reaction have so far yielded inconclusive results, probably because of the high dilutions employed. Further studies are in progress, following the recent reports of Weiss *et al.* (*9*), which appeared while the present study was being carried out.


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## The Decrease of Critical Flicker Frequency with Age


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The perception of flicker and fusion is one of the most interesting visual phenomena. In recent years considerable interest has been shown in the measurements of critical flicker frequency (cff), which have been used in many studies. Therefore, knowledge of all the factors determining cff has become of great theoretical and practical importance. A number of investigators have pointed out age as a factor in cff. Some investigators, such as Meili and Tobler (*1*), G. W. Hartmann (*2*), and V. L. Miller (*3*), comparing different age groups of children and young adults over a relatively narrow age range, have not found any change in cff with age. Investigators who studied larger age ranges, however, such as Simonson, Enzer, and Blankstein (*4*), Brožek and Keys (*5*), Weekers (*6*), and Misiak (*7*), reported a significant decrease in cff in older age groups. The results of their investigations have not been conclusive because:

1. They were based on relatively small numbers of Ss.
2. They failed in having a sufficiently wide age range.
3. The results were not comparable, since they were obtained by different methods.

From these studies nothing definite could be inferred concerning the form, extent, and cause of the decrease of cff with age. Thus it was thought to be of value to measure cff of sufficiently representative samples over a large age range, using the same apparatus and procedure throughout the study.[1]

The subjects were 182 males and 137 females free from any visual pathology, ranging from 7 to 89 years of age, with a mean age of 36 years. After the completion of the study, they were divided into 17 five-year groups and their cff's and variability compared.

With a few minor changes, the apparatus used in this study was built from the specifications and data presented in an article by F. Henry (*8*). It was an electronic apparatus which had a 3-w neon glow lamp giving an intermittent light at a rate determined by 3 adjustable resistors. Another neon lamp, similar to the lamp producing the flicker, served as a voltage regulator, thus assuring the constancy of the flicker rate, even if the supply voltage varied. A small cathode-ray oscilloscope tube built into the apparatus permitted its calibration. The circular test patch was 5 mm in diameter. From a distance of 12.8 in. the subtending visual angle was 48 min, assuring foveal observation of flicker when the eyes were fixated on the test patch.

All the Ss were adapted to the illumination level of the light source of the flicker apparatus before they were tested for cff. The observations were made with the dominant eye. The frequency of light flashes was gradually increased until the subject reported no flicker, and the frequency was then decreased until the flicker was again seen. The cff value of each S was the mean of the readings obtained from flicker to fusion and from fusion to flicker, which numbered 20 on the average. In the early stage of the research, Ss were tested for 10 days with the number of readings ranging as high as 80, but when no significant day-to-day changes were found, and the correlation coefficient between readings obtained on successive days was above .95, the number of readings was reduced.

The group results are presented in Table 1. The mean cff under the experimental conditions of the study was 41.18 cps for the males, 41.08 for the

TABLE 1

MEANS AND VARIABILITY OF CRITICAL FLICKER FREQUENCIES FOR DIFFERENT AGE GROUPS

| Age groups | N | Cff | Inter-individual variability SD | Intra-individual variability AD |
|---|---|---|---|---|
| 7–11 | 35 | 42.91 | 4.31 | .90 |
| 12–16 | 36 | 44.85 | 4.36 | .71 |
| 17–21 | 39 | 43.63 | 3.54 | .58 |
| 22–26 | 39 | 42.62 | 3.86 | .83 |
| 27–31 | 16 | 42.65 | 3.51 | .62 |
| 32–36 | 26 | 40.86 | 3.64 | .79 |
| 37–41 | 18 | 40.27 | 4.07 | .74 |
| 42–46 | 14 | 40.42 | 3.98 | .92 |
| 47–51 | 18 | 39.46 | 3.90 | .75 |
| 52–56 | 13 | 40.99 | 6.15 | .60 |
| 57–61 | 12 | 38.38 | 3.42 | .77 |
| 62–66 | 5 | 36.06 | 2.10 | .35 |
| 67–71 | 14 | 38.91 | 5.46 | .35 |
| 72–76 | 13 | 36.41 | 3.81 | .33 |
| 77–81 | 13 | 32.22 | 6.25 | .36 |
| 82–86 | 6 | 35.82 | 5.69 | .37 |
| 87–91 | 2 | 36.04 | 3.61 | .47 |
| Total | 319 | | | |
| Mean | | 41.14 | 4.22 | .68 |

[1] This undertaking was carried out through the help of I. McCormick, J. Doblmeier, and W. McGill, of Fordham University, who made their results available to the author and to whom he expresses his thanks and appreciation.

