Effects of Age on Peripheral Vision

ERNST WOLF, Retina Foundation and Massachusetts Eye and Ear Infirmary, Boston

Changes in visual sensitivity with age at photopic, mesopic and scotopic luminance levels have been found in studies on visual acuity, dark adaptation, and flicker. It also has been shown that sensitivity to glare increases with age. Approximately at the age of 40 years the pace of change is accelerated. This can be shown equally well for the dark adaptation, flicker, and glare data. Most studies thus far have been restricted to tests in the central visual field. Information on visual performance in the peripheral visual field is obtained by studies on dynamic visual acuity and flicker perimetry. Perimetric fields obtained by the flicker method in individuals between the ages of 6 and 93 years under various experimental conditions are presented, and the effects of alertness, training, and experience are discussed.

•IT IS WELL KNOWN that the efficiency of vital mechanisms of the body declines with age. Vision is no exception. In early youth, for instance, it is very easy to accommodate for objects at a short distance from the eyes, whereas above the age of 45 or 50 years accommodation needs assistance by reading glasses.

The range of dark adaptation becomes gradually smaller with age. Though in the young, adaptation can increase sensitivity in excess to 1:100,000, it may be reduced to 1:1,000 in advanced age. In the aged, therefore, scotopic sensitivity may be only 1/100 of the sensitivity found in young individuals (1, 2, 3).

The sensitivity to glare becomes progressively greater with age. Though young individuals can easily discern details in the vicinity of a glare source, older individuals encounter considerable difficulties. For both these visual functions a change in sensitivity is particularly noticeable at the age of 40 years. Changes in the transmissiveness of the ocular media and increase of scatter of light at that age are probably contributing factors (4, 5, 6).

Studies on responses to flicker in the central retina have shown that critical flicker frequencies decrease with advancing age. It appears however that for flicker perception a decisive change occurs rather at the age of 60 than at 40 (7, 8).

This relationship between sensitivity and age was found in direct vision. For moving objects or for an individual moving in a vehicle, peripheral vision becomes of considerable importance. It seemed of interest, therefore, to study flicker responses of the peripheral retina especially in relation to age.

For studies of this type, a flicker perimeter is used. This instrument incorporates an adjustable chair with head and chin rest mounted on a crossbar between the side arms so that the eye level of an observer can be adjusted in relation to the center of the perimeter which has an object distance of 1 m. The object is a Sylvania glow modulator tube activated by a Grayson stadler flicker apparatus. The light source has only a very small diameter in front of which a short focus lens is used to illuminate evenly a translucent screen yielding a round flicker field of 2° angular subtense. By means of diaphragms, as well as color and neutral filters inserted in front of the screen, size, brightness, and color of the testfield can be varied. The flicker light is mounted in a tubular enclosure with the circular field at one end and held by an arm originating above

the head of the observer. This arm moves through any desired arc to cover a hemispherical surface with 1-m radius. A second equally suspended arm bears a fixation point in relation to which the flicker field is adjustable. The positions of testfield and fixation point are read from scales at the base of the arms. Thus, flicker fields can be put accurately in any special relation to the fixation mark while the observer's eye remains fixed at the center of the hemispherical arrangement (Fig. 1).

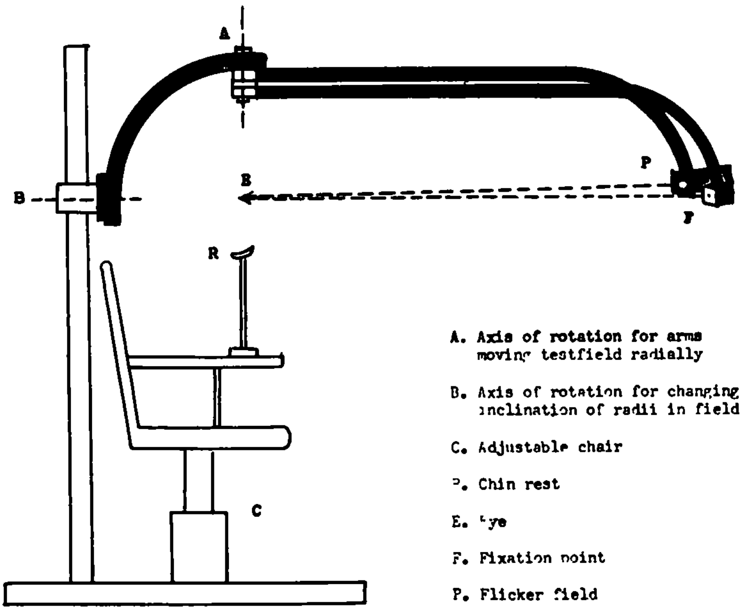

Figure 1. Diagram of flicker perimeter.

