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MODIFICATION OF THE AMPLITUDE OF THE HUMAN ELECTRO-OCULOGRAM BY LIGHT AND DARK ADAPTATION*

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WHEN an electrode is placed on the cornea and another near the posterior pole of the eye (or elsewhere on the body) a standing potential is found (Kohlrausch, 1931; Marg, 1951). In vertebrates the cornea is positive in relation to the retina. The axis of this electrical system is approximately the same as the optic axis. If electrodes are placed near the eye and if the eye is turned, the electrode closest to the positive corneal pole will be positive in relation to the others. This recorded electro-oculographic response (EOG) depends on the angle and speed at which the globe rotates; it is independent of the action currents of the eye muscles, which are not recorded.

Fig. 1 shows a normal human EOG; the electrodes are placed round the left eye, and when the patient looks to the right (MR) this eye is adducted and electrode (1) on the nasal side becomes nearer to the cornea and positive to electrode (3) on the temporal side; we obtain also an upward deflexion on the derivation 1/3.

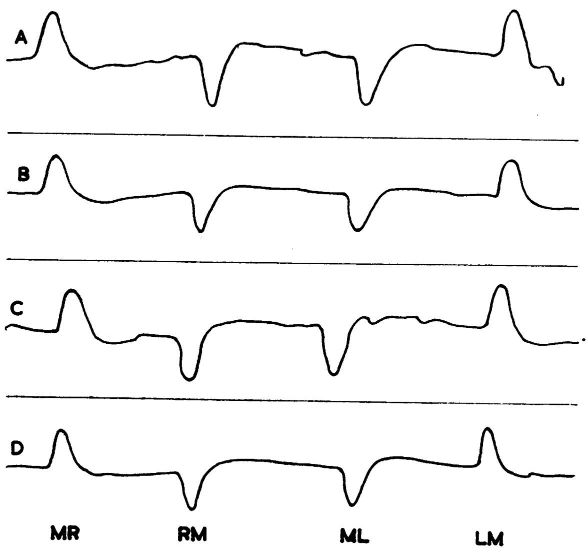

FIG. 1.—Electro-oculogram of Subject 2. Derivation 1/3.

A. Before light adaptation.
B. At the end of light adaptation (reduced).
C. At the beginning of dark adaptation (increased).
D. At the end of dark adaptation (again reduced).

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The only communication relating to the modification of the human EOG by light and dark adaptation is that of Miles (1940). According to this author, there is a statistically valid augmentation of 0·38 mV when the illumination of the subject varies from 0·001 to 5 mL†; each time the subject is submitted to a new illumination the amplitude of the EOG is modified for about 5 minutes and especially during the last 2 minutes.

We have, for two reasons, made a new study of the eventual relation between the amplitude of the EOG and the state of adaptation: first, because Miles's results are not in agreement with those of Wulff and Freyburger (1948) using animals (according to these authors, the standing potential of the excised eye of a frog augments during dark adaptation, as does the *b*-wave of the ERG), and secondly, because Miles based his experiments on levels of illumination and not on thresholds of perception.

Technique

Light and Dark Adaptation.—We used the Goldmann-Weekers adaptometer (2nd model). This apparatus consists chiefly of a hemisphere corresponding to the whole binocular visual field of the subject, who may thus be exposed to a global light adaptation which may be varied from 1,000 to 8,000 asb.

During dark adaptation, we determined the global thresholds for white light (integral adaptometry with contrast only in time; duration of the bright and dark phases: 1 sec.).

Electro-Oculography.—We used non-polarizable silver electrodes attached to the skin with collodion. The skin was cleansed with ether and contact was aided with commercial electrode jelly. Three electrodes were placed round the left eye:

(1) on the base of the nose near the inner canthus,

(2) on the inferior orbital margin, a little to the nasal side of the sagittal plane of the eye,

(3) on the temporal orbital margin, near the outer canthus.

A distant electrode (4) was placed on the occiput. At different stages of the experiments, the subject performed four successive ocular movements, as rapidly as possible:

(*i*) from the middle to the extreme right (MR),

(*ii*) from the extreme right to the middle (RM),

(*iii*) from the middle to the extreme left (ML),

(*iv*) from the extreme left to the middle (LM).

