US ARMY
MEDICAL RESEARCH LABORATORY
FORT KNOX, KENTUCKY 40121

REPORT NO. 984

VISION: MONOCULAR, BI-OCULAR, BINOCULAR

(Interim Report)

by

George S. Harker, Ph.D.

5 June 1972

Approved for public release; distribution unlimited.

**UNITED STATES ARMY
MEDICAL RESEARCH AND DEVELOPMENT COMMAND**

AD ____________________

REPORT NO. 984

VISION: MONOCULAR, BI-OCULAR, BINOCULAR

(Interim Report)

by

George S. Harker, Ph.D.

US ARMY MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky 40121

5 June 1972

Military Performance:
Psychophysiology of Vision
Work Unit No. 085
Physiology
Task No. 08
Basic Research in Support of Military Medicine
DA Project No. 3A061102B71P

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Medical Research Laboratory Fort Knox, Kentucky 40121	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

VISION: MONOCULAR, BI-OCULAR, BINOCULAR

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Report

5. AUTHOR(S) (First name, middle initial, last name)

George S. Harker, Ph.D.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
5 June 1972	9	10

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 3A061102B71P c. Task No. 08 d. Work Unit No. 085	9a. ORIGINATOR'S REPORT NUMBER(S) 984 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY US Army Medical Research and Development Command, Washington, D. C. 20314

13. ABSTRACT

Psycho-visual problems associated with utilization of monocular, bi-ocular, and binocular visual systems are reviewed in the context of present knowledge. It is noted that simply because an instrument has been designed to be binocular, it is not necessarily so used by an observer. A binocular is frequently a bi-ocular and is often a monocular as it is employed. The ultimate variable that determines which mode of functioning is used lies within the visual system and has not as yet been identified. It is concluded that the design of binocular optical instruments with specificity to their mode of use cannot be achieved until basic research has identified this aspect of the visual system and the variables which control its function.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Monocular						
Bi-ocular						
Binocular						
Stereoscopic Vision						
Optical Design						
Visual Rivalry						
Visual Suppression						

USAMRL REPORT NO. 984
DA PROJECT NO. 3A061102B71P

ABSTRACT

VISION: MONOCULAR, BI-OCULAR, BINOCULAR

OBJECTIVE

To review the state of knowledge with respect to the visual system and its selective functioning in the three modes--binocular, biocular, monocular.

METHOD

Summary and interpretation of laboratory and field experimentation.

CONCLUSIONS

Additional research is required specifically directed toward elucidating the mechanisms of interaction in the visual functioning of the two eyes.

VISION: MONOCULAR, BI-OCULAR, BINOCULAR*

INTRODUCTION

The terms, monocular, bi-ocular, binocular, are frequently used to categorize the intended mode of utilization of an optical instrument. A spotting scope is usually monocular, the standard microscope has come to be bi-ocular, and the usual sports glass is binocular. In a sense, the term applied to the optic summarizes certain characteristics of the observer-optic-target system. The monocular system is arranged to utilize one of the observer's eyes, a single optical axis, and a point in space from which to view the target field. The bi-ocular is arranged to utilize both eyes of the observer, a bifurcated optical axis, and a point in space from which to view the target field. The binocular is arranged to utilize both eyes of the observer, two optical axes, and two points laterally displaced in space from which to view the target field. In practice the choice of an optic is made to take advantage of certain strengths and/or economies associated with the particular system. Ideally a system would be maximized for efficiency and effectiveness by fitting the component parts one to the other.

