

is somewhat greater, extending from 420 to 685 cc (10). Even so, if its larger calculated possibilities prove to be valid, the cranial capacity of the Italian fossil also lies within the range of the giant African great ape. In any event, the cranial capacity of *Oreopithecus* is that of a hominoid. Its lowest estimated capacity, 276 cc, is much larger than that recorded for any Old World monkey; the capacities of even large adult baboons fall short of 200 cc (11).

The index of relative brain size, an expression of the cranial capacity (in cubic centimeters) as a percentage of body weight (in grams), is of considerable interest. Schultz (12) has reasonably argued that the body weight of the 1958 specimen of *Oreopithecus* must have been about 40 kg, which approximates the weight of the average chimpanzee or female orang-utan. With this figure, the body-brain index of the fossil could be as little as 0.69 or as much as 1.32. The minimum index, 0.69, lies well within the adult range of variation for the three great apes (11). The maximum index, 1.32, while considerably above that recorded for any adult gorilla, is but slightly larger than the adult maxima of both the orang-utan and chimpanzee; it is slightly smaller, however, than the minimum index for adult man (11). Both of these estimated *Oreopithecus* indices are paralleled among Old World monkeys. However, this index of relative brain size tends to be inversely proportional to body weight in primates (11). Consequently, if its larger index, 1.32, is valid, *Oreopithecus* can be regarded as somewhat advanced in relative cranial capacity and hence in relative size of brain, for it undoubtedly was a much bigger animal than any Old World monkey of comparable body-brain index. Indeed, this index falls below 1.0 in all Old World monkeys weighing more than 10 kg (11).

Its encephalic magnitude, both absolute and relative, confirms the assignment of *Oreopithecus* to the Hominoidea. It is not permissible, however, from this character alone, to allocate that fossil more precisely. Although the degree of its encephalic development is equivalent to that found in existing great apes, it does not of necessity follow that *Oreopithecus* belongs in the family of the great apes, the Pongidae. For one thing, we lack the truly requisite comparative data, since we are quite ignorant of the cranial capacities of the undoubted Lower Pliocene ancestors of the great anthropoids; hence we do not know whether the pongid brain of that time had as yet attained its present size. Nor does its

relatively moderate cranial capacity necessarily exclude *Oreopithecus* from the family Hominidae; for a Lower Pliocene hominid would scarcely be expected to possess a brain as large as those of undoubted men, since it now is quite evident that the brain lagged behind the rest of the body during hominid phylogeny (13). Hence, despite brains that were of great-ape dimensions, the early Pleistocene "man-apes" of South Africa, the australopithecines, have not been denied admission to the Hominidae. Size of brain per se therefore would not debar *Oreopithecus*; for not only is its cranial capacity within the great-ape range, but it may well be as large, both absolutely and relatively, as those of some australopithecines (for example, *Australopithecus* [Sterkfontein No. 5]; see Table 1, column a). Thus, although the cranial capacity definitely identifies *Oreopithecus* as a member of the Hominoidea, it is of no aid in deciding whether this creature belongs in the Pongidae, the Hominidae, or a family of its own.

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4. We are greatly indebted, respectively, to the Wenner-Gren Foundation for Anthropological Research, New York (W. L. S., Jr.) and the Fundación Creole, Caracas, Venezuela (M. A. S.) for grants which made our trips to Basel and this study possible. We also are grateful to Dr. Johannes Hürzeler for the opportunity to study the actual skull of *Oreopithecus* and its plaster reconstruction.
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6. The 21 skulls measured include representatives of all major groups of catarrhine primates: 4 Old World monkeys (2 macaques, *Macaca*; 1 baboon, *Papio*; 1 langur, *Presbytis*); 9 anthropoid apes (1 gibbon, *Hylobates*; 1 siamang, *Symphalangus*; 2 orang-utans; 2 chimpanzees; 3 gorillas); 1 australopithecine (*Australopithecus*; Sterkfontein No. 5); 3 fossil men (La Chapelle-aux-Saints and Gibraltar No. 1 Neanderthals, Rhodesian); and 4 modern men.
7. Each of the braincase volumes in Table 1 (column b) represents an average of three separate measurements. The volumes of the 4 fossil hominids were measured from standard plaster casts. Forty cubic centimeters have been subtracted from the measured *Australopithecus* volume because the infratemporal fossae are filled by foreign material, and 40 cc have been added to the measured La Chapelle-aux-Saints volume to account for defects in the skull. To prevent water from entering the cranial cavities of the actual skulls, all relevant foramina were first

plugged with raw cotton and then sealed, together with any open sutures, with paraffin. In each instance, the volume measurement has been corrected to account for the paraffin and cotton. Corrections also have been made for prominent nuchal and sagittal crests; wherever feasible, these have been reconstructed in modeling clay (Plastolene), and the water displacement has been measured. The cranial capacities of the 4 fossil hominids have been taken from the literature. Those of all other skulls were measured by us, using small dried peas; each figure in Table 1 (column a) is an average of three separate measurements.