The controlling device for the light source permits changes in luminance, in light time fraction from 2:98 to 98:2 in each flicker cycle and in frequency from 150 to $\frac{1}{2}$ cps. The light is bluish-white and presents no difficulties to perception in the periphery. In the experiments described here only the full brightness of the source (30 footlamberts) and a light time/dark time ratio of 1:1 was used.

The test room is dimly illuminated. One eye is occluded; the seeing eye fixates the red fixation point while the flicker field is positioned at any desired angle and distance. The size and luminance of the testfield are so chosen that the target is easily noticeable in any position. During tests, flicker frequency is gradually reduced from complete fusion to the point when the observer indicates that he sees flicker. This is the critical flicker frequency (CFF) to be determined. The CFF value in cycles per second is read from a scale on the flicker apparatus. The frequency is immediately raised again to a level above fusion to avoid undue fatigue by the flickering light, and after a short interval the critical frequency is determined for a second time. Usually first and second readings are in close agreement. If, however, a difference greater than 2 cps is found, additional readings are taken, and the mean is taken as the CFF value for that point of the visual field. Tests are made along the horizontal and vertical meridians and along the diagonals as far out as CFF values are obtainable. A complete flicker field includes as many as 70 CFF values. Usually, however, the number is smaller on account of the physical limitations presented by the structure of the face, when eyebrows, cheek bones, and nose obscure vision in certain directions.

Figure 2 shows a perimetric field chart with the CFF values for a 13-year-old. At the center, CFF is 51 cps. Similar high values are found to 50° and in the far periphery frequencies of one-half the central values are found. The distribution of CFF

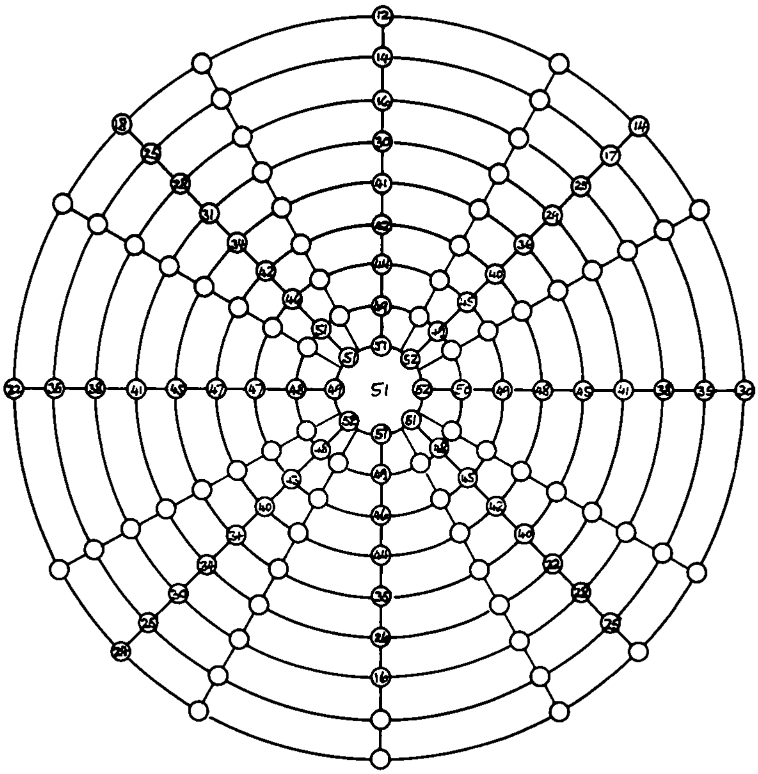

Figure 2. Flicker field (right eye) of a 13-year-old. White light; light time/dark time ratio 1:1.

is rather regular, and deviations from it may be used for diagnostic purposes, as sudden abrupt changes in CFF values are indicative of retinal lesions. Unfortunately, however, the usefulness of flicker perimetry as a diagnostic tool suffers because critical frequencies are not a series of absolute numerical values but depend on age. It is therefore necessary in relating changes in CFF to pathological conditions to correlate them to the flicker values normal for a given age (9).

Changes in flicker fields are particularly noticeable in advanced age. The results of a study of flicker fields in a group of 107 Spanish American War veterans between 73 and 94 years of age are shown in Figure 3 in which the CFF values along the eight principal radii of the visual field are given. These are plotted for five age groups, each covering a span of five years (10).