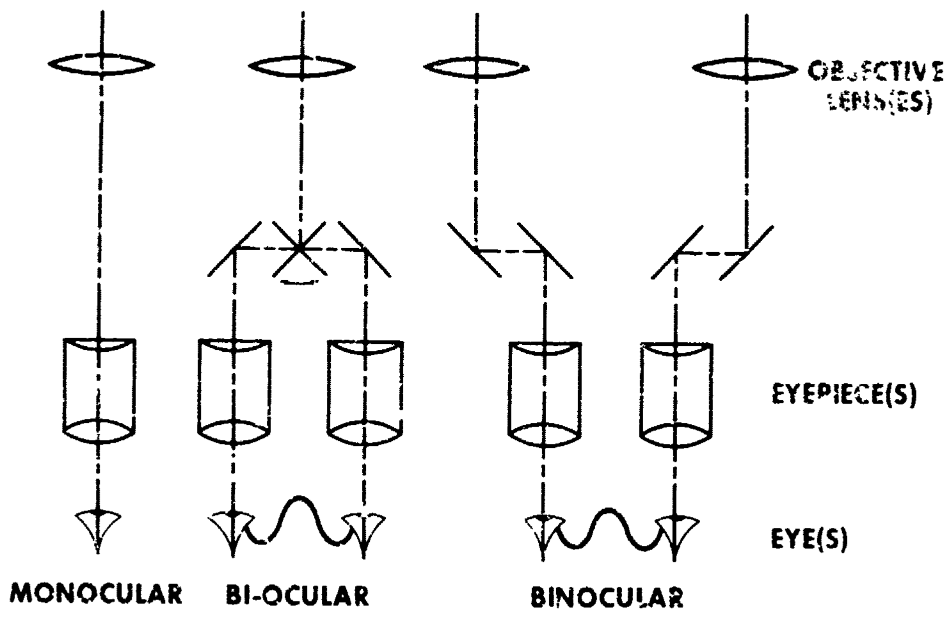

Fig. 1. Schematic of possible optical systems.

*Presented at the 16th Annual Army Human Factors R&D Conference (1970); published in the Conference Proceedings.

Given the desire to produce an optical system, the optic, in general, can be specified to a satisfactory degree and matched to the target requirements which in turn can be specified generally. The situation is different, however with respect to the observer. There is a great deal of information in the optical literature with respect to the single eye, its refractive capability, its resolution limits, its modulation transfer function, etc., but very little with respect to the interaction of the observer's eyes as he executes the many tasks in which he must use his eyes. For example, consider the discomfort experienced following a period of viewing with a night vision device, the Starlight scope. Difficulty originates from the extreme difference in adaptation level of the two eyes. One eye is light adapted, the other dark adapted. Closing the light adapted eye--a natural defense to excessive light--does not change the situation. The retinal state of adaptation continues and the observer is aware of an empty, dark hole in a light fog between himself and his surround. This situation is reminiscent of a solution offered for the maintenance of vision in the presence of an atomic blast. The observer was to be instructed to wear a patch over one eye in anticipation of the blast and to switch the patch after the blast to cover the exposed eye. These situations involve the assumption that an observer can function monocularly at will. In fact, the observer is binocular and unable to ignore the unwanted stimulation.

Suppose a binocular is designed--a hand-held optic to be provided to selected personnel for individual observation. The fact that it is a dual optic does not assure that the individual will use it binocularly. If the binocular is out of collimation, an observer who habitually uses both eyes will probably be aware of the lack of alignment and complain, particularly if the loss of alignment has been abrupt. Yet an individual, who by our usual tests has binocular vision, all too often will use a misaligned instrument without complaint, being totally unaware of the misalignment. It frequently can be demonstrated that such an individual is using only one eye (half the optics provided) while suppressing vision in the other eye. The observer is monocular. Between these two extremes, when viewing a distant scene, a movie or a television program, the observer is bi-ocular, using either eye or both eyes with no loss of information. The mode of functioning is determined by a selective mechanism internal to the observer.

THE SELECTIVE MECHANISM

Suppression of vision in one eye in response to conflicting inputs to the two eyes is a normal response of the binocular visual system. It is an adjustment which is readily learned, consciously or unconsciously, in response to a specific situation. This is the ability which permits a jeweler to use his loupe or a soldier to sight his rifle without closing or patching the unused eye. The eye is stimulated but the observer does not see. Suppression is not always confined to a single eye or the entire eye. The phenomenon of rivalry (1) occurs when suppression alternates from eye to eye and vision in the individual eye is lost momentarily either for the entire field of view or portions of the field. For example, the stadia reticle in the eyepiece of the military binocular induces suppression of the immediately adjacent areas in the other eye, and for some individuals, can induce suppression of the entire field of either eye. The stereoscopic impression of depth can also be considered a phenomenon of suppression since it is characterized by the inability to report certain local detail from the individual eye views. The phenomenon of single vision from disparate monocular views is usually termed "fusion," without specifying the underlying mechanism which is the subject of controversy.