We used this technique in preference to limited excursions (*e.g.* 30°) because the results are more constant. As a control these movements were performed in an uninterrupted series. An ink-electroencephalograph was used for the registration.

Experiments.—With each subject we first took an EOG in moderate brightness, without pre-adaptation to dark or light (WA). Subjects 1, 2, and 3 were then light-adapted (2,000 asb. for 5 min.) and the eye movements were recorded immediately after the fifth minute (L 1). The subjects were subsequently dark-adapted under adaptometric control and the EOG was recorded at different levels

† 1 apostilb (asb) = 1·0 10^{-1} millilamberts (mL) = $\frac{1}{\pi}$ 10^{-4} stilb (sb, 1 cd/cm^2), if luminance and brilliance may be confused.

of adaptation, referred to in the Tables in log asb (D 2). The subjects were then again light-adapted and a new EOG was recorded (L 2).

During the examination of Subject 4 we added between WA and L 1 a supplementary recording in moderate dark adaptation without previous light adaptation (D 1); we also followed the course of modification of the EOG for a few minutes after L 2, with Subject 4 in moderate brightness (return to normal: RN). This RN was also tested with Subject 2.

During the examination of Subject 5, the EOG-modification during dark adaptation was measured, first without previous light adaptation (D 1), then after previous light adaptation of 2,000 asb. for 5 min. (B 2), and finally after previous dark adaptation of 4,000 asb. for 5 min. (D 3).

Results

The mean amplitudes of the deflexions of the EOG, all converted into μV, are given in Tables I to V and in Figs 2 to 7. The results concerning the " monopolar " derivations 1/4 (nasal) and 3/4 (temporal) and the " bipolar " derivation 1/3 are fully reproduced; we have calculated for each the absolute mean (*m*) and the fourth of the algebraic sum (δ) of the deflexions; theoretically δ must equal zero and the values given indicate errors due to irregularities of conduction and differences of amplitude of the movements. *M* is the mean of the two *m* corresponding to the " monopolar " derivations. The infra-orbital derivation 2/4 was only used to control the vertical components of the movements; we have given only the values of MR. The duration of the deflexions remained constant in all conditions and for all the subjects (almost 0·60 sec.); the amplitude of the deflexion is thus proportional to the resting potential, disregarding the extra-ocular factors.

Conclusions

(1) Light adaptation (2,000 asb, 5 min.) gives a decrease of amplitude of the electro-oculographic deflexions; after the end of a period in the dark, the deflexions become larger, so that the values are soon greater than before the light adaptation.

(2) Dark adaptation after light adaptation is characterized by a fall in the EOG-amplitudes, which begins immediately after the rise which follows the end of the light adaptation; it is very rapid at first and becomes progressively slower. At the end of the dark adaptation the EOG remains stationary or rises slightly, even if the perception threshold continues to decrease. One of the subjects was light-adapted successively at 2,000 and 4,000 asb., and the modifications of the EOG were the same after these two different pre-adaptations.

(3) If the subject was dark-adapted without preliminary light adaptation, the amplitude of the EOG-deflexions for a given threshold was markedly higher than when the subject was in the dark.

(4) In contrast to the *b*-wave of the ERG, there is no constant relation between the thresholds of perception and the relative amplitudes of the