At the center of the visual field, a maximum flicker frequency of 32 cps is found for the youngest group, and 27 cps for the oldest. The CFF values drop systematically with age so that for each retinal position along the eight radii they become progressively smaller yielding in the far periphery values below 10 cps. If CFF values shown for an adolescent in Figure 2 were assumed to represent a normal flicker field, the values obtained with the veterans would seem abnormally low. But inasmuch as within the 25-year span represented by the veterans a systematic decline in CFF is noticeable, one may assume that the decreasing CFF values are typical for high age.

To obtain flicker data covering the entire span of human life it was necessary to extend the study of normal flicker fields to all age levels. For this purpose, individuals were used who visited the out-patient department of the Massachusetts Eye and Ear Infirmary and who according to their clinical records had no pathological conditions. The data are adequate to show the general trend of CFF in relation to age, but the results should be regarded as preliminary, because unequal numbers of individuals were used

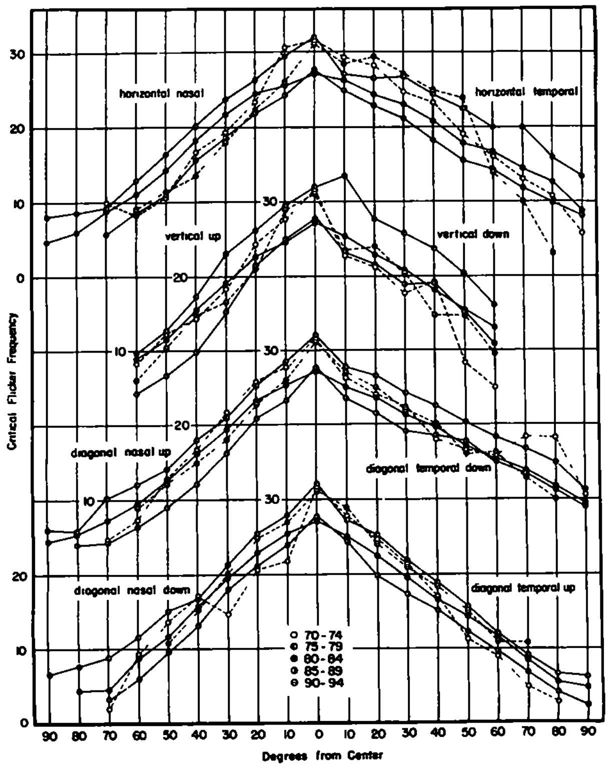

Figure 3. Data obtained from 107 individuals between 72 and 94 years of age. CFF values plotted for five age ranges of 5 years each against retinal position on 8 radii. Frequencies higher at center, declining steadily toward periphery.

in the various age groups (3-22). The same is true for the Veterans' data (2-64). Among the individuals below 75 years picked from the clinics those between 30 and 55 years are much less readily available than those younger or older. The numbers must therefore be suplemented before a complete analysis of the data can be carried out.

Figure 4 shows the results of flicker tests along the horizontal meridian of individuals between 5 and 75 years in groups of 10 years. They may be compared with the curves of the horizontal meridian in Figure 3. The top curve of the set in Figure 3 overlaps with the bottom curve of Figure 4 and represents a continuation of the age range from 5 to 95.

The curves of Figure 4 show for all age groups the highest frequency values at the center. Center values above 40 are found up to age 35, and slightly lower than 40 up to age 65. For young individuals CFF remains above or near 40 cps as far as 30° from center, and frequencies above 30 cps occur as far as 70° in the temporal field, and as far as 50° in the nasal field. As age progresses, the CFF values become smaller at all points but the drop is more pronounced in the far periphery and especially in the nasal field.

Figure 5 is a combination of the data presented in Figures 3 and 4 by plotting for various angular distances the CFF values against age. Each curve represents the changes in CFF with age for points located 0°, 20°, 40°, 60°, and 80° from center along the horizontal meridian in the nasal and temporal fields and along the vertical meridian above and below fixation. All curves show that at each point of the visual field CFF varies with age. From childhood, CFF rises to maximum values between 20 and 30 years, then drops to a lower level which is maintained until age 60. Above 60 years CFF declines faster, reducing flicker perception considerably, especially in the far peripheral field.