BINOCULAR VISION

Figures 2 and 3 represent the possible responses of the visual system to definitive stimuli that can be expected over its functional range. Figure 2 presents a physical model in terms of which Figure 3 may be interpreted. At the simplest level, the horizontal axis of Figure 3 represents a bi-directional gradient of light adaptation for the preferred eye relative to the non-preferred eye. Plus indicates that the preferred eye is adapted to a higher light level than the non-preferred eye; minus indicates the converse. On the left of the figure the preferred eye would generally be dark adapted and on the right, light adapted. The solid line with filled circles traces those conditions in which the preferred eye is provided the definitive contour and the non-preferred eye is uniformly stimulated as from a sky background. The

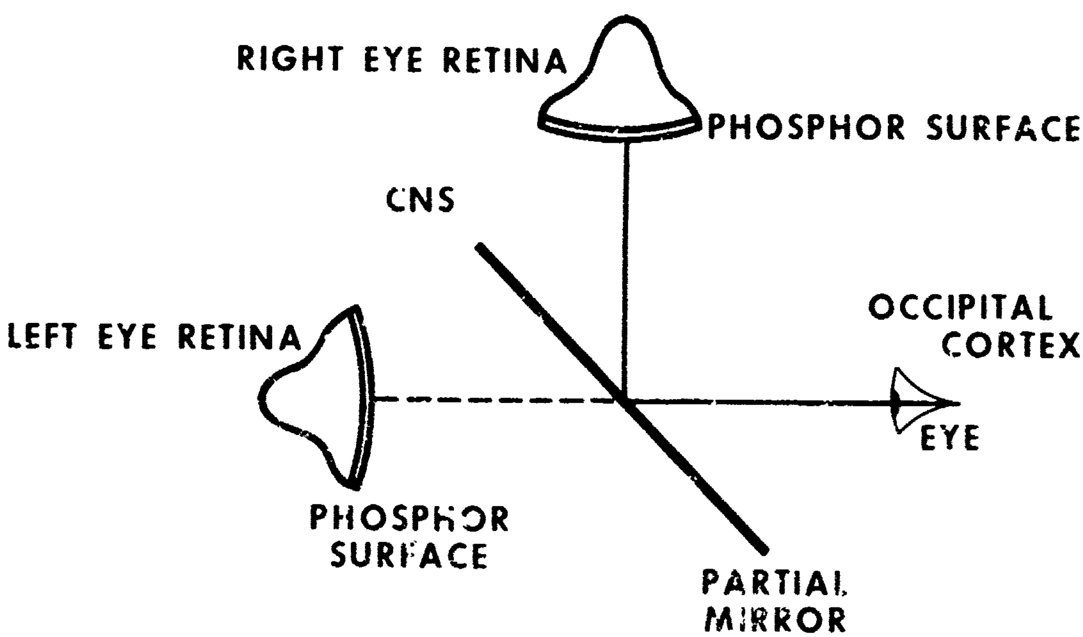

Fig. 2. Physical model of optical input to the visual system.