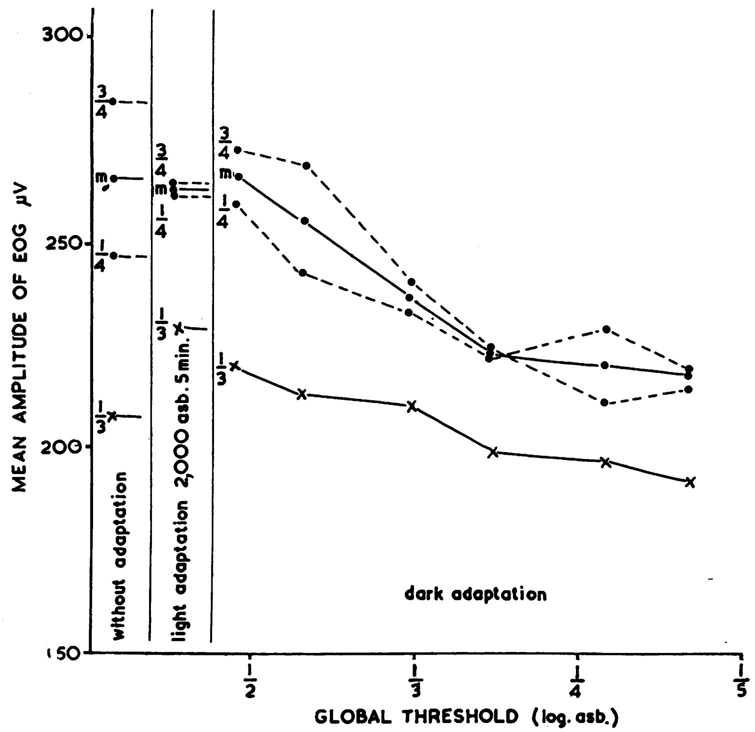

FIG. 2.—Subject 1.

TABLE I

SUBJECT 1

		W A	L 1	D 2					
				2·3 − 3·9	3·8 − 3·6	3·1 − 3·0	4·6 − 4·5	5·9 − 5·7	5·3
1/4	MR	+294	280	294	302	277	269	263	269
	RM	−255	235	286	252	244	224	218	190
	ML	−260	269	224	238	160	148	117	140
	LM	+305	269	280	286	280	258	249	266
	mean	*286*	*263*	*273*	*269*	*240*	*225*	*212*	*216*
	δ	+ 21	+11	+16	+24	+40	+40	+49	+51
3/4	MR	−235	255	255	207	211	187	198	176
	RM	+242	262	255	249	246	229	246	220
	ML	+262	301	279	268	242	242	246	251
	LM	−253	260	253	249	238	231	229	227
	mean	*248*	*264*	*261*	*243*	*234*	*222*	*230*	*218*
	δ	+ 4	+14	+6	+13	+10	+13	+17	+69
$\frac{1/4+3/4}{2}$	*M*	*267*	*264*	*267*	*256*	*237*	*223*	*221*	*217*
	δ	17	12	10	11	30	27	32	33
1/3	MR	+251	238	220	216	202	185	180	169
	RM	−187	205	202	191	196	185	180	174
	ML	−207	257	251	249	235	220	231	233
	LM	+189	220	213	198	207	205	196	194
	mean	*208*	*230*	*222*	*213*	*210*	*199*	*197*	*192*
	δ	+11	+1	−5	−6	−5	−4	−9	−11

