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STEREOSCOPIC AND RESOLUTION ACUITY WITH  
VARYING FIELD OF VIEW

by

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Bureau of Medicine and Surgery, Navy Department  
Research Work Unit MF12.524.004-9014D.02

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Naval Submarine Medical Center

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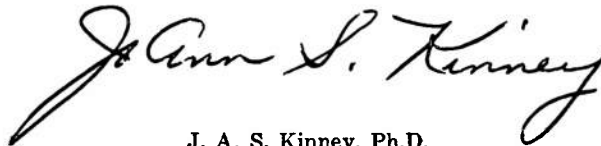
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## **SUMMARY PAGE**

### **THE PROBLEM**

To measure resolution and stereoacuity under fields of view of varying size.

### **FINDINGS**

Resolution acuity did not show marked or regular changes as the size of the field of view was varied, but stereoacuity underwent progressive deterioration as the limits of the field of view were constricted. This was true to some extent for all subjects, although there were marked individual differences.

### **APPLICATION**

This study shows that degradation of stereoacuity will result from the loss of peripheral visual cues, and supports the hypothesis that the decline in stereoacuity underwater is due to a lack of distinct visual cues, particularly in the periphery. It suggests that it should be possible to improve stereoacuity by providing peripheral cues when none exist.

### **ADMINISTRATIVE INFORMATION**

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit MF12.524.004-9014D, Improvement of Vision and Orientation Underwater. The present report is No. 2 on that Work Unit. It was approved for publication on 6 December 1968 and designated as Submarine Medical Research Laboratory Report No. 557.

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## **ABSTRACT**

Resolution and stereoscopic acuity were measured while the field of view was varied in size—without, however, obstructing the targets for either eye. Resolution acuity showed no marked or regular changes, but stereoacuity was progressively reduced as the field of view was constricted. This supports the hypothesis that the sharp decline in stereoacuity is due to loss of peripheral visual stimuli and suggests that the introduction of such cues underwater should improve stereoacuity. Several possible explanations of the phenomenon are discussed.

# STEREOSCOPIC AND RESOLUTION ACUITY WITH VARYING FIELD OF VIEW

## INTRODUCTION

Although there are many similarities in the behavior of resolution and stereoacuity as a function of physical conditions, recent studies of visual processes underwater have revealed a significant difference between them. In clear water, resolution acuity is at least as good as it is in air, if not better.<sup>1</sup> This is due to the fact that refraction causes the retinal image of an underwater object to be enlarged when the eye is near the air-water interface—as it is when wearing a facemask. Stereoacuity, on the other hand, suffers a marked deterioration, even in the clearest water when the targets appear to be as clearly visible as they are in air.<sup>2, 3</sup>

What causes this difference? The most notable characteristic of underwater viewing is, perhaps, the relative absence of many clearly visible objects. The field of view is generally hazy and relatively undefined. The psychological term “ganzfeld” refers to an unstructured, homogeneous field of view. The distorting effects of the ganzfeld have been pointed out for many visual functions, but not, apparently, for any form of acuity.<sup>4</sup> The reason doubtless is that the presence of a distinct target is, strictly speaking, incompatible with the idea of a ganzfeld.

It is well known that acuity is best in the fovea and deteriorates very rapidly as the target is imaged farther and farther out in the periphery; acuity for highly illuminated targets is one-tenth as good as foveal acuity when the target is only about  $10^\circ$  from the fovea.<sup>5</sup> From this it might be supposed that the peripheral field of vision plays little part in determining the acuity for a foveal target.

Nevertheless, it has long been known that target-detection is impaired in an empty field;<sup>6</sup> other reports state that certain functions which are thought to be basically foveal in nature—such as reading—suffer in the absence of peripheral cues.<sup>7</sup> Such may also be the case, therefore, with more elementary visual processes.

This study investigated the effects on foveal stereo and resolution acuity in the loss of increasing amounts of the peripheral field of view—conditions under which, it should be emphasized, the targets always remained unobstructed for both eyes.

## APPARATUS AND PROCEDURE

Resolution thresholds were measured with a series of grating targets, consisting of six black bars alternating with five white bars, which were reproduced photographically in various sizes.

Stereo thresholds were measured using a 3-rod Howard-Dolman apparatus. The three vertical rods stood in a box with a 16x20 in. dark gray front in the center of which was a 5x14 in. window. The two outer rods were fixed in position, parallel to the front of the box. The middle rod was movable. The rods subtended a visual angle of  $.06^\circ$  and were separated by  $.78^\circ$ . With the stationary rods positioned 18 ft. 4 in. from the subject, the box subtended visual angles of  $3.8 \times 4.8^\circ$  and those of the window were  $1.4 \times 3.8^\circ$ . The grating targets were presented just behind this window, at a distance of 17 ft. 7 in. from the subject.

