DUCTION, FIELD OF VIEW, AND IMPROVED STEREOACUITY FOR NAVY DIVERS

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SUMMARY PAGE

THE PROBLEM

To determine whether the power of duction* is the basis for stereoacuity and whether stereoacuity losses (such as occur under water in divers) can be restored by methods which restore duction.

FINDINGS

Duction in an empty visual field is amenable to improvement by introducing a few, simple stimuli in the periphery of the visual field; however stereoacuity is not.

APPLICATION

It is unlikely that the loss in stereoacuity which occurs under water can be significantly improved by the introduction of a few simple peripheral stimuli not at the same distance as the target--methods which will restore duction to its normal level.

ADMINISTRATIVE INFORMATION

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Duction - the ability of the eyes to overcome either converging or diverging prism-power and maintain binocular fusion.

ABSTRACT

There is a loss in duction as the field of view is progressively restricted while holding the light-level constant. This is similar (i) to the loss in stereoacuity which occurs for Navy divers under the same conditions, and (ii) to the loss in duction which occurs in the dark. However, introducing a few simple peripheral stimuli into the empty visual field restores the level of duction but not that of stereoacuity. It was concluded that in an empty visual field the poor duction is not the basis for the decrement in stereoacuity, but rather that other mechanisms produce the loss in both. It is unlikely therefore, that the underwater stereoacuity of Navy divers will be improved by those methods which improve duction.

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INTRODUCTION

Stereoacuity is considerably worse in water than in air (Ross, 1966; Luria and Kinney, 1968). To test the hypothesis that this loss is due to the notable lack of peripheral stimuli in the typical underwater environment, stereoacuity in air was measured with various amounts of the peripheral field of view screened from view by curved, white sheets of cardboard close to the subject's eyes; although the Howard-Dolman test apparatus was always clearly visible to both eyes, stereoacuity decreased as more of the peripheral field of vision was removed from view (Luria, 1969). Similarly, Goldstein, Clahane and Sanfilippo (1966) had reported that the "appreciation of stereopsis" was poorer in observers who had lost much of their peripheral vision as a result of retinitis pigmentosa. These results strongly suggested that peripheral vision was essential for maintaining optimal binocular vision, although they did not, of course, identify the underlying mechanisms.

Goldstein, Hornblass, and Clahane (1968) have reported, furthermore, that when peripheral stimuli are removed by testing in the dark, there is a significant decrease in duction, that is, the power of both converging and diverging prisms through which an observer can maintain binocular fusion. This finding led to the suggestion that it is this loss of duction which is the basis for the loss of stereoacuity in the absence of peripheral stimulation.

This interpretation is somewhat tentative, however, for several reasons. First of all, the above experiment does not rule out the possibility that the decrease in duction which occurs in the dark is somehow simply the result of dark adaptation. It must be shown that duction also decreases as the field of view is decreased while maintaining a constant photopic illumination.

Second, the relation between duction and dynamic stereoacuity has recently been studied by Luria and Kent (1969). They found that the correlations between these two variables, measured for a group of men who typically suffered from some degree of myopia, were low. Although they were improved when the sample was restricted to men with very little refractive error, there was still no relation between good stereoacuity and those values of duction which the authors felt to be characteristic of a good visual system. Their conclusion was that duction was not the sole determinant of dynamic stereoacuity. This study is again not conclusive, however, since dynamic and static stereoacuity are not closely related (Luria and Weissman, 1968). It is conceivable that higher correlations exist between duction and static stereoacuity.

A third consideration is that there should be a reduction in stereoacuity when an individual is made to observe through prisms which reduce the power of duction remaining to him without, however, inducing diplopia. It has long been known, in fact, that this often occurs. Fry and Kent (1944) studied this phenomenon in considerable detail. They found that the prisms do not always impair stereoacuity, that in some cases only base-out prisms produce a loss, while in other cases only base-in prisms do so. They were unable to arrive at a completely satisfactory explanation, and the problem is still unresolved.[1]

A more conclusive evaluation of the hypothesis would come from a study of the effects on both duction and stereoacuity of adding more and more peripheral stimuli to an unstructured field of view. The problem of improving visual performance in the absence of much stimulation has occupied a great deal of attention over a long period of time (Cf. Whiteside, 1954), often with equivocal results at best (Brown, 1957). But if duction is the essential factor in stereoacuity, then both should be correspondingly improved by the gradual introduction of peripheral stimuli in an unstructured field.

EXPERIMENT I

The purpose of the first experiment was to measure duction at a photopic luminance level as a function of the extent of the field of view.

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[1] *Interestingly, Fry and Kent suggested the possibility that the effect occurs because "convergence in some way influences the interpretation of the retinal impression after they reach the cortex," a notion which has been supported by recent studies by Richards (1967).*

METHODS

Since field of view was the experimental variable, it was desirable to use a set of prisms which would permit a view as wide as possible. The standard phoropter was unsatisfactory, since it permitted a field of only around 35° visual angle. In place of it, therefore, a pair of horizontal prism-bars was used. These permitted a field of view of slightly more than 50°. Each bar was composed of a series of prisms ranging in power from 1 to 40 diopters, for the most part in 2-diopter steps.

The target was a vertical black rod, 37 mm long and 0.75 mm thick; it appeared above a horizontal black curtain at a distance of 20 ft from the subject and one foot in front of a neutral colored wall. This rod was similar to the rods in the Howard-Dolman apparatus used in the previous study (Luria, 1969).