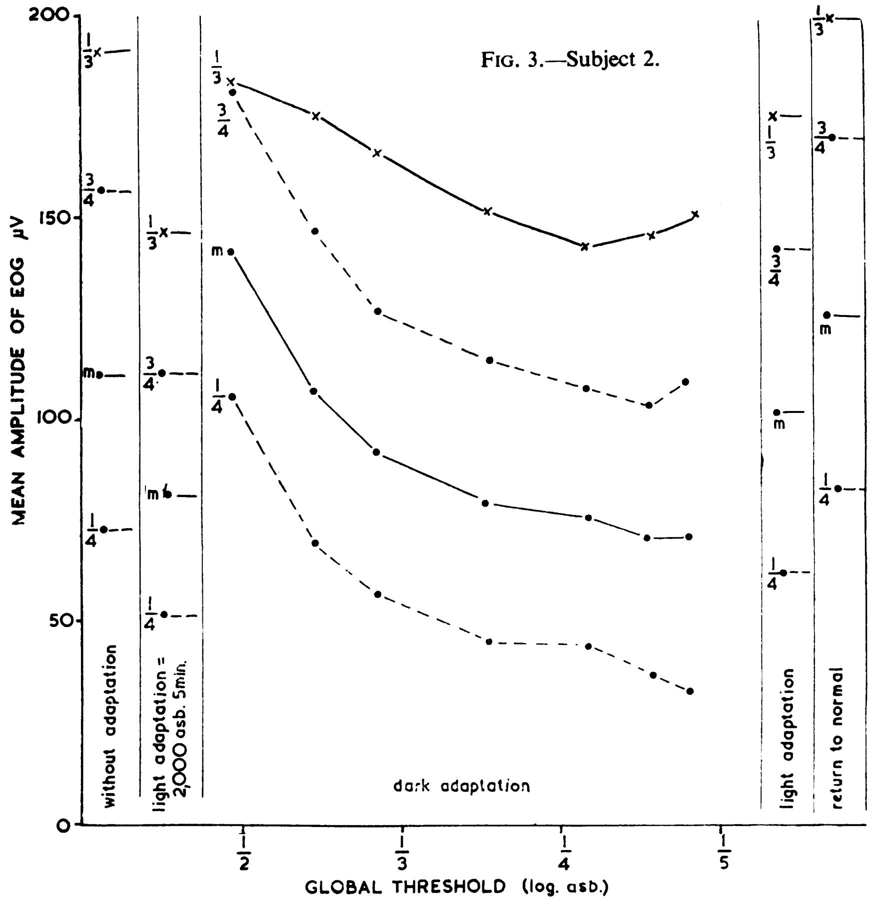

FIG. 3.—Subject 2.

TABLE II
SUBJECT 2

		W A	L 1	D 2							L 2	R N
				2·5 −3·8	3·6 −3·5	3·3 −3·0	4·7 −4·2	5·9 −5·7	5·6 −5·3	5·3 −5·2		
1/4	MR	+80	45	131	71	72	55	60	55	63	73	99
	RM	−60	36	108	93	53	45	41	46	33	58	73
	ML	−32	43	66	33	25	25	8	0	0	33	41
	LM	+116	81	116	76	81	55	65	45	33	33	116
	mean	*72*	*51*	*105*	*69*	*57*	*45*	*43*	*36*	*32*	*61*	*82*
	δ	+26	+12	+18	+5	+18	+10	+18	+14	+16	+4	+25
3/4	MR	−130	85	154	100	75	66	65	55	66	160	149
	RM	+166	158	201	183	153	140	133	133	123	171	183
	ML	+166	100	201	154	149	103	111	116	123	147	188
	LM	−156	103	164	149	129	149	120	110	123	146	159
	mean	*155*	*111*	*180*	*146*	*127*	*114*	*107*	*103*	*109*	*141*	*170*
	δ	+38	*+17*	+21	+6	+24	+7	+15	+21	+14	+3	+15
$\frac{1/4+3/4}{2}$	*M*	*113*	*81*	*142*	*108*	*92*	*80*	*75*	*70*	*70*	*101*	*125*
	δ	12	5	3	1	6	3	3	7	2	1	10
1/3	MR	+198	151	183	168	146	156	143	138	143	166	212
	RM	−196	149	176	168	172	153	143	149	154	183	191
	ML	−196	148	194	169	168	143	143	148	149	181	219
	LM	+173	143	166	166	179	153	143	148	167	166	171
	mean	*190*	*146*	*180*	*175*	*166*	*151*	*143*	*146*	*151*	*174*	*198*
	δ	−5	−1	−5	−1	−4	+4	0	−3	+1	+8	−7
2/4	MR	83	81	78	83	78	50	63	63	63	83	90

