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PILOT VISION CONSIDERATIONS:

The Effect of Age on Binocular Fusion Time

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When a person looks at one object that is nearer to him than six meters, other objects at other distances are out of focus and appear double. When the gaze is directed to objects that are more than six meters distant, objects that are nearer than six meters appear double and are out of focus. Singularity of vision in people with two functional eyes occurs because (1) the visual axes of their eyes can be aligned so that similar images fall on corresponding parts of their retinas or (2) vision is suppressed in one eye when the visual axes cannot be properly aligned. In the latter case images fall on non-corresponding parts of the retinas and double vision results unless suppression occurs.

Binocular single vision is attained at a cost of the time necessary for proper alignment of the visual axes. The time required for such alignment is a component of total reaction time and occupies a certain primacy when an action is to be initiated. That is, before a person can initiate an appropriate reaction to a stimulus, he must sense and understand that stimulus. A good example is a situation in which a pilot shifts his gaze from the empty sky to his instrument panel. Before any of the instruments are meaningful to him he must focus and converge his eyes on them.

Clinical determinations of "ocular motility" in reality are determinations of the extent and direction of visual axis deviation and the ability to accomplish fusion. The cover test gives the examiner some appreciation of rate of fusion but no objective measure of it.

Brecher (2) has described a method for the quantitative determination of the time necessary for an individual to accomplish fusion. The method involved the interrupted presentation of a light to one eye and the steady presentation of that light to the other eye. When heterophoria was present, diplopia occurred; reflex fusion was slowed depending upon the rate and duration of presentation of the light to the covered eye. The slowed fusional process was easily measured with an electric timer. It was also possible to produce standard displacement of the image of the light with crossed Risley rotary prisms. Fatigue had little effect on binocular fusion time until virtual exhaustion occurred, at which time fusion was broken up and diplopia resulted (4). Caffeine and dexadrine afforded subjective relief of fatigue symptoms but did not improve fusion time. These workers also found that barbiturates interfered with binocular fusion by slowing the fusion reflex time and not by increasing heterophoria (4). At high blood alcohol levels the eyes tended to assume a rest position with the visual axes crossing at about 82 cm. These alcohol-intoxicated subjects were esophoric when tested with an object six meters away and exophoric when tested with an object at 33 cm (3).

Bennett, Wells, Binder, and Brecher (1) compared the subjective method of interrupted stimulus presentation with an objective motion picture method. These workers found good agreement between the two methods and further found that fusion time was not necessarily related to the extent of heterophoria. Some subjects with large phorias fused more rapidly than others with small phorias. They also found that subjective fusion could occur at different vergences, as objectively measured, because of the extent of Panum's Area.

The work cited above shows that the time necessary for a person to accomplish binocular fusion is affected by fatigue, drugs, and alcohol. The purpose of the investigation reported here is to determine to what extent the binocular fusion reflex is affected by age.

METHODS AND RESULTS

The method employed was, in principle, the same as described by Brecher (2). The measurement device consisted essentially of a rotating cylindrical shutter slotted on two sides. The cylinder was driven by an electric motor and geared to rotate at a rate of 2.5 rps, thus yielding an exposure rate of 5 per sec. The measured duration of each exposure was 0.09 sec. Crossed Risley rotary prisms were mounted in a metal tube which was fitted to the front of the shutter housing so that the target image could be positioned as desired. An iris diaphragm shutter was positioned behind the cylindrical shutter to act as an occluder. The diaphragm shutter was opened by a wire connected to a push-button and closed by a spring. A switch controlling a 0.01 second timer was wired to the same push-button so that the timer was started at the instant the occluder shutter was opened (Fig. 1).

The fixation target was a white light positioned in a hole at the center of a black screen 30 × 40 cm in size. The board was marked off with white plastic tape into 5 cm squares. All measurements were made at an observation distance of 6 meters.