Both sets of thresholds were measured with binocular vision using the method of constant stimuli. The subject was given as much time as he wished to reach a judgment. For resolution acuity, a set of four or five targets in an appropriate range of sizes for the subject, were presented randomly for both size and horizontal-vertical orientation. The subject reported the target-orientation using a forced choice procedure. A frequency-of-seeing curve was drawn on cumulative probability paper, and the 75% correct point was taken as the threshold.

For stereoacuity, the middle rod was set at various positions, and at each setting, the subject judged whether it was closer or farther than the outside rods. The setting at which the middle rod was judged to be farther (or closer) 50 percent of the trials was

taken as the equidistance setting. The standard deviations of the thresholds could be read directly off the plot on the cumulative probability paper.

Subjects observed under four conditions: unrestricted field of view, 45°, 7.5°, and 3.8° field of view. The field of view was restricted by placing a large sheet of curved, white bainbridge board six inches in front of the subject's eyes. The targets were viewed through a pair of circular holes of appropriate sizes cut in the board. One hole was fixed in the board, and the other one could be moved horizontally to adjust for differences in interpupillary distance. The subject's head was held in position with a chin and forehead rest.

The four conditions were assigned to the subjects in counterbalanced order as shown in Appendix I. The presentation of the two sets of thresholds was also counterbalanced so that the acuity thresholds were taken first during half the trials and last during the other half.

The room was lighted with overhead fluorescent fixtures which illuminated the white background of the apparatus to 1.0 foot-lamberts (ft-L). The wall in back of the apparatus was yellowish, unpainted wallboard; its brightness was 0.6 ft-L. The brightness and color of the bainbridge board were matched to this wall by properly positioning a tungsten light over the subject's head. Thus, changes in the field of view did not entail much change in illumination for the subject.

The room was rather crowded with various pieces of equipment along the walls. As the field of view was enlarged, more and more of the usual scenery was visible.

Eight staff members of the laboratory served as subjects.

## RESULTS

The resolution acuity thresholds and their standard deviations are given in Table I for the eight subjects. There are no consistent trends either for a given S or between Ss. Mean resolution acuity remained essentially unchanged as the field of view was reduced

from an unrestricted one to about four degrees. There were also only minor differences in the standard deviations; the smallest field of view actually yielded the greatest precision. It is clear that reduction of field-size did not harm resolution acuity.

TABLE I.

Resolution Acuity in Minutes of Visual Angle with Fields of View of Different Extent.

O	UNR	$\sigma$	45°	$\sigma$	7.5°	$\sigma$	3.8°	$\sigma$
SL	.588	.08	.528	.06	.660	.04	.528	.10
JW	.576	.05	.408	.09	.624	.15	.564	.02
FD	.624	.02	.576	.05	.588	.04	.624	.03
CL	1.026	.04	.840	.06	.858	.06	.726	.02
JL	.774	.06	.828	.10	.708	.07	.858	.03
HM	.858	.12	.840	.06	.840	.07	.840	.03
AR	.942	.09	.960	.11	.540	.15	.972	.07
RE	.726	.09	.708	.02	.660	.04	.756	.07
Mean	.764	.07	.711	.07	.685	.08	.734	.05

The results for stereoacuity, shown in Table II, however, are quite different. Both the mean stereoacuity thresholds and their mean standard deviations increase with decreasing field of view. The decrease in sensitivity and precision is especially marked when the restriction of the field of view is very great. These mean values well reflect the individual results; every subject's performance deteriorated with increasing restriction, although the performance of those subjects who had better thresholds under the unrestricted condition deteriorated less than those with worse unrestricted thresholds.

TABLE II.

Stereoacuity ( $\eta$ ) in Seconds of Arc with Fields of View of Different Extent\*

O	Unrestricted Field	45°	7.5°	3.8°
SL	1.4±4.2	5.5± 8.3	6.9± 8.3	6.9± 8.3
JW	4.2±4.2	5.5± 3.6	5.5± 2.8	5.5± 8.3
FD	6.1±1.4	17.2± 4.2	12.5± 4.2	36.0± 8.3
CL	6.9±2.8	6.9±24.9	49.9±12.5	130.2±44.3
JL	6.9±6.9	6.9± 8.3	13.9± 2.8	16.6± 5.5
HM	33.2±6.9	34.6± 4.2	24.9±13.9	131.6±21.6
AR	8.9±3.6	6.9± 9.7	13.9±48.5	27.7±60.9
RE	0.6±4.7	1.4± 6.4	13.9± 7.8	13.8± 5.5
Mean	8.6±7.2	10.5±11.1	17.7±12.5	46.0±20.5

\*Without regard to direction of error.

## DISCUSSION

These results confirm previous exploratory data which indicated that stereoacuity is progressively reduced as the field of view is constricted,<sup>3</sup> although the targets are not occluded for either eye. It is, indeed, somewhat surprising that there is a measurable reduction even when the field of view is as large as 45°. (It may be noted in comparison, however, that a diver's face mask permits a horizontal field of view of about 120° and a vertical field of view of 80°.) The results indicate that peripheral visual cues are necessary to maintain good stereoacuity but are not necessary for resolution acuity—at least when there are no restrictions on exposure-time. In other words, the peripheral cues are needed for the task which requires both eyes but not for a task whose results are generally those for the best eye alone.