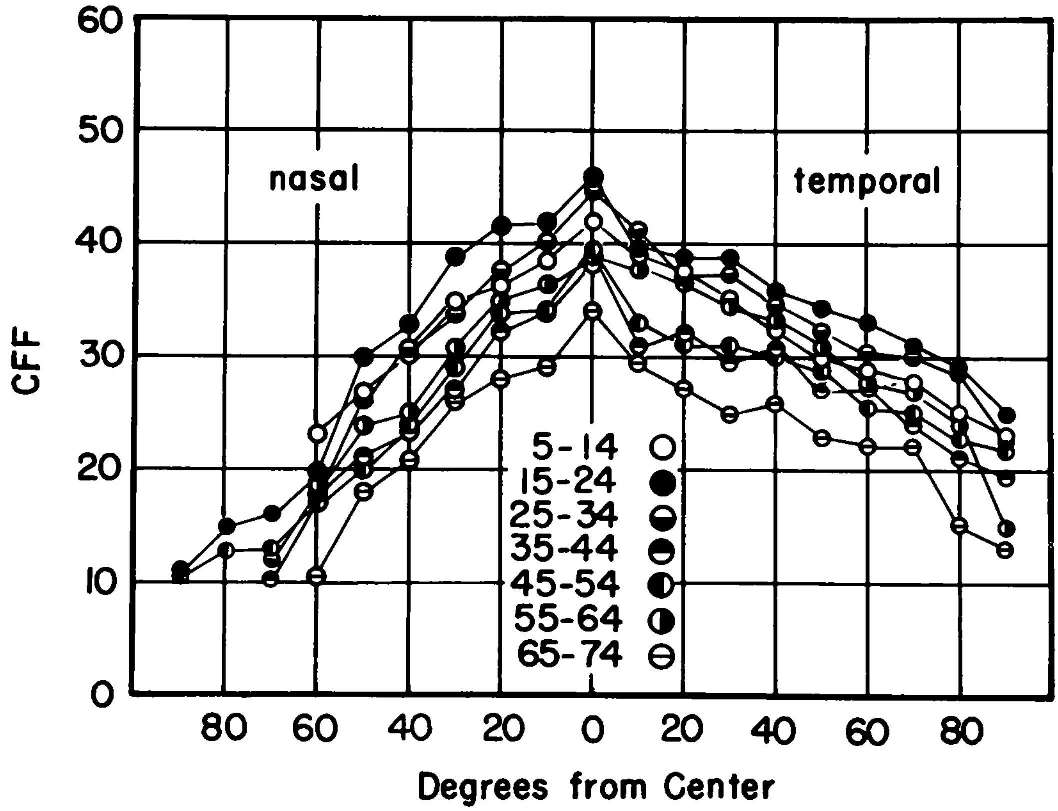

Figure 4. Data obtained from individuals between 5 and 75 years of age. CFF values for horizontal meridian of visual field given for seven age ranges of 10 years each. For each age, frequencies higher at center, declining toward periphery. At every retinal point, CFF becomes smaller with age.

The data presented unquestionably show an interdependence of mean CFF and mean age for a given group of individuals. There is, however, a great deal of variability between individuals, a fact that should be emphasized. In some cases a CFF level that lies considerably below normal is found throughout a rather limited visual field, and it appears as if CFF depended not only on the receptive power of the retina but also on the mental alertness of the individual under study. A well-motivated child of 10 years or less may show a flicker field with frequencies between 40 and 50 cps up to 60° from center in all directions, and beyond 60° a slow decline up to angles where it becomes physically impossible for rays from the flicker light to enter the pupil. Equally high values may be found in a 50- to 60-year-old professional man or woman who is mentally alert and has experience in visual observation. In contrast to this, a much younger person may give central CFF values that are as low as those of the Veterans and who will not respond to flicker with certainty when the field is presented 40° to 50° in the temporal field. For further study it might perhaps be of interest to correlate low CFF's with other psychological tests and perhaps the occupations of subjects.

In the peripheral retina, visual acuity becomes progressively poorer. When acuity in direct vision is 20/20, it is only 20/40 at 5° and only 20/80 at 10° from center. The perception of details in the peripheral visual field is therefore very difficult as compared with the center of the retina. When visual acuity is studied while test objects are in motion (dynamic visual acuity), it is found that acuity deteriorates rapidly with

the increase of the angular velocity of a test object. The correlation between static and dynamic acuity is low. Even in individuals with 20/20 vision or better, it cannot be predicted how they will respond to objects in motion. Static visual acuity increases with luminance until a maximum is reached; dynamic acuity, however, requires 20 times more light until a significant effect is noticeable (11, 12, 13).

In flicker recognition the perception of detail is not necessary. For this reason peripheral sensitivity can be studied advantageously by the flicker method. Where acuity would have become immeasurably low in the periphery, good responses to flicker are still obtained.