For determinations of their binocular fusion times, the subjects were seated at a table to which was clamped the headrest and shutter assembly. The subject was made comfortable with his head positioned in the headrest and with his right eye centered in the open aperture of the occluder shutter. A rubber bite piece was used to assure reproducibility of head position. The occluder shutter was then closed and the cylindrical shutter set into rotation. The subject was allowed to fixate with his left eye while his right eye was occluded for 30 seconds. He was then requested to open the occluder shutter by pressing the switch button momentarily and to report the position of the "second light" in terms of squares to the right or left and above or below the center line. The rotary prisms were turned appropriately to displace the "second light" to the desired extent and direction. The extent of displacement was tested by repeated trials until variability was minimal.

Trials were made at one, two, and three squares of lateral displacement in each direction. Ten determinations were made at each setting. The endpoint of each determination was the subject's appreciation of singleness of the light. The eccentric light appeared to "hop" with each exposure toward the center steady light. When the "two lights" became "one light", the subject released the switch button, thus stopping the timer and simultaneously closing the occluding shutter.

Subjects selected to have good vision in both eyes were recruited by the University of Oklahoma Research Institute. They were paid subjects with only casual interest in the experiment. Eye dominance, visual acuity with correction in both eyes (Snellen chart), and heterophoria (Maddox rod) were determined. The instructions given to each subject were standardized and kept at the minimum consistent with their understanding of their duty. A learning period was necessary, however, in order to be certain that the subjects were seeing the phenomenon that was being measured. When they could describe with alacrity what had transpired during a trial, readily detect changes in prism settings, and when the times necessary for fusion became consistent within limits, the subjects were considered to be ready for experimentation.

Subjects were selected to fall into two age groups, those between the ages of 25 and 30 and those between 45 and 60. Eight subjects were studied in each group. Table I shows the distribution of the subjects with regard to age, eye dominance, visual acuity and heterophoria.

Figure 2 shows that the average fusion time increases with the extent of image displacement in both age groups. Table I shows the individual averages of fusion times and affirms that in all cases fusion time increases with increasing image displacement. The rate of fusion, expressed as squares per second, is fairly constant, however (Table II and Fig. 4). Fusion rate is uniformly slower in the older group than it is in the younger group. Figure 4 also shows that fusion rate was consistently less when the

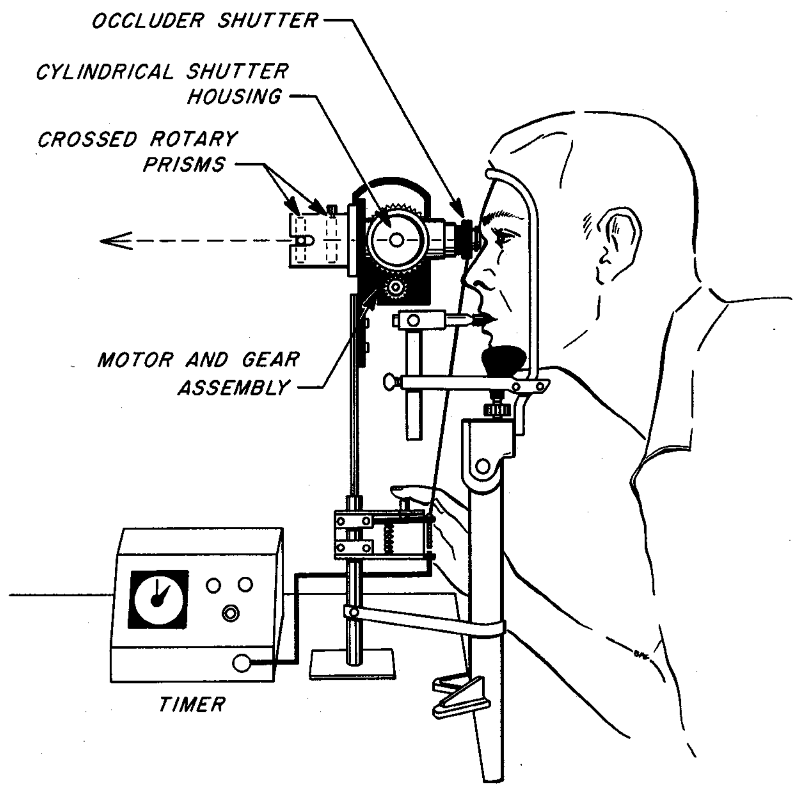
OCCLUDER SHUTTER
CYLINDRICAL SHUTTER HOUSING
CROSSED ROTARY PRISMS
MOTOR AND GEAR ASSEMBLY
TIMER

