APPARENT OBJECT MOVEMENT PRODUCED BY HEAD MOVEMENT UNDER WATER

by

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SUMMARY PAGE

THE PROBLEM

To determine whether the optical distortion produced by wearing a facemask under water causes a loss of visual position constancy, that is, whether it causes stationary objects to appear to move when the head is moved.

FINDINGS

Twice as much apparent object movement occurred under water than in air. Specific underwater adaptation procedures produced a small reduction of object movement.

APPLICATION

The results indicate that the constancy of visual position is not maintained under water. Therefore, apparent movement of stationary objects should be added to the list of visual problems which confront Navy divers.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4306.03-2050DXC5, Evaluation of Sensory Aids and Training Procedures on Navy Divers' Visual Efficiency. The present report is No. 8 on that Work Unit. It was approved for publication on 14 January 1972 and designated as Naval Submarine Medical Research Laboratory Report No. 694.

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ABSTRACT

It was predicted that due to the optical distortion produced.by wearing a facemask, the constancy of visual position would not be maintained under water, i.e., stationary objects should appear to move when the head is moved. Subjects made magnitude estimates of object movement in both air and water. Twice as much movement occurred in water as in air. Two underwater activities, head rotation while observing vertical stripes, and practice in hand-eye coordination, produced a small reduction in object movement. The results indicate that apparent object movement (loss of position constancy) should be added to the list of visual problems which confront the diver.

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INTRODUCTION

When a stationary observer views a physically moving object, a moving pattern of retinal stimulation is produced which gives rise to the perception of a moving object. However, an identical retinal movement can occur when the object is stationary, but the observer moves. The term constancy of visual position (or visual direction) refers to the fact that stationary objects do not appear to move when the observer moves.[1] A mechanism apparently exists whereby the extent of retinal movement is compared with the amount of eye, head, or body movement. When these two sources of stimulus input "match", the result is the perception of a stationary visual world.[2] Wallach and Kravitz[1,3,4] have studied this process in considerable detail. By means of a variable-ratio mechanical linkage between head movement and stimulus movement, they verified that a single target in darkness remains stationary when the head movement and the retinal image movement properly correspond. When the amount of image movement was artificially altered, predictable target movement was perceived. Furthermore, prolonged experience with the distorted relationship between head and image movement, using lenses, resulted in an adaptation to the distortion, that is, less movement was produced by the distorted arrangement, and opposite movements (an aftereffect) occurred when the head-image relationship was restored to normal.

An additional factor in maintaining position constancy has been emphasized by Hay and Sawyer.[5] Based on the geometry of motion parallax, it is apparent that less image movement will be produced by a given magnitude of head movement as the physical distance of the target is increased. Thus, a given head movement will not uniquely match a given image movement unless information concerning the distance of the target is also available to the matching process. Hay and Sawyer presented a target which was electronically coupled to the observer's head movement. By artificially altering eye-convergence, thus distorting potential distance information, apparent target movement was produced by the head movement.

In the research discussed above, distortion of position constancy was artificially produced in the laboratory. There is a natural situation, however, which theoretically should produce a similar distortion. When a diver wears a facemask under water, light refraction at the water-air interface magnifies the retinal image of an object by a factor of about 1.27, a condition sufficient for upsetting the normal head-image relationship. Therefore, it may be predicted that the constancy of visual position will not be maintained under water, that is, objects will appear to move when the head is moved. A further prediction is that experience in the underwater environment will produce a reduction in the amount of apparent object movement. These two predictions were tested in the present experiment.

METHOD

Subjects

Eighty Navy enlisted men served as subjects. None had any prior experience with the experimental situation.

Apparatus

The difficulties inherent in working under water made it unfeasible to use a complicated mechanical or electronic system for precisely measuring apparent object movement. The simpler method of direct magnitude estimation was used instead. The experiment was carried out in an outdoor, above-ground swimming pool which was 20 ft (6.1 m.) in diameter and 44 in. (111.8 cm.) deep. A white background, 5 ft (1.52 m.) wide, was mounted against the wall of the pool. It extended above the surface from the bottom of the pool, to a height of 7.25 ft (2.21 m.). A horizontal rod was mounted just below the surface, parallel to the background, and 3 ft (91.4 cm.) away. This rod served as a marker for the observer's head position. A vertical test rod, 1/2 in. (1.27 cm.) in diameter and painted fluorescent red-orange, was placed 18 in. (45.7 cm.) from the observer and centered against the background. The subject wore a facemask, snorkel, and weight-belt.

Procedure

The subjects were assigned to one of four groups, 20 subjects in each. The initial procedure was the same for all groups. The subject stood facing the background, and with the test rod temporarily removed, a similar vertical rod was held in front of the subject. The subject was instructed to rotate his head rhythmically from side to side and to report whether he observed any movement of the rod. Almost all of the subjects perceived a slight movement. The subject was informed that the amount of movement he had just perceived had an arbitrary reference magnitude of "10", and that his task was to make some additional judgments of degree of movement in relation to this reference movement, that is, relative to 10. To further explain this scaling procedure, it was stated that for movement greater than the reference movement, a number larger than 10 should be chosen, and for movement less than the reference movement, a number less than 10 should be chosen. The subject was then asked to observe the reference movement a second time. When the subject was satisfied that he knew what the reference magnitude looked like, the temporary vertical rod was removed, the test rod was replaced, and the subject lowered himself into the water. With his eyes first just above the water, and then just below the water, the subject rotated his head and decided on a number for the amount of movement observed. The air and water numbers were both reported when the subject returned to the surface.