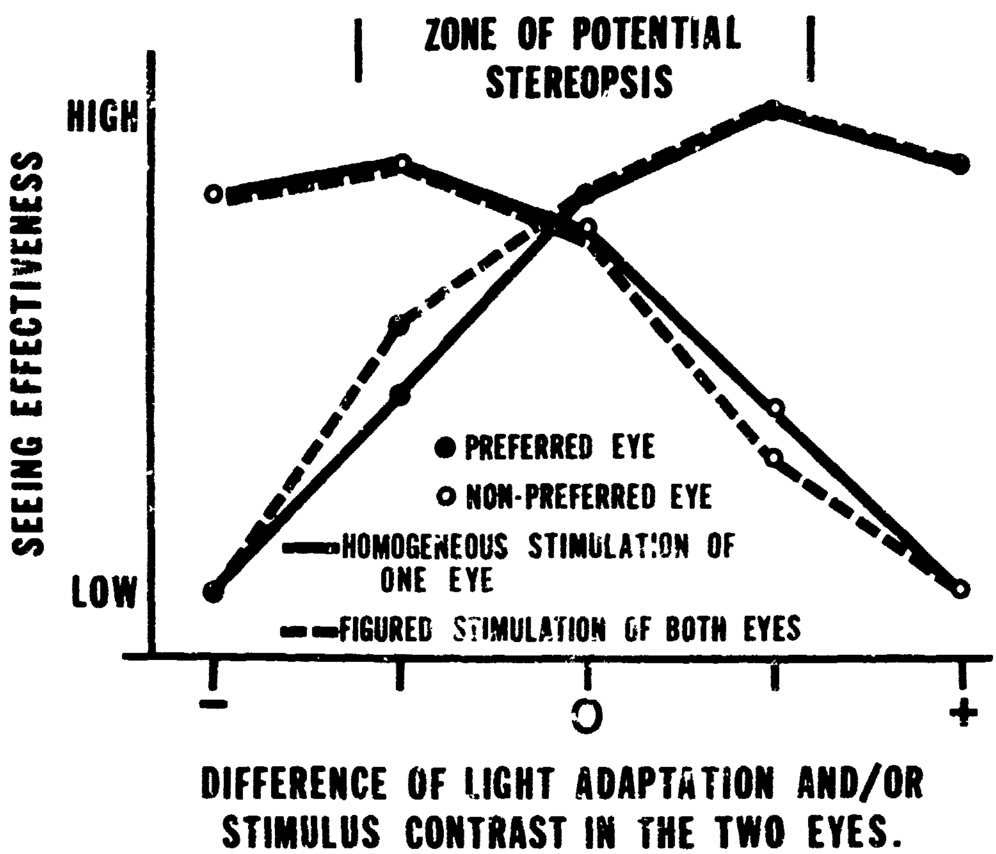

Fig. 3. Dominant visual response to definitive stimuli over the range of potential visual function.

solid line with open circles represents the converse. The dotted line traces those conditions in which both eyes receive contoured stimulation but each eye a different figure as in the acuity tests of the Sight Screener, a stereoscope, or a visual rivalry demonstration. The stimulation which will be seen for any combination of conditions is that which adapts the stimulated eye to the higher light level. Thus, on the left of the figure the stimulation or image presented to the non-preferred eye will dominate even though the observer may wish to see with the preferred eye. If the observer could consciously suppress the non-preferred eye, he would be prepared to see "in the dark" with the preferred eye.

The functions for both the preferred and non-preferred eye are shown in the figure; the function for the non-preferred eye is essentially a mirror image of the preferred eye function. This makes the figure somewhat confusing but it serves as a reminder that the visual system is always binocular and apparently responds otherwise only because of the unique combination of conditions.

In the middle of the figure, both eyes receive essentially the same level of stimulation and the definition of "preferred eye" is presented as that eye which provides the best capability under normal viewing conditions. Alternate definitions might be: that eye which is used the greater percent of time in a rivalry situation; or that eye towards which the "fused" detail is displaced in stereoscopic vision (2). On the right side of the figure, maximum effectiveness occurs for the preferred eye for some general level of stimulation of the non-preferred eye which is less than the stimulation level of the preferred eye (3). Finally, at the right of the figure is depicted the condition in which the preferred eye alone is stimulated and the non-preferred eye is covered with a black patch. This is the condition experienced by an observer with the Starlight scope. The filled circle portrays viewing with the scope and the open circle portrays the attempt to see immediately following a period of viewing with the night vision device. Since the stimulation provided by the more light adapted eye will dominate, visual effectiveness will be high with the device. On the other hand, the residual light adaptation will preclude seeing in the dark with the preferred eye as well as with the non-preferred eye when the device is initially laid aside. Given time, the adaptation state of the two eyes becomes equal, as pictured in the center of the figure, and visual effectiveness is appropriate to the available light.

The situation is essentially parallel for figured stimulation in both eyes with the definitive contour in one. This is represented by the dotted lines. It is assumed that local suppression of contour will occur in the eye with the lesser relative contrast. Thus, the usual experience would be to see with the preferred eye when the contrast is greatest in the preferred eye, and to see with the non-preferred eye when the contrast is greatest in the non-preferred eye. The relation is asymmetrical and favors the preferred eye.

STEREOSCOPIC VISION

Special attention is directed to the central portion of the figure titled "zone of potential stereopsis." For these stimulus conditions, the range of which is unique to the individual, the stimulation of the two eyes is sufficiently balanced both in contrast and adaptation level that both eyes will function rather than one or the other eye. It is within this range of conditions that the phenomena of stereoscopic vision and rivalry occur. With appropriate "disparate" images, fusion or selective suppression occurs and the stereoscopic impression of depth is seen. With markedly different images, rivalry occurs with its characteristic partial suppression, twinkle, and other associated visual impressions.