Fig. 1

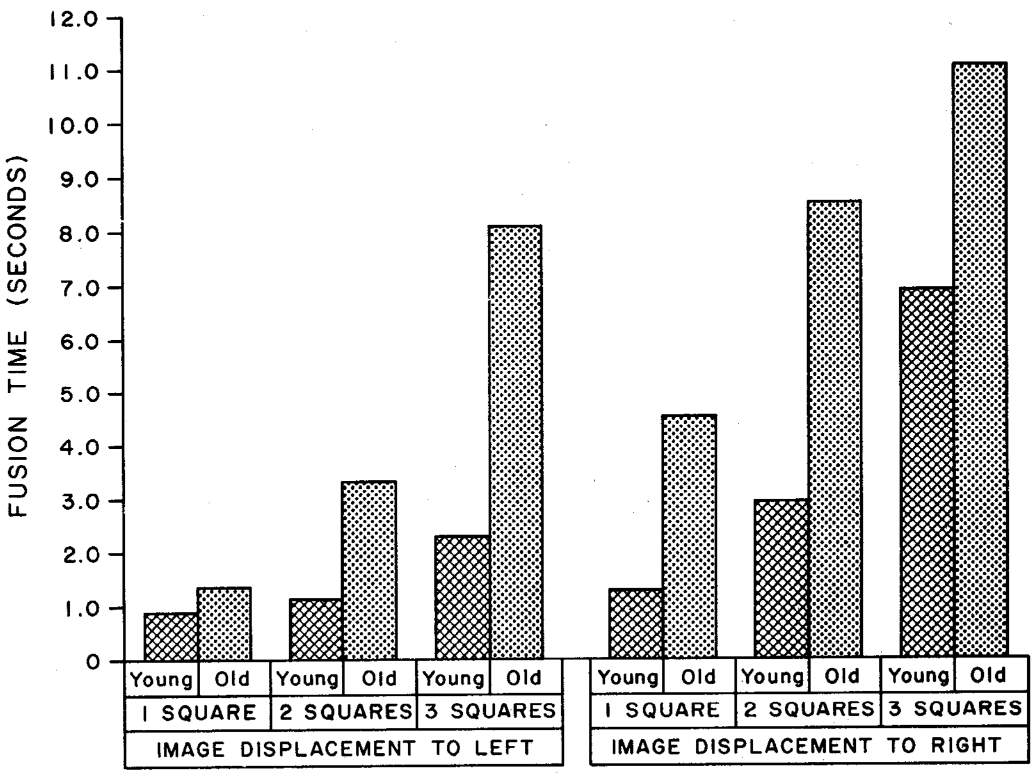
FUSION TIME (SECONDS)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
Young
Old
1 SQUARE
2 SQUARES
3 SQUARES
IMAGE DISPLACEMENT TO LEFT
IMAGE DISPLACEMENT TO RIGHT

