Flicker Fusion, Dark Adaptation and Age as Predictors of Night Vision

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Dark adaptation and critical flicker fusion thresholds for 60 subjects ranging in age from 16 through 89 were obtained. A methodical analysis of the statistical interrelationship among dark adaptation thresholds and critical flicker fusion thresholds as function of surround, light/dark ratio, and age were systematically examined. The prediction of dark adaptation threshold at the 40th minute was significantly increased by certain critical flicker fusion data.

•THE THRESHOLD of dark adaptation and the rate at which it is achieved are two inexorably related phenomena underlying perception as a function of low levels of luminance. Although photopic thresholds are quickly restored by the presence of high light levels, scotopic sensitivity develops much more slowly. For example, it requires approximately 30 min to achieve 98 percent dark adaptation, but only a few seconds to return to photopic thresholds provided the retina is not "bleached." Thus, tasks that depend on rapid dark adaptation may exceed the capacity of the visual mechanism to adapt. This means that the respondent is more or less handicapped when required to perform precise tasks where luminance varies rapidly, intermittently, and irregularly over a wide range of intensity. It is well known that these are the characteristics of nighttime, especially in urban and highway environments.

The prediction of dark adaptation thresholds has infrequently been attempted, although it is known to vary as a function of several important conditions such as age, vitamin A deficiency, variations in light frequency, intensity and duration of pre-adaptation light conditions, and post-adaptation stimuli. The function, however, is unusually stable and, on occasion, is used as a clinical research tool, alone with the measurement of critical flicker fusion; but for purposes of prediction, few if any standards have been developed. As a consequence the clinical psychologist, physiologist, and physician have had no usable referent distributions available to assist them in locating any given individual in a population. It is suggested that a frame of reference would be useful for both clinical and experimental reasons.

Therefore, two sets of data (one of dark adaptation thresholds and one of critical flicker fusion thresholds) have been statistically examined to determine whether such data would be potentially useful for developing methods of predicting DA and CFF thresholds for individuals. The author's first exploration was published in the American Journal of Ophthalmology (1). In this experiment there were 240 male subjects ranging in age from 16 through 89 years. It was shown that, by combining DA thresholds obtained at 60-sec intervals from minute 2 through minute 9 with the ages of subjects in a multiple correlation technique, the DA threshold at the 40th minute was easily predicted by the obtained multiple R of 0.91. This is an unusually high value. The statistical properties of this sample indicated that it would be highly suitable for representing the larger population from which it was drawn, thus providing a functional frame of reference for

TABLE 1

CRITICAL FLICKER FUSION AND DARK ADAPTATION MEANS AND STANDARD DEVIATIONS FOR 64 SUBJECTS

Variable	Mean	Standard Deviation
Age(1)	53.0156	16.0317
Low surround LDR:		
2	36.5801	3.4418
3	38.7910	3.4760
4	40.3066	3.3718
5	40.9980	2.9825
6	40.4238	2.8202
7	39.8027	2.7283
8	35.1855	2.6919
9	27.2891	3.3418
10	19.5195	3.1805
11	10.5371	2.4997
High surround LDR:		
12	38.9336	3.4403
13	40.8016	3.3673
14	42.1875	3.3881
15	43.2676	3.0487
16	42.7246	2.7419
17	42.0586	2.7841
18	37.2246	2.6567
19	29.2266	3.5438
20	20.0781	3.8449
21	9.2793	2.2090
Dark adapt. threshold:		
22	6.8059	0.3283
23	6.4916	0.4683
24	6.2775	0.5486
25	6.1498	0.5950
26	5.9194	0.6133
27	5.6423	0.6321
28	5.4036	0.6727
29	5.1328	0.7133
30	4.7981	0.7533
31	4.5109	0.7674
32	4.2695	0.7825
33	4.0486	0.7693
34	3.8119	0.7534
35	3.6458	0.7419
36	3.5166	0.7024
37	3.4212	0.6670
38	3.3444	0.6550
39	3.3089	0.6527
40	3.3048	0.6529
41	3.3041	0.6509

TABLE 2
MULTIPLE CORRELATION (R) OF AGE, 20 CFF VARIABLE, AND 20 DARK ADAPTATION VARIABLES WITH THE 40th MINUTE DARK ADAPTATION THRESHOLD, THE CRITERION N = 64