The procedure which followed differentiated the four experimental groups. Members of the Head-Movement-in-Water (HMW) group sat under water, 3 ft (91.4 cm.) from a sheet of clear plexiglass which was 40 in. (101.6 cm.) high and 31 in. (78.7 cm.) wide, and which contained 1-in. wide, vertical red stripes. The subjects rotated their heads for 15 min. while looking at the stripes. Wallach and Kravitz[3] found that a similar head-movement procedure produced significant adaptation. After this adaptation period, the subjects returned, under water, to the test rod, and made two final motion judgments, first in water and then in air. Members of the Head-Movement-in-Air (HMA) group followed the same procedure, but looked at the stripes in air, rather than under water. Members of the Checkers-in-Water (CW) group (two at a time) played a game of checkers under water during the 15 min. adapting period. Playing checkers under water is known to produce adaptation to distortion in hand-eye coordination.[6] This activity provides practice in hand-eye coordination to the displaced images, while at the same time insuring adequate subject motivation and attention. Members of the final No-Adaptation (NA) group relaxed outside the pool during the adaptation period.

RESULTS

Initial Air-Water Difference

As a measure of the relative difference between their initial air (Air_1) and their initial water ($Water_1$) estimates, the ratio $Water_1/Air_1$ was computed for each subject. Since this ratio was greater than 1.0 for all but one subject, constancy of visual position was not maintained under water. The median ratio was 2.0 for the 80 subjects. The subjects reported seeing only a slight movement of the rod in air, presumably due to the presence of peripheral stimuli, and perhaps to imperfect eye-tracking. But under water, the rod distinctly jumped from side to side, coincident with the head movements. Of course, the crudeness of the response measure precludes a precise statement as to the amount of distortion in terms of a true ratio-scale measure.

Adaptation

The ratio of the final to the initial water estimate ($Water_2/Water_1$) and the ratio of the final to the initial air estimate (Air_2/Air_1) were computed for each subject. The median ratios for the four groups are listed in Table I. A water ratio of less than 1.0 represents compensation for the distortion, and an air ratio greater than 1.0 represents an after effect. The results indicate that the two groups who remained under water during the adaptation period (HMW and CW) did in fact show a slight adaptation to the distortion of position constancy. The two air-control groups showed no adaptive changes. The statistical significance levels for between-group ratio differences (Mann-Whitney

Table I. Median Ratios Between Magnitude Estimates

Group	$Water_2/Water_1$	Air_2/Air_1
HMW	0.94	1.33
CW	0.83	1.14
HMA	1.05	1.00
NA	1.00	1.00

test, 1-tail) are given in Table II. Since the significance levels in some cases are quite marginal, conclusions regarding the occurrence of adaptation must remain tentative. In view of the considerable individual differences observed in this experiment, a more precise method for measuring target movement would be desirable for assessing adaptive changes.

Effective of Previous Diving Experience

Since the adaptation procedure used in this experiment apparently produced a slight reduction in target movement, it might be expected that subjects having considerable previous diving experience would show less target movement under water than inexperienced subjects. By means of a questionnaire filled out by all the subjects prior to the experiment, information was obtained concerning their degree of previous experience. There was no relationship between previous experience and initial distortion $Water_1/Air_1$). Furthermore, for the two water groups (HMW and CW), there was no relationship between experience and either the amount of compensation in water or the amount of aftereffect in air. The unimportance of previous experience is surprising, since experienced subjects show less underwater distortion of hand-eye coordination than do inexperienced subjects.[7]

Table II. Statistical Significance of Ratio Differences Between Groups (Mann-Whitney Test)

Group	HMA	CW	NA
$Water_2/Water_1$			
HMW	.05	n.s.	n.s.
HMA		.01	.01
CW			.10
Air_2/Air_1			
HMW	.025	n.s.	.025
HMA		.10	n.s.
CW			.10

DISCUSSION

The results verify the prediction that the constancy of visual position is not maintained under water. This outcome results directly from the optical distortion produced by wearing an air-filled facemask. For an object at a particular physical distance, the amount of retinal-image movement produced by a given head movement is greater under water than in air. As a result, the visual and proprioceptive inputs under water do not match, and the object appears to move.

Since adaptation to experimentally produced loss of constancy occurs in air, it is not surprising that the second prediction of an adaptation to apparent object movement under water was tentatively verified. Although a precise statement as to the amount of adaptation which occurred cannot be made, it is clear that the adaptation was small in comparison with the amount of initial distortion. The fact that previous diving experience was not related to the amount of initial distortion in position constancy may be related to a similar finding in regard to distortion of size and distance.[7] Both size-distance perception and position constancy are highly dependent on strictly visual information. Although position constancy has an obvious proprioceptive component, there is some evidence that proprioception is not involved in the adaptation process.[3,4] It is therefore possible that long-term, intermittent exposure to a distorted environment does not produce adaptation of primarily visual processes.

The results of this experiment indicate that distortion in the constancy of visual position should be added to the list of vision-related problems which occur in the underwater environment. These other problems include poor visibility and stereoacuity; distorted size, distance, and color perception; and distortion of hand-eye coordination.[8] Further research is required to determine the extent to which adaptation to distortion of position constancy occurs with specific underwater experience. It is possible that training procedures can be developed which will hasten adaptation to the distorted head-image relationship.

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