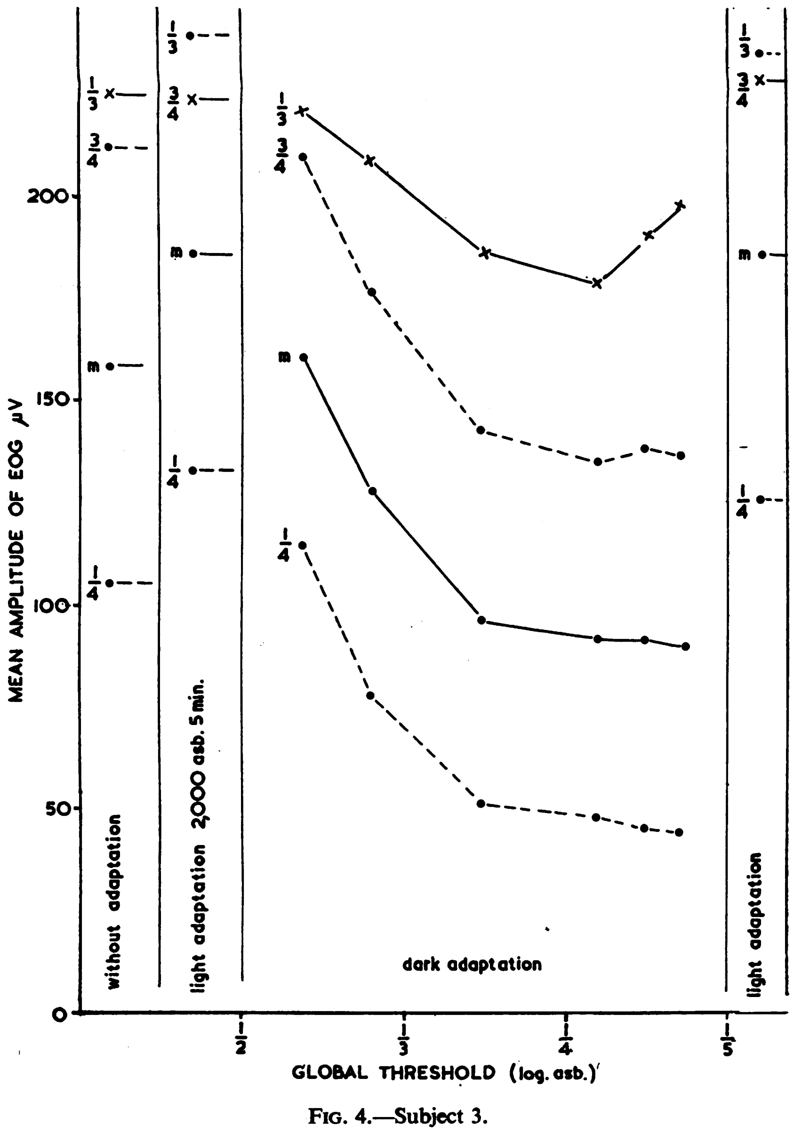

FIG. 4.—Subject 3.

TABLE III
SUBJECT 3

		W A	L 1	D 2						L 2
				3·6	3·2	4·5	5·8	5·5	5·3	
1/4	MR	+100	138	110	68	50	54	46	52	118
	RM	− 72	40	54	28	0	0	22	16	84
	ML	+ 94	140	132	90	76	50	52	60	154
	LM	+154	214	156	126	82	88	60	50	192
	mean	*105*	*133*	*113*	*78*	*52*	*48*	*45*	*44*	*137*
	δ	+22	+43	+20	+19	+14	+23	+8	+6	+18
3/4	MR	−176	198	156	116	66	66	96	98	216
	RM	+246	254	236	194	143	124	128	152	240
	ML	+228	274	244	214	200	188	166	152	274
	LM	−194	232	204	186	164	166	164	146	212
	mean	*211*	*239*	*210*	*177*	*143*	*136*	*138*	*137*	*235*
	δ	+26	+25	+30	+26	+28	+20	+8	+15	+21
(1/4+3/4)/2	*M*	*158*	*186*	*161*	*128*	*97*	*92*	*92*	*90*	*186*
	δ	4	18	10	7	14	3	0	9	3
1/3	MR	+252	254	250	210	156	156	214	200	272
	RM	−200	190	194	184	150	132	154	176	182
	ML	−208	222	206	204	210	192	194	192	228
	LM	+240	232	236	240	228	234	200	224	234
	mean	*225*	*224*	*221*	*209*	*186*	*178*	*190*	*198*	*229*
	δ	− 21	+18	+21	+16	+6	+17	+17	+14	+24
2/4	RM	134	152	158	112	76	72	86	78	204