Fig. 2

TABLE I

SUBJECT	AGE	HETERO-PHORIA	EYE DOMI-NANCE	ACUITY (WITH CORRECTION)	FUSION TIMES (SEC) IMAGE DISPLACEMENT TO LEFT			IMAGE DISPLACEMENT TO RIGHT		
					1	2	3	1	2	3
RW	25	1ΔD EXO	R	R 20/20 L 20/20	0.75	1.08	1.38	1.15	2.60	4.89
LR	26	0	R	R 20/20 L 20/20	0.54	0.67	1.05	0.76	1.07	1.79
JF	27	0	R	R 20/20 L 20/20	0.74	0.95	1.31	0.88	1.38	12.98
TP	27	0	R	R 20/20 L 20/20	0.92	1.22	1.69	1.68	2.65	5.97
DW	28	1ΔD ESO	R	R 20/20 L 20/20	1.28	2.49	7.98	2.35	7.12	11.78
JA	29	1ΔD EXO	L	R 20/20 L 20/20	0.70	1.00	1.17	1.09	3.06	6.25
RC	29	0	R	R 20/20 L 20/20	0.84	1.36	2.23	2.03	4.67	9.45
WM	29	0	R	R 20/20 L 20/20	065	0.94	1.36	0.63	0.96	1.59
AVERAGE					0.80	1.21	2.27	1.32	2.94	6.84
EA	46	0	L	R 20/20 L 20/20	1.44	3.25	10.27	10.55	No Fusion	No Fusion
OF	47	1ΔD EXO	L	R 20/25 L 20/20	0.75	0.89	1.37	4.48	9.90	19.45
RM	47	1ΔD EXO	R	R 20/20 L 20/25	0.69	0.95	1.59	1.68	3.55	No Fusion
NY	49	0	R	R 20/30 L 20/20	0.99	2.73	8.69	5.72	16.36	No Fusion
GI	50	0	R	R 20/20 L 20/20	2.94	9.75	17.40	2.67	10.17	11.75
FA	55	0	R	R 20/20 L 20/20	0.98	2.16	6.30	5.49	3.80	No Fusion
EW	56	3ΔD EXO	R	R 20/20 L 20/20	1.48	2.06	2.68	1.50	1.40	1.94
EF	59	1ΔD EXO	R	R 20/20 L 20/25	1.15	5.05	16.03	4.40	14.17	No Fusion
AVERAGE					1.30	3.35	8.04	4.56	8.48	11.75

TABLE II

RATE OF FUSION (SQUARES/SEC)

SUBJECT	AGE	IMAGE DISPLACEMENT TO LEFT			IMAGE DISPLACEMENT TO RIGHT		
		1	2	3	1	2	3
RW	25	1.32	1.85	2.17	0.87	0.77	0.61
LR	26	1.85	2.98	2.86	1.32	1.87	1.68
JF	27	1.35	2.11	2.29	1.14	1.45	0.23
TP	27	1.09	1.64	1.78	0.60	0.75	0.50
DW	28	0.78	0.80	0.38	0.43	0.28	0.25
JA	29	1.43	2.00	2.56	0.92	0.65	0.48
RC	29	1.19	1.47	1.35	0.49	0.43	0.32
WM	29	1.54	2.13	2.21	1.60	2.09	1.89
AVERAGE		1.32	1.87	1.95	0.92	1.04	0.75
EA	46	0.69	0.62	0.29	0.09	No Fusion	No Fusion
OF	47	1.37	2.25	2.19	0.22	0.20	0.15
RM	47	1.45	2.11	1.89	0.60	0.56	No Fusion
NY	49	1.01	0.73	0.35	0.17	0.12	No Fusion
GI	50	0.34	0.21	0.17	0.37	0.20	0.26
FA	55	1.02	0.93	0.48	0.18	0.53	No Fusion
EW	56	0.68	0.97	1.12	0.67	1.43	1.55
EF	59	0.87	0.40	0.19	0.23	0.14	No Fusion
AVERAGE		0.93	1.03	0.84	0.32	0.45	0.65

image was displaced to the right than when it was displaced to the left.

On the average, the fusion times at all image displacements for the older group were longer than those of the younger group for equal displacements. Table I shows that there is overlap of the individual values in the two groups, however. The differences in fusion times between the two age groups became more pronounced as the extent of image displacement was increased (Figs. 2 and 4, Tables I and II). All of the young group accomplished fusion of images at least one time at all displacements. In the older group, however, only three could accomplish fusion when the displaced image was three squares to the right (Fig. 3). One of the older subjects ceased fusing when image displacement was two squares to the right. A comparison of mean squares revealed the largest source of variation to be between the two age groups (759.40). The second largest source of variance was between subjects within the two groups (244.70). The data further reveal that experimental design can be improved in future experiments by reducing both the number of runs, the number of readings, and the number of repeat visits on different days.