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1 August 1960

#### Differential Sensitivity of Peripheral Retina to Intermittent White Light

**Abstract.** The ability of the eye to detect differences in the interruption rate of white light was investigated for various rates and for several locations on the temporal periphery of the right eye. The complex relationship previously reported was again found, but only for stimulation of the fovea. The results from the peripheral regions indicate that differential sensitivity is a decreasing function of the rate of intermittence.

Within recent years the differential sensitivity of the fovea to intermittent white light has been investigated several times, always with the same result (1, 2). Simply stated, the differential sensitivity appears to be a complex function of the rate of intermittence, decreasing as the rate of intermittence increases to 22.5 cy/sec, after which it increases sharply to the neighborhood of 35 cy/sec and then decreases again as the fusion point is approached. The luminance of the flickering source was such that fusion occurred in the neighborhood of 40 cy/sec for all observers. This effect has been found for numerous observers with different psychophysical methods and different on-

off ratios of the flickering stimulus source (2).

Since all of the data reported so far have been obtained from foveal measurements, it was decided to investigate the peripheral retina before concluding that the effect observed is a general one.

The intermittent stimulus light was produced by a Sylvania R1131C glow-modulator tube operated independently from two variable-frequency square-wave generators. The stimulus spot subtended  $0.5^\circ$  of visual angle and had a homogeneous luminance of 1800 mlam. It appeared in the center of a white, semicylindrical surround with a fixed luminance of 22 mlam. Small, dim fixation lights were so positioned that when viewed foveally the stimulus spot stimulated points  $5^\circ$ ,  $10^\circ$ ,  $15^\circ$ ,  $20^\circ$ , or  $30^\circ$  peripheral to the fovea on the temporal retina of the right eye. The observer's position was maintained at the center of curvature of the surround by a fixed chin-and-forehead-rest. Foveal judgments were obtained by having the observers fixate the stimulus spot directly.

The observer sat in a room darkened except for the light from the surrounding field. The standard and comparison channels were programmed through one cycle so that each was presented for 1 second with a 1-second interval between. The initiation of this cycle was under the control of the observer. Half of the judgments were made with the standard presented first and half with the comparison presented first. The observer also controlled the frequency of appearance of the comparison stimulus by a linear, multirevolution potentiometer. Equality judgments were obtained by the method of adjustment, with ascending and descending matches alternately. All observers were allowed to view as many cycles of the standard and variable as they felt necessary. The discrepancy between the standard and the comparison frequency was measured by an electronic counter to an accuracy exceeding that of the generating equipment.

Six observers were given practice in making this type of judgment before any experimental data were collected. After the practice sessions each observer made from 9 to 18 judgments at each retinal position for each of the following interruption rates: 5, 10, 15, 20, 22.5, 25, 30, and 35 cy/sec. Combinations of frequency and retinal position were presented in a random order. Three consecutive thresholds were obtained for each condition before a different condition was imposed.

The pooled results obtained from all six observers are shown in Fig. 1, where the difference-limen ( $\Delta f$ ) and

the relative difference-limen ( $\Delta f/f$ ) are plotted as a function of the interruption rate for all retinal positions. Each plotted point is based on a total of 66 to 84 judgments. This range of judgments per point is due to two factors. First, not all observers provided the same number of judgments for each condition because of scheduling difficulties and time limitations. Second, in making tedious and patience-demanding judgments of the type required here, occasional aberrant readings are produced that are entirely unrepresentative. Therefore, those readings that exceeded the average deviation (computed with the aberrant reading included) by a factor of 3 were excluded. The judgments so excluded represented only 2.3 percent of the total.

The data from the fovea ( $0^\circ$ ), plotted in Fig. 1, resemble closely those obtained in previous experiments. The difference-limen here is somewhat higher over-all than those reported

earlier. This may be a result of the different experimental conditions under which these data were collected.