TABLE IV
SUBJECT 4

		W A	D 1 5·8 −5·3	L 1	D 2							L 2	R N
					2·2 −3·8	3·6 −3·3	4·8 −4·7	4·6 −4·5	4·2 −4·0	5·9 −5·6	5·5		
1/4	MR	+139	119	145	191	178	142	99	73	56	53	165	191
	RM	−129	82	79	139	178	125	63	69	106	102	148	149
	ML	−106	62	30	82	95	40	36	16	23	0	49	92
	LM	+234	135	165	221	181	122	109	96	66	73	145	191
	mean	*152*	*99*	*105*	*158*	*158*	*107*	*77*	*63*	*62*	*57*	*127*	*156*
	δ	−82	+28	+22	+48	+21	+25	+27	+21	−2	+6	+3	+35
3/4	MR	−168	158	139	277	251	184	125	109	72	63	165	264
	RM	+254	191	241	333	301	195	198	135	165	132	251	370
	ML	+280	208	211	254	280	195	158	122	132	125	185	287
	LM	−264	235	238	287	261	247	224	188	221	211	247	307
	mean	*241*	*198*	*207*	*288*	*273*	*205*	*173*	*138*	*148*	*132*	*212*	*307*
	δ	+25	+1	+18	+6	+17	−10	+2	−9	+1	−4	+6	+21
(1/4+3/4)/2	*M*	*196*	*148*	*156*	*223*	*215*	*156*	*125*	*100*	*105*	*95*	*169*	*231*
	δ	16	27	4	42	4	35	25	30	1	10	3	14
1/3	MR	+290	274	254	323	304	284	228	185	172	158	205	316
	RM	−260	231	257	271	297	251	224	200	241	214	284	312
	ML	—303	274	274	297	297	261	221	165	148	165	238	288
	LM	+297	271	288	287	271	270	264	208	251	251	257	296
	mean	*288*	*262*	*278*	*294*	*292*	*266*	*234*	*189*	*203*	*172*	*246*	*328*
	δ	+6	+10	+2	+11	−5	+10	+12	+7	+8	+7	+15	+28
2/4	MR	82	96	30	79	99	46	90	0	0	0	92	33