DISCUSSION

One of the primary characteristics of the aging process is a loss of skeletal musculature. Where these muscles are normally concerned with movement of bony levers, some of this loss of muscle might be related to the "rigors

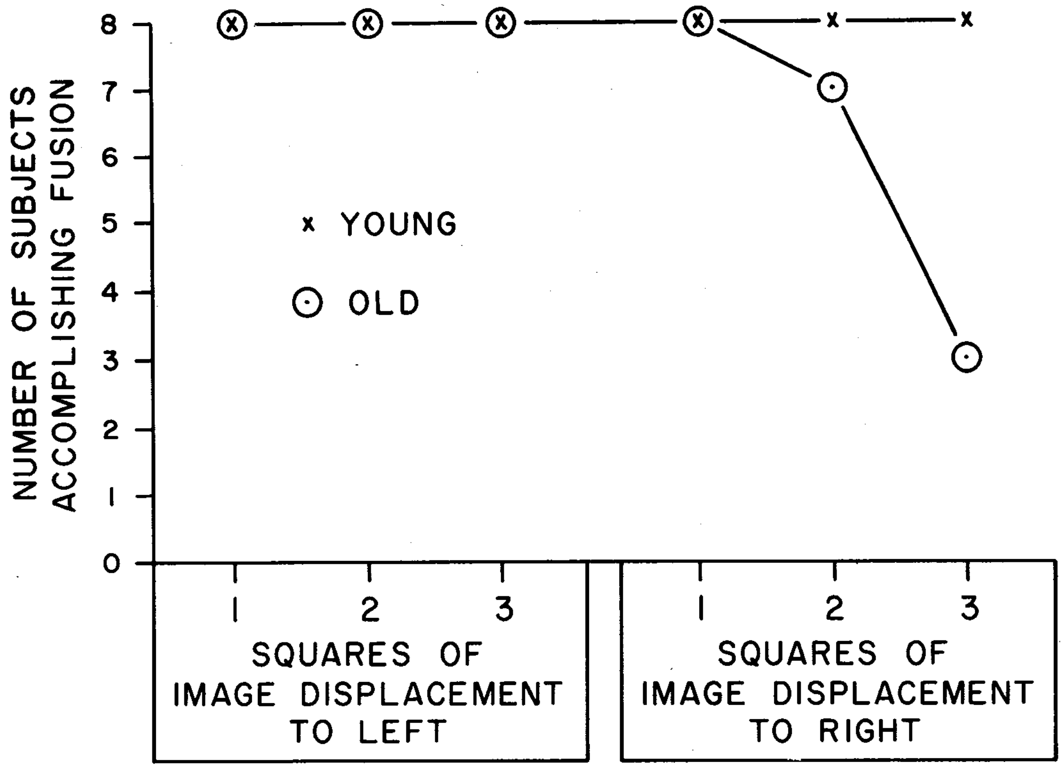
NUMBER OF SUBJECTS ACCOMPLISHING FUSION
8
7
6
5
4
3
2
1
0
x YOUNG
⊙ OLD
1
2
3
SQUARES OF IMAGE DISPLACEMENT TO LEFT
1
2
3
SQUARES OF IMAGE DISPLACEMENT TO RIGHT