In flicker perimetry the CFF values obtained for all ages decrease progressively as one moves out in the peripheral field. Moreover, frequencies for each retina point become smaller as a function of age. This means that for older individuals frequencies that would be seen as definitely flickering by a younger individual would appear fused and as a stationary stimulus possibly not noticeable at all.

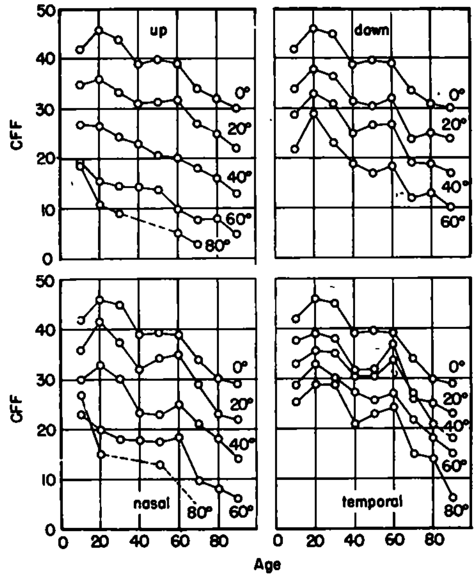

Figure 5. Relationship between CFF and age at center of retina and 20°, 40°, 60°, and 80° from center on four principal radii of visual field. At each retinal location, CFF highest between 20 and 30 years, then remaining relatively steady up to 60 years. After 60 years, a faster decline in CFF noticeable.

In a moving vehicle peripheral visual perception is of great importance. Probably at all times information gathered by the peripheral retina is used subconsciously and utilized for road safety. With increasing velocities of travel and density of vehicles on the road, peripheral visual perception might be even more important than is attributed to it. In view of the fact that the driving population over 55 or 60 years is steadily increasing, the changes in peripheral visual perception with age as indicated by the study to responses to flicker should be taken into consideration in the presentation of visual information that must be assimilated by drivers of all ages (14, 15).

REFERENCES

1. McFarland, R.A., and Fisher, M.B., "Alterations in Dark Adaptation as a Function of Age." Jour. Gerontol., 10: 424 (1955).
2. Domey, R.G., and McFarland, R.A., "Dark Adaptation Threshold, Rate, and Individual Prediction." HRB Bull. 298, 3-17 (1961).
3. Birren, J.E., and Shock, N.W., "Age Change in Rate and Level of Visual Dark Adaptation." Jour. Appl. Physiol., 2: 407 (1950).
4. Wolf, E., "Glare and Age." AMA Arch. Ophthalm., 64: 502 (1960).
5. Wolf, E., and Zigler, M.J., "Some Relationships of Glare and Target Perception." Aero Med. Lab. Wright-Patterson Air Force Base. WADC Tech. Report 59-394 (1959).
6. Allgaier, E., "Age and the Ability to See at Night." Traffic Engin. and Safety Dept., Amer. Auto. Assoc., Washington, D.C., Research Report 43 (March 1953).
7. McFarland, R.A., Warren, A.B., and Karis, C., "Alterations in Critical Flicker Frequency as a Function of Age and Light-Dark Ratio." Jour. Exp. Psychol., 56: 529 (1958).
8. Copinger, N.W., "Relationships Between Critical Flicker Frequency and Chronological Age for Varying Levels of Stimulus Brightness." Jour. Gerontol., 10: 48 (1955).

9. Miles, P.W., "Flicker Fusion Fields I. The Effect of Age and Pupil Size. II. Technique and Interpretation." Amer. Jour. Ophthalm., 33: 769, 1069 (1950).
10. Bell, B., Harrison, R., Trotter, R.R., and Wolf, E., "Aqueous Dynamics, Scleral Rigidity and Field Studies in 107 Spanish-American War Veterans." Arch. Ophthalm. (submitted for publication).
11. Ludvigh, E., and Miller, J.W., "Studies of Visual Acuity during the Ocular Pursuit of Moving Test Objects. I. Introduction." Jour. Opt. Soc. Amer., 48: 799 (1958).
12. Miller, J.W., "Studies of Visual Acuity During the Ocular Pursuit of Moving Test Objects. II. Effects of Direction of Movement, Relative Movement and Illumination." Jour. Opt. Soc. Amer., 48:803 (1958).
13. McColgin, F.H., "Movement Thresholds in Peripheral Vision." Jour. Opt. Soc. Amer., 50: 774 (1960).
14. O'Hara, H., "Vision from a Moving Car." Acta Soc. Ophthal., 54: 320 (1950).
15. Feldhaus, J.L., Jr., "Dynamic Visual Acuity— Effect on Night Driving and Highway Accidents." HRB Bull. 298, 1-2 (1961).