The results from the peripheral retina do not exhibit the same complexity that has been found for the fovea. Neither does there seem to be any consistent effect on the difference-limen as a result of viewing the stimulus spot at different points on the peripheral retina, except perhaps for the increased variability of the threshold judgments in the far periphery as compared with the near. This latter result is not surprising in view of the difficult nature of peripheral judgments. Small stimuli viewed obliquely are subject to a rapid adaptation or fading that increases with eccentricity (3). Therefore the time available to make rate judgments in the periphery is much more limited than in the fovea. What is surprising is the fact that the differential-limens for flicker rate are practically identical for all areas of the

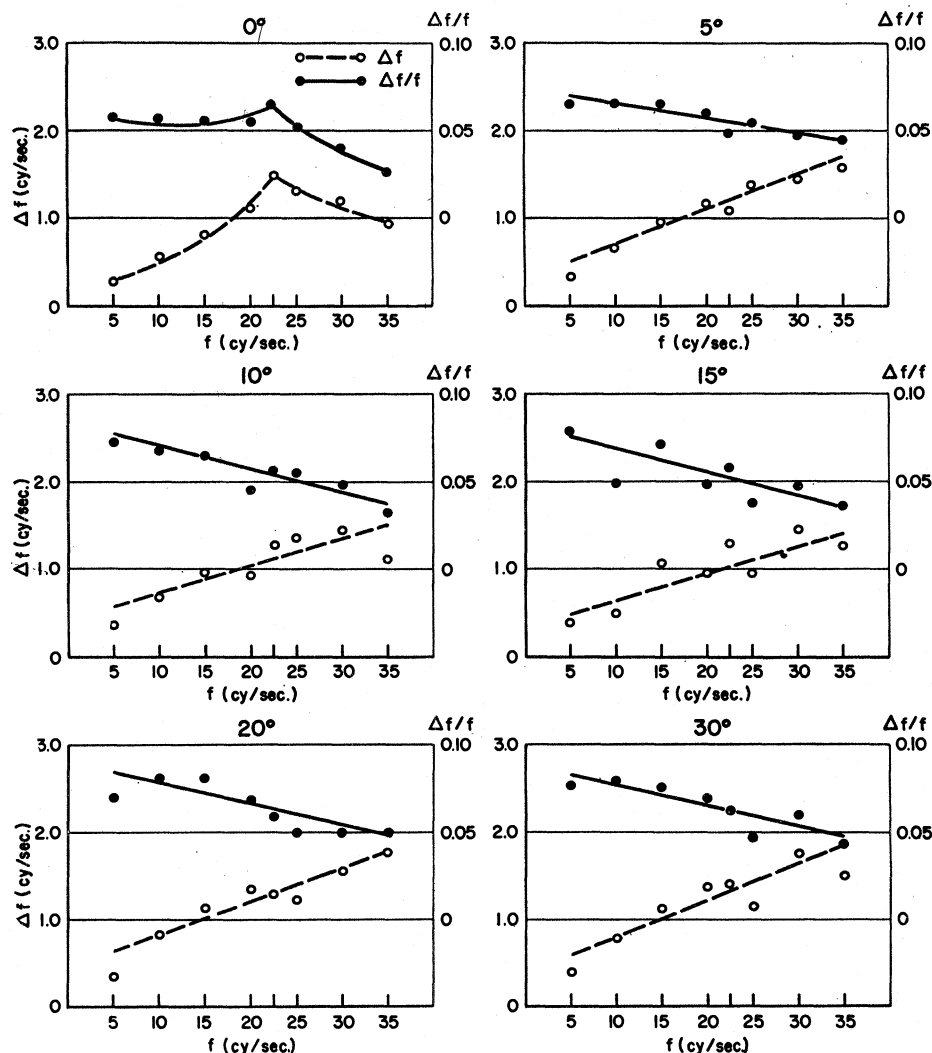


Fig. 1. The differential-limen ( $\Delta f$ ) and the relative differential-limen ( $\Delta f/f$ ) for intermittent white light. The data are measurements from different regions of the temporal retinae of six observers.

temporal retina that lie outside of the fovea. One must conclude that the complex function describing the differential sensitivity of the eye to intermittent white light is somehow peculiar to foveal stimulation. The precise nature of this peculiarity is yet to be revealed (4).

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### Observing Behavior in a Vigilance Task

**Abstract.** It has been suggested that level of performance in a vigilance task is accurately reflected by frequency of observing responses. By means of photography it has been demonstrated that under conditions where a decrement in vigilance performance does not occur, the frequency of nonobserving behavior and general activity increases in time.

Studies of vigilance, that is, monitoring performance as a function of time, have recently raised questions of theoretical as well as practical importance. Holland (1) studied frequencies of observing responses—pressing a key to illuminate the display—during a vigilance task. Using the Mackworth (2) schedule of signals occurring at intervals of  $\frac{3}{4}$ ,  $\frac{3}{4}$ ,  $1\frac{1}{2}$ , 2, 2, 1, 5, 1, 1, 2, 3, and 10 minutes, in that order, and repeated for three further half-hour periods, he reported a decrement in performance and a parallel decrement in observing rate and concluded that “the detection data of vigilance studies may reflect the observing response rates generated by the particular schedules employed.”