Fig.3

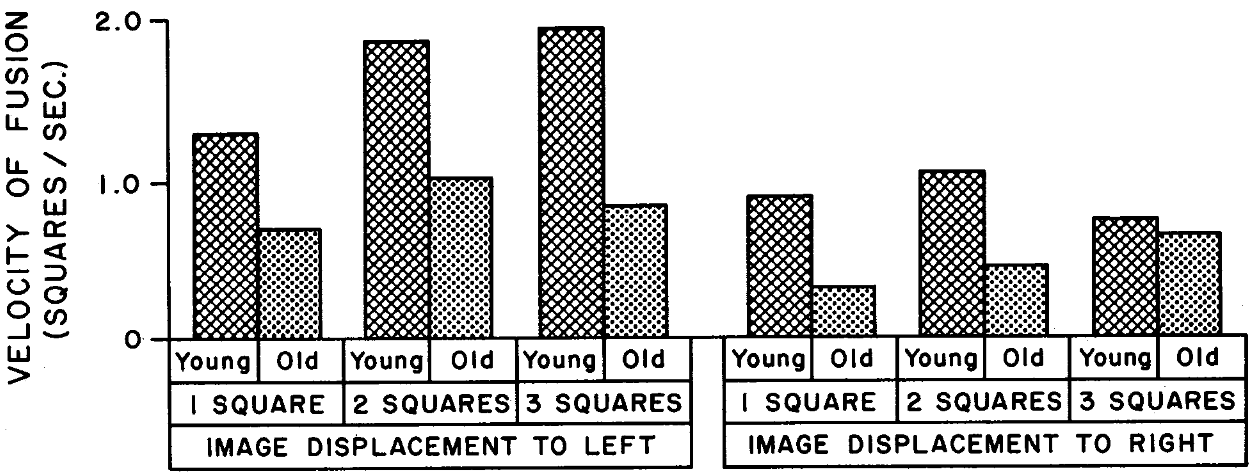
VELOCITY OF FUSION (SQUARES / SEC.)
2.0
1.0
0
Young
Old
Young
Old
Young
Old
1 SQUARE
2 SQUARES
3 SQUARES
IMAGE DISPLACEMENT TO LEFT
Young
Old
Young
Old
Young
Old
1 SQUARE
2 SQUARES
3 SQUARES
IMAGE DISPLACEMENT TO RIGHT

Fig. 4

of life." The extraocular muscles however, are largely protected from trauma and do about the same amount of work day in and day out. In short, these muscles might make a contribution toward answering the question of whether the loss of muscle with age is due to wear or is a symptom of the aging process itself. This question has been considered from a histochemical point of view by Dogliotti (7), and Kny (9) on skeletal muscles, Lowry, et al (10) on heart and skeletal muscle, and Jayne (8) on heart. These workers showed the presence of "aging pigments" in muscles taken from senescent individuals. Bucciante and Luria (5), more directly pertinent to the subject of this report, showed that the average diameter of extraocular muscle fibers increased from 16μ in men less than 40 years of age to 23μ in men 80 or more years of age. The suggestion was that the increase in muscle fiber diameter represented hypertrophy in compensation for degeneration or atrophy of other fibers. The degeneration appeared to consist of myofibrillar intertwining and eventual distintegration.

Cowdry (6) states that, while the amplitude of convergence decreases and the extent of exophoria increases with age, there is no evidence for a weakening of extraocular muscles. The evidence put forward in this report suggests that such a weakening of the extraocular neuromusculature does in fact occur with age. This weakening is manifested in a lessened ability to fuse when the image is displaced and by the reduced speed of fusion in the older group.

Both groups exhibited a decreased fusional ability, as reflected by fusion time and fusion rate, when the image was displaced to the subject's right, though the effect was less pronounced in the young group. It must be recalled that the situation in these experiments does not duplicate heterophoria; the image of the target light was only prismatically displaced on the retina. The visual axis was not affected. This means that an individual would actually have to diverge his visual axes in order to fuse an image displaced onto a noncorresponding part of his nasal retina. A neuromuscular mechanism for active divergence of the visual axes beyond the rest position is not recognized to exist. The demonstration in these experiments, however, of fusion of images displaced to the subjects' right (nasal retina) may represent a slight ability to diverge the axes, at least enough to bring the images onto Panum's Areas of the two eyes. The deterioration of the ability to fuse right-displaced images in the older group may constitute a test for neuromuscular aging.

SUMMARY

1. Binocular fusion time increases with the extent of image displacement. The rate of fusion of any individual, however, is not markedly affected by the extent of image displacement.
2. Young men (25-30 years of age) accomplish fusion faster than older men (45-60 years of age).
3. Fusion time is greater (velocity less) when divergence of the visual axes is necessary to accomplish fusion than when convergence is called for. The 25-30 year old group could execute such divergent fusional movements faster than the 45-60 year old group. Further, five of the eight members of the older group failed to fuse when the apparent image was laterally displaced to the subjects' right whereas none of the younger group failed to fuse under these circumstances.

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