Variable	df_1	Multiple R	SE(est)	F-Ratio	$1-R^2$	R^2	df_2
Age(1)		0.6899	0.4750	56.30	0.5241	0.4759	62
Low surround LDR:							
2/98	2	0.7161	0.4580	32.11	0.4872	0.5128	61
5/95	3	0.7213	0.4546	21.69	0.4797	0.5203	60
10/90	4	0.7406	0.4411	17.92	0.4515	0.5485	59
25/75	5	0.7452	0.4378	14.48	0.4447	0.5553	58
40/60	6	0.7453	0.4378	11.87	0.4446	0.5554	57
50/50	7	0.7459	0.4374	10.04	0.4436	0.5564	56
75/25	8	0.7766	0.4138	10.45	0.3969	0.6031	55
90/10	9	0.7892	0.4034	9.91	0.3771	0.6229	54
95/5	10	0.7915	0.4015	8.89	0.3735	0.6265	53
98/2	11	0.7920	0.4012	7.95	0.3728	0.6272	52
High surround LDR:							
2/98	12	0.7987	0.3955	7.49	0.3621	0.6379	51
5/95	13	0.7991	0.3953	6.79	0.3615	0.6385	50
10/90	14	0.7991	0.3953	6.18	0.3615	0.6385	49
25/75	15	0.8037	0.3914	5.84	0.3541	0.6459	48
40/60	16	0.8039	0.3913	5.37	0.3538	0.6462	47
50/50	17	0.8043	0.3910	4.96	0.3531	0.6469	46
75/25	18	0.8050	0.3905	4.60	0.3520	0.6480	45
90/10	19	0.8100	0.3860	4.42	0.3439	0.6561	44
95/5	20	0.8133	0.3832	4.20	0.3386	0.6614	43
98/2	21	0.8133	0.3832	3.91	0.3385	0.6615	42
Dark adapt. threshold at minute:							
2	22	0.8357	0.3600	4.38	0.2987	0.7013	41
3	23	0.8445	0.3529	4.33	0.2868	0.7132	40
4	24	0.8501	0.3472	4.23	0.2774	0.7226	39
5	25	0.8629	0.3333	4.43	0.2554	0.7446	38
6	26	0.8922	0.2979	5.56	0.2039	0.7961	37
7	27	0.8952	0.2941	5.38	0.1986	0.8014	36
8	28	0.9085	0.2759	5.91	0.1746	0.8254	35
9	29	0.9217	0.2562	6.62	0.1505	0.8495	34
10	30	0.9354	0.2336	7.70	0.1250	0.8750	33
12	31	0.9420	0.2218	8.14	0.1126	0.8874	32
14	32	0.9440	0.2181	7.94	0.1088	0.8912	31
16	33	0.9456	0.2152	7.69	0.1058	0.8942	30
19	34	0.9576	0.1908	9.41	0.0831	0.9169	29
22	35	0.9739	0.1504	14.72	0.0516	0.9484	28
25[a]	36						
28[a]	37						
31[a]	38						
34[a]	39						
37[a]	40						
40[b]	41						

[a] 25 - 37 not used because R is so high.
[b] To be predicted.

clinicians. A second study (2) of CFF as a function of age, two surround levels, and ten light/dark ratios suggested that these variables were intercorrelated. However, inasmuch as CFF is also used to test visual thresholds and measure elements of vision different from those measured by dark adaptation, the question has arisen as to relationship between the two phenomena. Therefore, data obtained from 64 subjects common to an extensive age study of CFF and the aforementioned dark adaptation study were examined.

The 64 subjects common to both studies were distributed in age from 21 through 88 years. Critical flicker fusion data were taken under two different surround levels using ten different light/dark ratios ranging from 98/2 to 2/98. Thus, there were twenty different CFF observations for each subject. There were also twenty dark adaptation thresholds obtained for each subject. Because the subject's age was known, 41 variables in all were available for analysis (see table 1 for variable means and SD's).

The 40th minute of dark adaptation was again chosen as the datum to be predicted. Then, an extensive 41-variable, multiple correlation was computed. Table 2 shows the order in which the variables were entered in the equation, the corresponding multiple R values, the associated, $SE_{(est)}$, F ratios, $1\text{-}R^2$ values, R^2, and the degrees of freedom at each level for n_1 and n_2.

The results show that age alone accounted for the greatest portion of the variance by far, inasmuch as R for the 40th minute and age alone was 0.70. The standard error of estimate was exceedingly small, and the F ratio extremely high, thus giving assurance that this R was highly significant. However, 0.70 is not sufficient for individual prediction of high accuracy. The next twenty variables, in successive order, were the twenty light/dark ratios under their respective high and low surround conditions. In all, they increase the R value from 0.70 to 0.8133. The LD ratios under low surround conditions account for nearly all of the increase. However, this reflected the effect of the order in which the variables were entered into the equation. Had the order been reversed, then the high surround data would have accounted for approximately the same degree of increase in R.

The ten dark adaptation thresholds were then introduced in order of time beginning with variable 22 in Table 1. The multiple R continued to rise. By using only the 7 values obtained during minutes 2 through 8 of the dark adaptation process, R was increased to 0.91. This magnitude is sufficient to allow predicting individual dark adaptation thresholds. The standard error of estimate for R = 0.91 was 0.26, which was very small. The 6.62 F ratio was large, thus assuring the significance of the correlation. The 6.62 F ratio, the $1\text{-}R^2$ value 0.17, and R^2 (0.82) show that R (0.91) was reliable for this sample and for the population from which the sample was drawn.

Not all the dark adaptation thresholds were used in the multiple regression equation. It was felt that, because R had risen to 0.97 with the 35th of 40 predictor variables, no further computations were necessary inasmuch as the obtained values accounted for nearly all the variance.

CONCLUSION

Combining critical flicker fusion observations and dark adaptation thresholds obtained from representative age samples yields data of such validity and reliability as to make prediction of individual performance possible to a highly accurate degree. Thus, developing statistical standards representative of the population would enhance the clinical usage of both these measures for experimental and diagnostic purposes.

REFERENCES

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