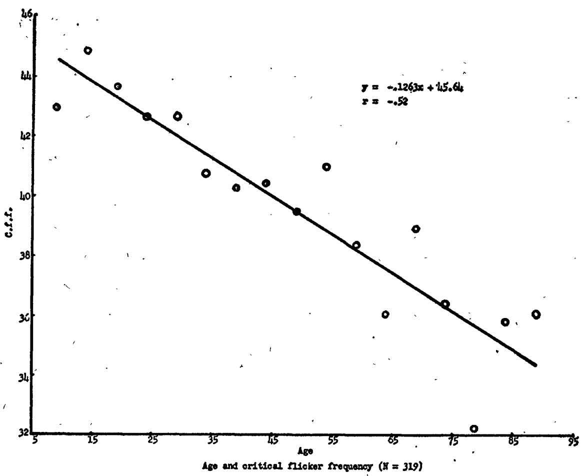


FIG. 1.

females. The mean cff for the youngest group (7-11) was 42.91, for the oldest (87–91) 36.04. The striking fact about these cff's is the large range of individual measures of 37.35 cps (18.29–55.64) and the great variability of 4.22 of the total group. In addition, there was appreciable interindividual variability within the age groups. No significant sex differences were found. The relationship between age and cff is linear and negative, the correlation coefficient, based on all individual cases, being significant but small -.52 (Fig. 1). The differences between groups are statistically insignificant, except between the groups below 30 and above 55 years of age. Thus it can be concluded that cff drops with age, this drop becoming significant in individuals later in life (after 55). However, it must be pointed out that there were cff's at age 82 as high as at age 7, and on the other hand there were cff's at age 7 as low as at age 80.

The interindividual variability tends to increase with age, a tendency generally characteristic of many mental and physical capacities. The intraindividual variability, on the contrary, shows tendency to decrease.

There is a strong indication, however, from other investigations still in progress that the relationship between cff and age differs with intensities of light, the higher the intensities the greater the slope of the line expressing this relationship.

The cause of the decrease of cff with age is hard to understand. It may lie in peripheral factors (the retina), or in central factors (subcortical or cortical), or both. A Belgian investigator, Weekers (*6*), has suggested that smaller diameter of pupil and its diminished mobility in old age may be the cause of lower cff. When he used mydriatics in his subjects, he did not find any change in cff until after 50 years of age. It is true that the iris becomes thinner and more rigid with age, and that the pupil becomes smaller and less mobile, but the present investigator does not feel that this is the sole explanation for the lower cff, especially in view of the gradual decrease of cff even before the age of a diminished mobility of the pupil, and in view of the fact that injuries of the cerebrum lower cff (*9*). The pupil factor seems to be, nevertheless, an important one. In another study (*10*), using a different apparatus with lower intensity of the flickering light, we found difference in cff between groups 20–30 and 40–50 (32.00 and 31.16, respectively), but when artificial pupils were used the cff for both groups was almost identical (24). It is possible that the key to the solution of the decrease of cff when no artificial pupils or any drugs affecting the pupil are used lies in the relationship between the sympathetic and parasympathetic systems with regard to the pupil. If the parasympathetic system becomes more dominant with age, the fact that the light reflex is more pronounced would result in the diminished diameter of the pupil, in turn lowering the retinal illumination and consequently also the cff. That is why higher intensities of flickering light would show greater differences in cff with age than lower intensities. We intend to investigate this hypothesis by further experiments.

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## A Nomogram for the Calculation of Relative Centrifugal Force

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It is well known that the centrifugal force developed in a rotating system is proportional to both the radius and the square of the frequency of revolution. Nevertheless, many experiments in which centrifugal separation is an important procedure are reported merely in terms of "revolutions per minute" (rpm). Results, so reported, are of little quantitative significance. Therefore, when the rate of sedimentation is of importance, as in centrifugal fractionation, or when the volume of the sediment is measured, a more complete specification should be provided.

A convenient measure of centrifugal force is given by the ratio of the weight of a mass in the centrifugal field to the weight of the same mass when acted upon by gravity alone. This relative centrifugal force, *G*, is proportional to the absolute force applied to a suspended particle and, therefore, also is proportional to the speed of free sedimentation in a wide variety of