Holland defined a key depression as an observing response. On the other hand, Blair (3) stated that “observing responses refer to the relation, through time, between sense-organ orientation and displays . . . the depression of a key may or may not be the same as actual head and eye movements involved in monitoring tasks.” He arranged a vigilance situation in which the presence or absence of a signal could be detected only when the head was oriented toward the display. Only two of his five

subjects exhibited behavior such as Holland described. Blair did not present data on detection performance, nor did Carpenter (4), who found that frequency of blinking increased during a vigilance task.

During six vigilance experiments, I registered general activity or “restlessness” by means of counters activated by microswitches placed under the subjects’ pivotally mounted chair (Baker, 5). I found that whereas general motor activity increased markedly in time “there is little possibility of predicting the level of vigilance from motor activity during the task.”

Since key pressing is a form of motor activity, the Blair, Carpenter, and Baker studies raise a question about the generality of Holland’s tentative conclusion. To examine this question, a Mackworth-type clock test was devised having a single hand jumping forward to a new position once a second, 100 jumps per revolution. Double jumps, designated as signals, occurred as per the Mackworth schedule. The clock face was a Lucite panel behind which a 16 mm camera was mounted. Photographs (1/32 sec exposure) were taken of subjects’ heads and shoulders once per second for an hour. A ring-shaped fluorescent tube mounted around the clock permitted satisfactory photography and rendered the camera invisible. Subjects were not informed that they were being photographed, and possible auditory cues were deleted by a steady masking noise plus ear defenders. Viewing distance was 20 inches. [Fraser (6) has reported that when the clock test is used at such viewing distances a decrement in performance is not demonstrable, presumably because of the large signal magnitude (7); a

decrement was not required for our purpose.] In addition, microswitches under the subjects’ pivotally mounted chair gave a measure of general activity or “restlessness.”

The task was to press a button when a signal was detected. Subjects were 19 paid housewives.

The data consisted, then, of the number of signals reported, a record of general activity, and 64,698 photographs (8). An observing response was defined as eyes open and oriented toward the display. A decision as to whether subjects met the criteria of an observing response was made by two judges who together examined the photographs and reached agreement in each case. When not meeting the criteria, subjects were blinking, yawning with eyes closed, turning to look behind, reaching down toward the floor, looking overhead, and so forth.

Percentages of time the subjects observed the display ranged from 90.6 to 99.4 with a mean of 97.2 and a median of 98.2. The frequency distribution of nonobserving responses (which consumed an average of 2.8 percent of the hour) showed a marked change with time: 16.8 percent occurred in the first quarter-hour and 31.4 percent in the last. This difference is significant at the 0.01 level. General activity showed a parallel increase, 16.4 percent of the activity occurring in the first quarter-hour and 29.6 percent in the last, a difference also significant at the 0.01 level. These percentages are very similar to those previously reported (5).

There was no decrement in number of signals reported, 36 percent of the signals not being reported in the first half-hour and 30.7 percent in the second. The difference is not significant. (In only one case was the subject actually not observing the display when a signal occurred.)

Figure 1 shows how closely the increasing frequency of nonobserving responses paralleled increasing general activity, while neither paralleled the frequency of signal reports (9).

Three Spearman rank-difference coefficients were calculated between the total values of the three variables recorded for each subject, and none differed significantly from zero. To consider one case only, the subject who spent the lowest percentage of time observing the display (90.6) had the smallest record of total general activity over the hour and failed to report only three signals (all appearing in the first half-hour). It is recognized, of course, that in a situation where the range of nonobserving responses is much greater than that reported here a relation must exist with the number of signals reported.

However, in this experiment the fre-

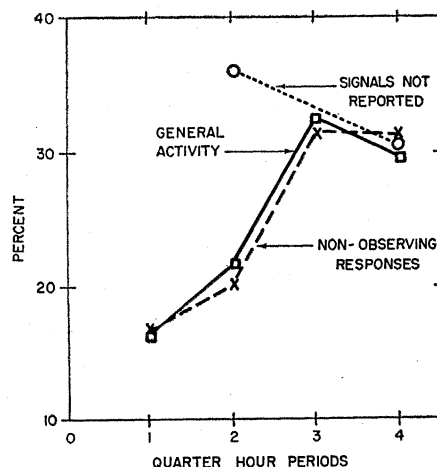


Fig. 1. Mean percentages of general activity, nonobserving responses, and signals not reported, as functions of time. Data for signals not reported are plotted for half-hour periods.