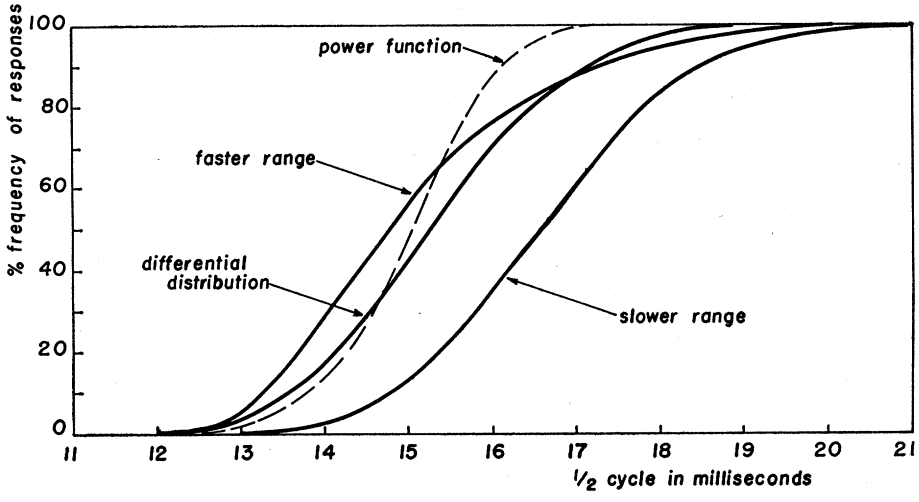

Fig. 2. Three retinal functions are represented by these distribution curves. The slower and faster range curves are traced from Fig. 1. The power function (broken line) represents the slower range curve raised to the power of $n = 5$ in the transformation $p_n = 1-(1-p)^n$. This represents spatial summation, but it cannot fit the faster range curve for any value of n. The differential distribution of the shaded area in Fig. 1 fits a log $(X-A)$ distribution where $A = 0$ and may represent the result of temporal summation.

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