I have designated this the "zone of potential stereopsis" because the impression of depth from static stereoscopic stimuli is generally stable over such a range of illumination imbalance, as depicted in the figure. The facts are quite different for the case of movement of the observer or objects within the field of view. In the center of this zone where the adaptation level of the two eyes is equal, the path of movement is as truly perceived as it can be, given the geometric relation of the object in motion to the background. (Specific configurations give particular distortions (4), and only in rather limited circumstances is the true path perceived at all.) When one eye is relatively light adapted with respect to the other eye (left or right of center in the figure) moving stimuli are displaced in depth. This is the Pulfrich (5) effect which is usually demonstrated with an oscillating pendulum and a filter, such as half a sunglass held before one eye, both eyes being open. The effect can also be seen when looking from a moving vehicle at right angles to the line of travel (6). The half-sunglass is held before either the leading or trailing eye and the surround is viewed with both eyes open. The effect with the sunglass over the trailing eye is that of looking with an increased base stereoscopic instrument. The depth distance between objects is increased and all objects appear closer and smaller. The effect is most pronounced in the middle distances from 30 to 150 feet when viewing with the unaided eye. The converse--the impression of looking with a decreased base stereoscopic instrument--occurs when looking with the sunglass over the leading eye. Thus, the view from a moving vehicle seen with a binocular observation device with unbalanced light transmission will be perceptually distorted. The phenomenon is usually demonstrated with an order of magnitude imbalance in the stimulation of the two eyes; however, a 10% difference of illumination to one eye could produce a noticeable effect since the function is continuous.

Flicker or shuttering of the field of view--a method of achieving light transmission reduction--produces unique visual phenomena with or without movement. It is well established that seizures can be precipitated in persons with a history of epilepsy by synchronous flicker at an appropriate frequency. This is a matter of concern in the selection of helicopter pilots. It is also well established that brightness enhancement occurs with flicker of approximately nine cycles per second (7).

A less known consequent of flicker called the Mach-Dvorak (8,9) effect involves asynchronous stimulation of the two eyes. This, as in the Pulfrich phenomenon, produces depth displacements of moving targets as a function of their direction and speed of motion. Independent shuttering of the two eye views, in addition to reducing the overall illumination level, opens the possibility of manipulating the timing relations between the two eyes. In the simplest instance, if the left eye is stimulated before the right eye, an object moving from left to right will be displaced away from the observer and an object moving from right to left will be displaced toward the observer; or vice versa with symmetrical interaction of eye sequence and direction of motion (10). The entire matter is seemingly consistent with the geometry of stereoscopic vision and reminiscent of the procedures of air reconnaissance where two cameras are exposed in sequence to achieve an extended stereoscopic base in the line of flight of the airplane.

This simple relationship falls apart, however, when the duty cycle of each eye is manipulated in conjunction with the phase relationship between the eyes. At one extreme a relatively long, 80 msec, exposure of one eye, and a relatively short, 10 msec, exposure of the other eye, with a recycle time of 110 msec, results in the short exposure always initiating the perception without regard to eye sequence. The direction of target motion remains effective in determining the relative depth displacement toward or away from the observer; however, the timing relation between the two eyes (left-before-right or right-before-left) is no longer effective and the interaction of exposure duration and target motion is asymmetrical. Systematic laboratory research of these phenomena has been initiated only recently.

The potential payoff of the knowledge to be gained from such research was intimated some years ago in the observation that the visibility of low contrast targets was enhanced with an apparent movement, coincidence rangefinder under test for Frankford Arsenal by the Nortronics Division of Northrop Corporation. Apparently the flickering of the field of view permitted the observers to work both earlier and later into the twilight hours. Extensive followup was not supported and the understanding that was achieved did not identify the critical dimensions.