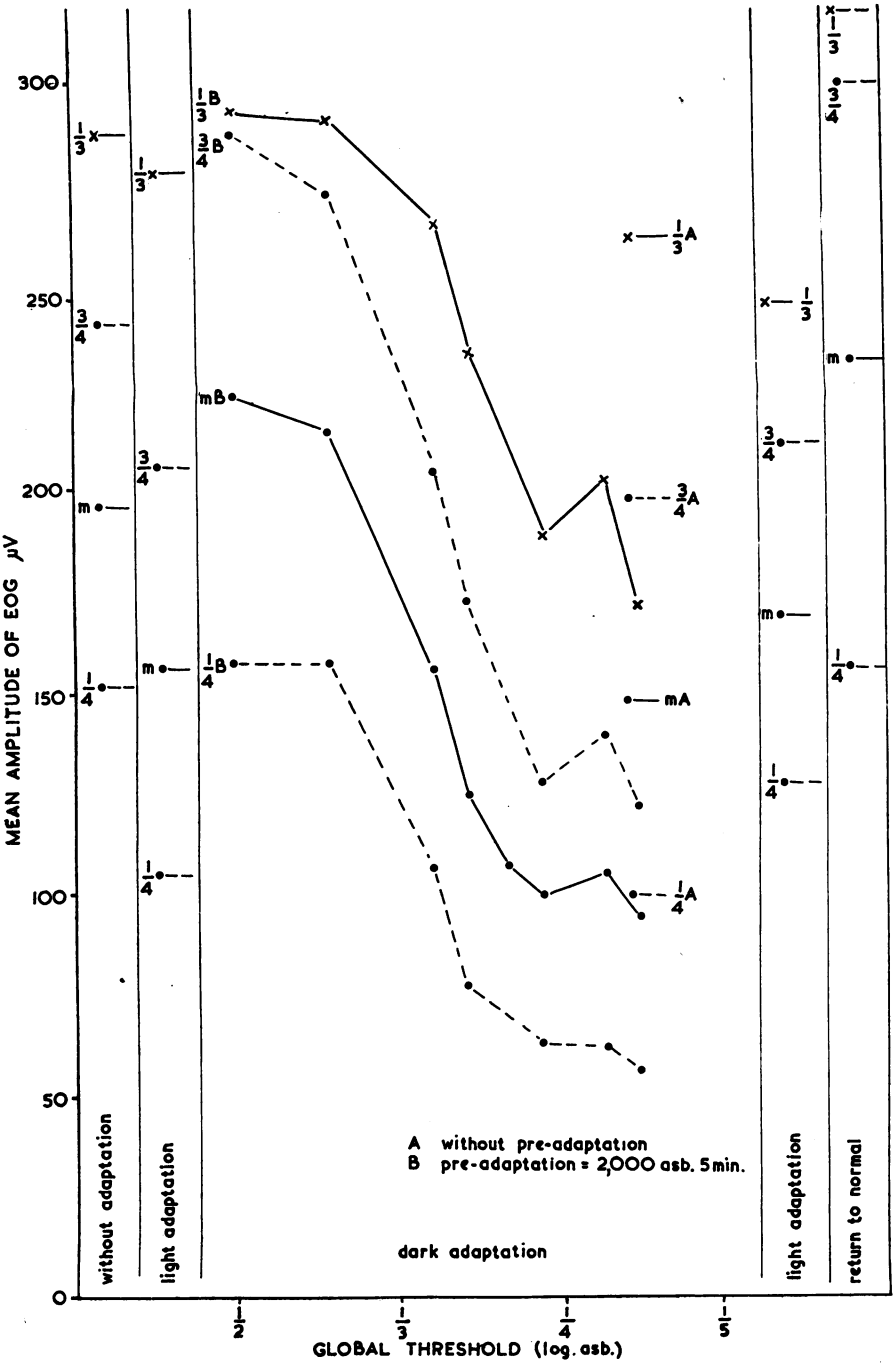

FIG. 5.—Subject 4.

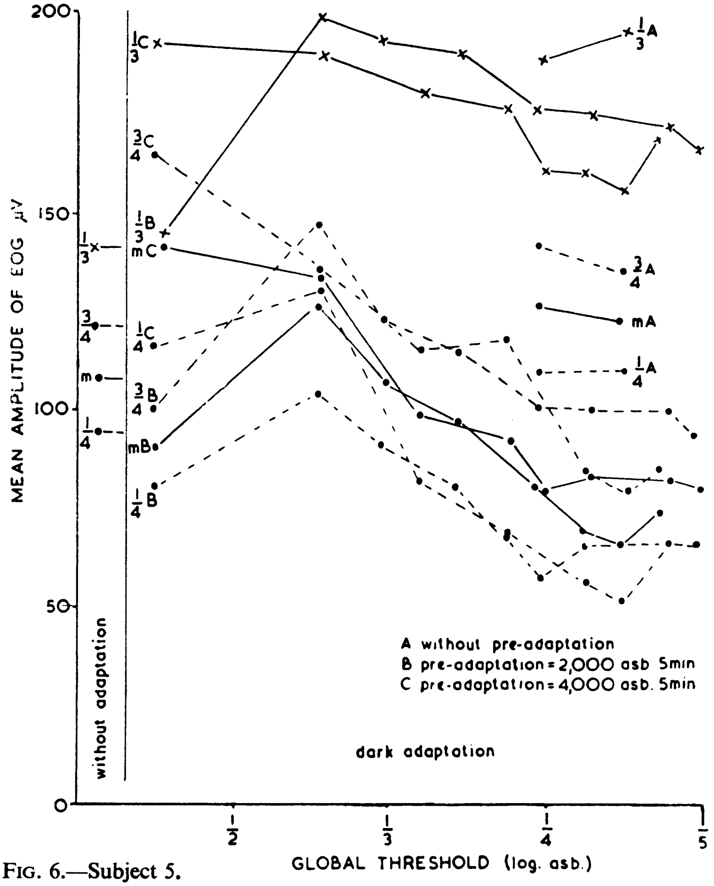

FIG. 6.—Subject 5.