The two bars were positioned above eye level and as close to the subject's eyes as possible. At the start of each test session, the subject was looking through the one-diopter prisms, either base-in or base-out. He reported whether the target was single or double. If single, both bars were simultaneously moved downward to the two-diopter prisms, and so on in two-diopter steps until the rod could no longer be fused. At this point, the bars were now moved upward one step at a time until the subject again reported a unitary perception. These two points constituted the "break/recovery ratios."

Break/recovery ratios were measured for both base-out and base-in prisms for a field of view unrestricted except by the prisms, and for fields of view of 23° and 12° visual angle. The smaller fields were obtained by placing, about six inches from the subject's eyes, curved sheets of white bainbridge board with circular holes. One large hole served to produce a 23° field of view. Two small holes gave a 12° field; one of these holes was movable to compensate for differences in interpupillary distance. A separate low voltage tungsten bulb was used to illuminate the bainbridge board so that it matched the far wall in brightness and color. The level of illumination was 1 ft-L.

The various conditions were presented in counterbalanced order. No more than two measurements were taken on one day, one in the morning and one in the afternoon.

Five women and one man who had 20/20 vision without spectacles (which would prevent placing the prisms close to the eyes) were chosen as subjects.

RESULTS

Table 1 presents the break-recovery ratios in prism diopters for the six subjects under the various conditions. When the field of view was restricted, there was a corresponding decrease in the mean prism power needed to induce diplopia as well as the mean power which the subjects could overcome to restore fusion. For the base-out condition (divergence), this is shown by every subject. For the base-in condition, there is no change for most subjects from the unrestricted field to the 23° field, but every subject suffered a loss in duction under the 12° field.

Table 1. Break/Recovery Ratios of Convergence and Divergence in Prism-Diopters with Various Fields of View

Subject	Field of View		
	Unrestricted	23°	12°
	BASE-IN		
SL	4/2	4/1	2/1
AR	6/4	6/4	4/2
CM	4/2	4/2	2/1
TS	4/2	4/2	2/1
KN	4/2	4/2	2/1
EG	6/2	4/2	4/1
Mean Midpoint	3.50	3.25	1.92
	BASE-OUT		
SL	20/18	20.16	16/12
AR	6/4	6/2	2/0
CM	16/8	14/6	14/4
TS	10/6	8/6	4/2
KN	14/10	10/8	6/4
EG	14/8	8/6	4/2
Mean Midpoint	11.17	9.17	7.33

These results completely conform to and complement those of Goldstein and his co-workers in showing the loss of duction with decreasing peripheral

dark adapted for 10 minutes for all dark conditions.

(3) "One light" -- A flashlight was

Table 4. Stereoacuity Thresholds without Regard to Direction of Error and Standard Deviations in Seconds of Arc

O	Light		Dark					
			No screen		1 screen		2 screens	
	ηt	σ	ηt	σ	ηt	σ	ηt	σ
SL	0.00	3.66	2.29	6.87	0.92	3.66	0.00	4.12
AR	17.86	8.98	4.58	9.62	16.03	6.87	0.00	7.79
CM	4.12	1.83	2.29	3.21	4.58	4.12	6.87	5.04
EG	1.83	5.04	4.58	17.40	1.28	20.15	4.58	11.91
DW	38.93	8.70	38.93	8.70	35.72	10.08	35.27	10.08
RB	21.07	6.41	10.99	10.99	36.64	29.31	15.57	10.99
JH	0.00	38.47	*		34.81	41.22	10.08	43.05
RT	3.66	3.66	2.29	4.58	0.37	4.12	0.00	4.12
RB	1.37	5.50	4.58	5.95	2.29	5.68	0.92	4.58
JP	4.58	21.07	*		18.32	13.74	9.16	19.24
FL	9.16	19.24	9.16	11.91	16.49	15.57	0.00	32.06
EP	9.36	7.33	4.58	10.08	9.16	10.99	11.91	15.57
Mdn	4.40	6.87	4.58	9.89	12.55	10.99	4.58	10.44

*No threshold could be measured due to limitations of apparatus.

conditions for stereoacuity; the subjects maintain their relative position on the duction measures.

DISCUSSION

These results confirm the observations by Goldstein, et al (1968) that there is a loss of stereoacuity--in precision at least--in the dark; there is also a loss in duction with decreasing field of view when illumination is constant. The losses in duction are thus similar to those which occur in stereopsis under similar conditions. The results also show, however, that as limited stimulation is added to an unstructured peripheral field of view, duction and stereoacuity show markedly different susceptibility to improvement. Duction can apparently be improved with minimal peripheral stimulation, while stereoacuity requires a much closer approximation to the normal visual environment.

This suggests that duction is not the basic factor underlying stereoacuity but rather that other factors affect both. It seems more likely that in an unstructured visual field many visual functions are simultaneously impaired, thus degrading binocular vision and producing losses in both duction and stereoacuity. For example, the accuracy of binocular fixation (Ratliff and Riggs, 1950: Ditchburn and Ginsborg, 1953) may worsen, due, perhaps, to an increase in the non-uniform drift patterns of the two eyes (Fiorentini and Ercoles, 1968) of which the observer is not aware (Matin, et al, 1966). Fender and Julesz (1967) have found that very small disparities of fixation in conjunction with brief occlusions--such as might occur with eye-blinks--produce loss of fusion.

A second possibility is that accommodation is impaired. Loss of peripheral vision is known to result in "empty-field myopia" (Whiteside and Gronow, 1954). This is characterized by increased amplitude of oscillations of accommodation and by an average accommodation for a distance of only about one meter (Campbell, Robson and Westheimer, 1959), and has been shown to result in increased difficulty in detecting a target (Whiteside, 1954).

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13. ABSTRACT

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