It is not certain from these results, however, which visual functions are being degraded by the loss of peripheral cues. One possibility is that the ability to maintain binocular fixation suffers under these conditions. It is well known that the eyes are constantly in motion;<sup>8</sup> proprioceptive cues apparently do not effectively signal these small movements,<sup>9</sup> and the eyes cannot be kept precisely on target.<sup>10</sup> It is also clear that some degree of eye-movement is necessary for optimal vision, and so it is assumed that stereoacuity is enhanced by involuntary eye-movements.<sup>11</sup> But it is possible that such enhancement occurs only for movements whose magnitude is within certain limits. Do these involuntary drifts become greater in the absence of peripheral cues—perhaps large enough to degrade stereoacuity?

The experimental evidence on both points is inconclusive. Studies of fixation in the dark have reported that fixation typically does not wander off target by more than 10 min. of arc,<sup>12</sup> approximately the same magnitude as the limits of Panum's fusional areas in the macular region.<sup>13</sup> These studies, however, dealt with monocular fixation. Are the effective limits of these involuntary drifts significantly greater if both eyes are taken into account?

Although the larger drifts of the two eyes are reported to be about equal and synchronized, the smaller drifts and tremors are not correlated;<sup>14</sup> furthermore, Fiorentini and Ercoles<sup>15</sup> have found that the two eyes of a given individual exhibit drift-patterns with directional non-uniformities which are markedly different. This would suggest that fixation disparities would be introduced which are greater than those measured for each eye separately, but Riggs and Niehl<sup>16</sup> and Hebbard<sup>17</sup> did not find large disparities when they measured binocular eye-movements simultaneously.

Nevertheless, Fender and Julesz<sup>18</sup> have recently found that disparities of less than 40 min. of arc, when rapidly introduced, are enough to produce loss of fusion of line-targets; and very small disparities, in conjunction with brief occlusions, will also destroy fusion. It remains possible, then, that disparities of the magnitude known to exist, in connection with eye-blinks, can result in loss of fusion.

A second possibility is that accommodation is differentially affected by changes in the field of view. It is generally held that accommodation requires a visual stimulus.<sup>19</sup> A paucity of stimulation results in "empty-field myopia",<sup>20</sup> characterized by an average accommodation for a distance of only about one meter and by increased amplitude of oscillations of accommodation<sup>21</sup> which, unlike small drifts of the eyes, appear to be highly correlated with the two eyes.<sup>22</sup> Campbell, Robson and Westheimer<sup>21</sup> report, furthermore, that marked changes in the pattern of fluctuations can be induced by variations in the visual stimulus.

It has long been known that empty-field myopia results in increased difficulty in detecting a target.<sup>6</sup> Considerable effort has been made to alleviate this difficulty for pilots. Whiteside and Gronow<sup>23</sup> reported that superimposing a reticule on the target-area reduced the size of the target needed for detection by half, and Brown<sup>24</sup> found slight improvements in the effectiveness of the reticule when its size was increased. This appears to indicate that as larger areas of

the retina are stimulated, the effects of empty-field myopia are progressively reduced, and leads to a third possible factor.

Kaufman<sup>25</sup> argues that stereopsis occurs when correlated stimuli are out of phase with respect to a reference system composed of another set of correlated stimuli. This suggests that stereopsis might be facilitated by an increase in the amount of stimuli available for correlation. White<sup>26</sup> has performed a related test, that of varying the proportion of inner to outer matrix in a display of constant size; he found that all of his conditions, except the limiting case where the inner matrix made up the whole display, yielded stereopsis on an all-or-none basis, but there is no measure of the effectiveness of quality of stereopsis; it is not reported, for example, whether the latency of the effect varied between conditions. Or, in the Fender and Julesz<sup>18</sup> experiment, the duration of interrupted fusion may vary.

All of this suggests that, whatever the basic reason for the worsening of stereoacuity, it should be possible to improve it by introducing peripheral visual cues. Brown<sup>24</sup> concluded that the improvement in target-detection which results from the introduction of a reticule is insignificant in comparison with the differences between individuals. The present results also indicate very wide individual differences; the ratio of stereoacuity under maximum restriction to that in unrestricted viewing conditions varies from 1.3 (indicating very little deterioration) to 23.0. Yet every subject suffered some deterioration both in localization error and precision of setting, and the attempt to improve acuity would seem to be worthwhile.

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#### APPENDIX I.

The Order of Viewing Conditions Presented to Each Subject.				
S	Unrestricted viewing	3.8°	7.5°	45°
SL	1*	2	3*	4
AR	4*	1	2*	3
CL	3*	4	1*	2
HM	2*	3	4*	1
RE	4	3	2	1
FD	3	2	1	4
JW	2	1	4	3
JL	1	4	3	2

\*Acuity thresholds taken first.

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## 13. ABSTRACT

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