TABLE V

		W A	D 1		D 2				
			4·2–5·9	5·6–5·4	2·8–2·2	3·6–3·3	3·1–3·0	4·6–4·5	4·2–5·9
1/4	MR	+110	129	129	112	110	110	98	81
	RM	−93	96	108	80	106	103	70	63
	ML	−50	89	78	86	86	65	63	33
	LM	+123	116	120	129	115	83	88	56
	mean	*93*	*108*	*109*	*80*	*104*	*90*	*79*	*58*
	δ	+28	+15	+16	+19	+8	+6	+13	+10
3/4	MR	−73	109	100	121	131	100	86	65
	RM	+123	166	153	150	153	117	108	93
	ML	+157	161	161	163	166	156	150	129
	LM	−133	129	123	129	129	117	112	115
	mean	*121*	*141*	*134*	*100*	*145*	*122*	*113*	*100*
	δ	+18	+19	+22	+8	+15	+14	+15	+11
(1/4+3/4)/2	*M*	*108*	*125*	*121*	*90*	*125*	*106*	*96*	*79*
	δ	10	4	6	11	7	8	2	2
1/3	MR	+197	189	180	198	194	192	197	170
	RM	−166	181	191	179	198	188	177	170
	ML	−209	211	207	214	219	214	214	195
	LM	+189	166	197	180	179	164	168	163
	mean	*190*	*187*	*193*	*139*	*198*	*192*	*189*	*174*
	δ	+3	−9	−5	−4	−9	−11	−6	−8
2/4	MR	88	31	0	12	20	25	25	25

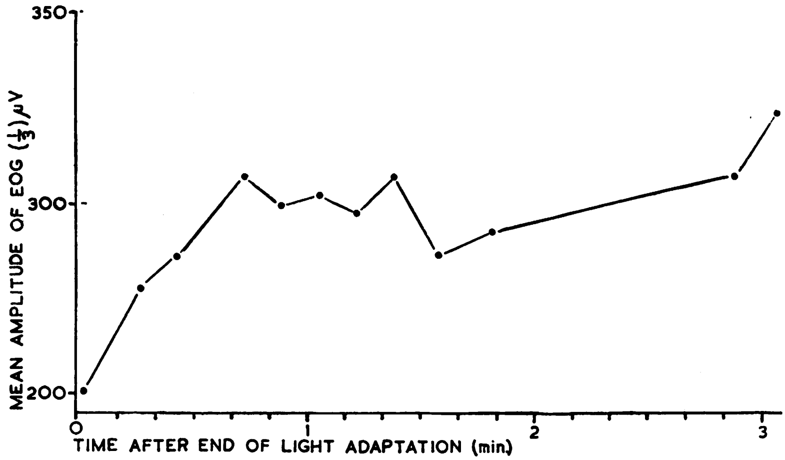

FIG. 7.—Modification of amplitude of EOG after the end of light adaptation (Subject 4).

SUBJECT 5

			D 3						
5·8—5·4	5·3—5·1	5·1	2·8—2·2	3·6—3·2	4·9—4·7	4·3—4·2	5·8—5·7	5·4	5·3
100	86	65	156	153	119	92	70	63	70
38	70	70	100	76	67	55	46	58	53
65	36	50	54	166	55	32	20	16	53
61	65	71	153	119	86	44	85	66	85
66	*64*	*64*	*116*	*128*	*82*	*68*	*55*	*51*	*65*
+14	+11	+ 4	+39	+8	+21	+25	+22	+14	+12
60	61	55	136	119	80	81	51	50	50
84	96	75	192	154	111	114	78	66	75
129	128	129	197	172	151	136	104	118	116
119	106	111	129	131	119	133	100	84	86
98	*98*	*92*	*163*	*144*	*115*	*116*	*83*	*79*	*82*
+8	+16	+22	+28	+18	+16	+9	+9	+12	+15
82	*81*	*78*	*140*	*136*	*98*	*92*	*69*	*65*	*73*
6	5	18	11	10	5	16	12	2	0
166	164	146	186	207	179	163	154	144	154
153	166	154	189	163	177	169	148	146	143
195	200	190	230	214	198	191	167	169	181
181	154	166	166	166	163	171	166	158	158
173	*170*	*164*	*192*	*188*	*179*	*176*	*158*	*154*	*159*
0	−12	−8	−17	−1	−8	−6	+1	−3	−3
25	25	80	32	16	16	0	0	0	0

EOG; since it is not possible to measure a true perception threshold without removing the adapting surrounding light, the study of the possible relation between the value of the resting potential and the threshold by means of EOG encounters insurmountable difficulties which are certainly partly due to non-controllable psychogalvanic reflexes.

(5) It is recommended that the EOG should be used clinically in testing the motility of the eyes or as a functional test of the retina; it should be used in moderate brightness, without previous dark or light adaptation.

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