DESIGN CONSIDERATIONS

Returning to considerations of optical design, another characteristic of the visual system and of visual stimuli needs to be appreciated. For example, in designing a binocular instrument, the question must be answered, "What shall be the axial alignment of the two optical systems?" This question arises from the fact that the accommodation drives the convergence of the eyes and conversely, but not to the same degree. In general, once fusion is achieved, an observer can encompass considerable variation in vergence distance without experiencing loss of clear vision. Yet, a change in accommodative distance is accompanied by a corresponding change in convergence distance. At the present time there is no single answer to this question just as there is no single answer to a number of other questions which stem from the fact that naturally occurring visual stimuli and the response of the visual system change along several dimensions simultaneously. For example, a change in the physical distance of a fixated object results in lateral displacement of the object in the field of view, a change in angular subtense, and a change in contrast or some other aspect of the illumination. Optical manipulations similarly affect the interrelation of stimulus variables. Telescopic magnification changes in the angular relation between frontal and depth extents from that existing in the natural environment. Lateral displacement in the single eye view of a stereoscopic ranging reticle neglects the stimulus to accommodation and the apparent size change associated with the depth displacement of a real object. The choice of a single line width to produce a stadia reticle for use at multiple distances ignores the change of angular subtense with distance which characterizes a real object. Each compromise has its perceptual consequence. Vehicles moving obliquely across the field of view are seen, through a binocular, to scuttle sidewise. The stereoscopic wandermark moves obliquely getting larger as it goes out. The stadia reticle, in addition to occluding increasingly larger portions of more distant targets, appears as a window through which the observer looks into the field of view. In some instances for some observers, the perceptual distortion is sufficient to preclude the observer using the optic as intended.

Because of this, one can legitimately ask, "Can we identify those compromises that optical instruments impose on visual functioning which are and are not acceptable?" Certainly, if this information was available beforehand optical design efforts could be more effective. Unfortunately, at present, this information is a matter of accumulated experience. For example, in a recent developmental effort two unity power optics were offered for a headmounted viewing device: the one, optically refined and expensive; the other, relatively inexpensive. These optics were evaluated against one another and against the headmounted housing with no optics. The test used was truck driving, a series of standardized maneuvers for which there were accumulated Army population measures. The results ranked the optics in order; first, the headmount with no included optics; second, the headmount with the expensive optics; and third, the headmount with the inexpensive optics. The primary performance decrement was associated with the reduction in field of view and the mount which obstructed head movement. In no instance did the average performance with either optic fall outside the range of performance to be expected of 80% of the Army population. Stated another way, there was no statistically significant difference in performance of the soldiers with the devices on the truck driving tasks. Presumably one could substitute the less expensive for the more expensive optic. In fact, the more expensive optic was adopted to assure maximum capability with the item.

RESEARCH REQUIREMENTS

Such testing can substitute for field experience with the system under development and offers a degree of objectivity often lacking in a field test. Yet it does not provide hard data for design guidance. Much as the measures taken and the items of equipment tested represent real variations within the design criteria and test situations used, they do not necessarily represent significant differences along critical dimensions of visual functioning. The whole exercise may, in fact, have been nothing more than a test of minor variations of essentially equivalent visual conditions. The determination of the truth or falsity of this last point will not be resolved by more and more elaborate field tests. Fundamental knowledge of the visual system in all its aspects is necessary to identify the stimulus dimensions critical to effective visual functioning, including their range and the magnitude of a significant change within each dimension. Only when such information is available will it be possible to evaluate an optical design variation in terms of its significance for effective seeing.

LITERATURE CITED

1. Woodworth, R. S. and H. Schlosberg. Experimental Psychology, Rev. Ed. New York: Holt, Rinehart and Winston, Inc., 1954, p. 399.

2. Walls, G. L. A theory of ocular dominance. AMA Arch. Ophthal. 45: 387-412, 1951.

3. Hartmann, G. W. The increase of visual acuity in one eye through the illumination of the other. J. Exp. Psychol. 16: 383-392, 1933.

4. Gogel, W. C. The measurement of perceived size and distance. In: W. D. Neff (Ed.), Contributions to Sensory Physiology, Vol. 3, New York: Academic Press, Inc., 1968, pp. 125-148.

5. Lit, A. The magnitude of the Pulfrich stereo-phenomenon as a function of binocular differences of intensity at various levels of illumination. Amer. J. Psychol. 62: 159-181, 1949.

6. Enright, J. T. Distortions of apparent velocity: a new optical illusion. Science, 168. 464-457, 1970.

7. Bartley, S. H. The psychophysiology of vision. In: S. S. Stevens (Ed.), Handbook of Experimental Psychology, New York: Wiley, 1951, pp. 921-984.

8. Dvorak, V. Uber analoga der personlichen differenz zwischen beiden augen und den netzhautstellen desselben Auges. Sitzgsber.d.k. bohm. Gesellsch. d. Wiss. in Prag, 1872, pp. 65-74.

9. Harker, G. S. A saccadic suppression explanation of the Pulfrich phenomenon. Percept. & Psychophys. 2: 423-426, 1967.

10. Lee, D. N. Spatio-temporal integration in binocular-kinetic space perception. Vis. Res. 10: 65-78, 1970.