

FURTHER TESTS OF TRAINING TECHNIQUES TO IMPROVE VISUAL-MOTOR
COORDINATION OF NAVY DIVERS UNDER WATER

by

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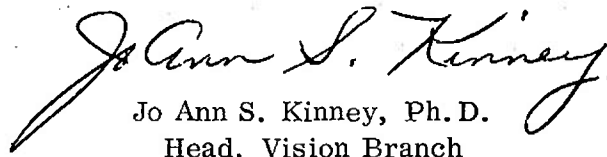
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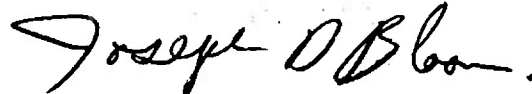

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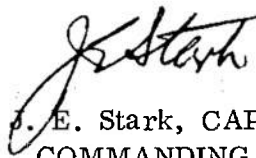
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SUMMARY PAGE

THE PROBLEM

To determine whether long term training techniques or previous exposure to magnifying lenses significantly aids divers' adjustment to the underwater distortion of size and distance perception.

FINDINGS

Typically, a small amount of adaptation to the visual distortion experienced underwater is rapidly achieved. Neither prior exposure to magnifying lenses nor ten weeks of underwater training sessions significantly improved the amount of adaptation shown. Inter-subject variability was high, suggesting that prospective divers might be originally chosen on the basis of test performance.

APPLICATION

The results are applicable to the selection of prospective SCUBA divers.

ADMINISTRATIVE INFORMATION

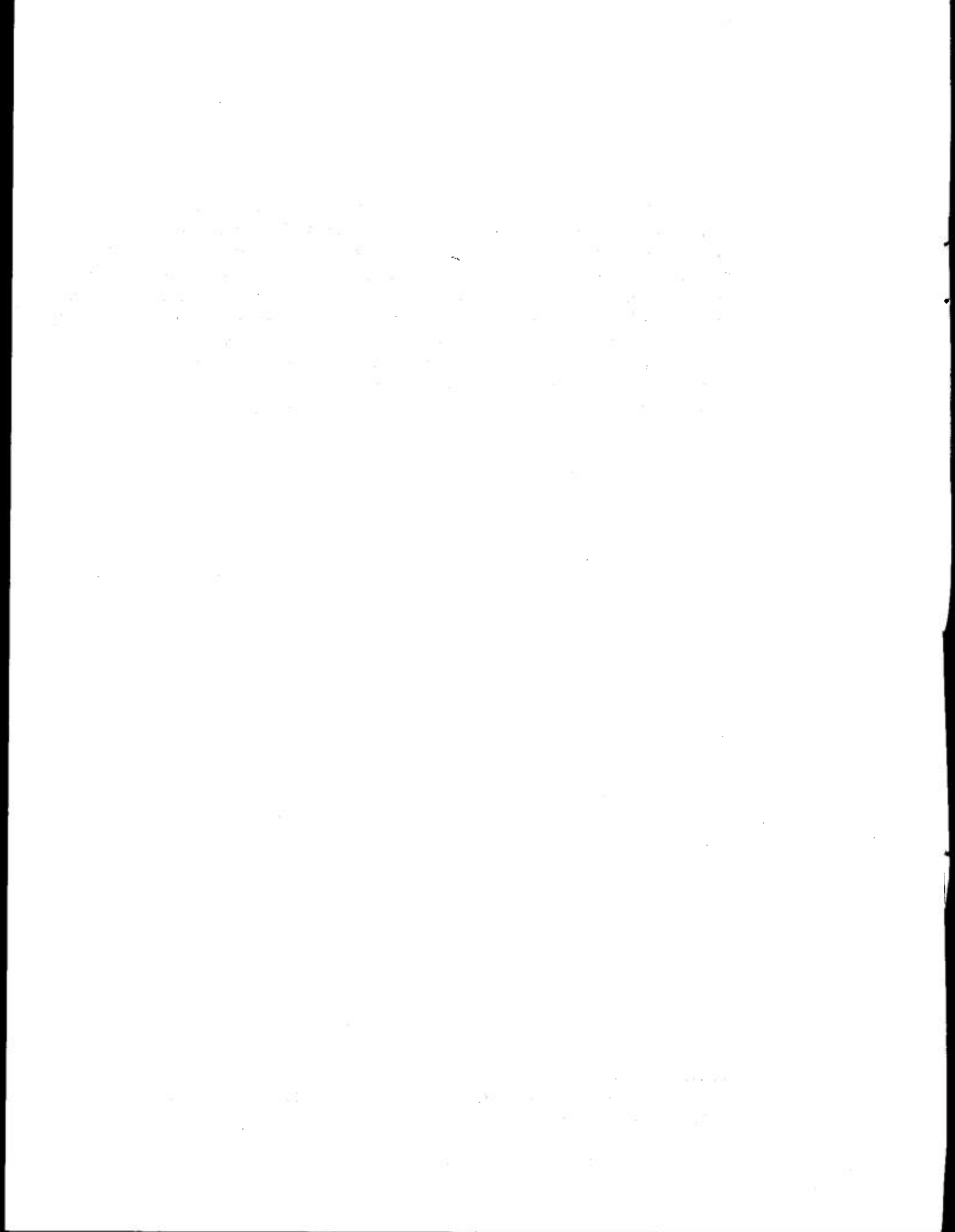
The investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4306.03-2050DXC5 - Evaluation of Sensory Aids and Training Procedures on Navy Divers' Visual Efficiency. The present report is No. 7 on that Work Unit. It was approved for publication on 26 October 1971 and designated as Submarine Medical Research Laboratory Report No. 684.

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ABSTRACT

Two underwater experiments were undertaken in a further* attempt to facilitate a diver's adjustment to the underwater distortion. One group of divers was given previous exposure to magnifying lenses before entering the water, while a second group received one training session a week for ten weeks. Neither technique significantly improved on the amount of adaptation found in previous studies. Inter-subject variability was high, however, with one subject showing practically complete adjustment for the distortion. Some preliminary screening tests might be devised to select future divers on the basis of relevant variables, including relative adaptability.

* Previous studies - see NSMRL Reports No. 541, 612, 613, and 633 (references 1-4).



FURTHER TESTS OF TRAINING TECHNIQUES TO IMPROVE VISUAL-MOTOR COORDINATION OF NAVY DIVERS UNDER WATER

INTRODUCTION

One of the biggest visual problems facing the underwater diver is the distortion of the optical image and the subsequent disruption of visually guided localization and judgments of size and distance under water. Due to the refraction of the light rays at the face mask, the virtual image of an object is formed at $3/4$ of the actual distance of the object. Similarly the retinal image of the object is larger, the magnification averaging 1.27 for the typical face mask.

At least three studies^{1,2,3} have suggested that with proper and sufficient underwater experience man can compensate, at least partially, for this distortion and can function fairly efficiently under water. The maximum amount of compensation reported for inexperienced divers is only about 46%, but these studies used fairly short durations of underwater experience (less than 1 hour total).

It is conceivable, therefore, that 100% compensation for the distortion may require extensive underwater training, perhaps over a period of several weeks or months; indeed, the evidence on experienced Navy divers suggest that their adaptability is based upon many hundreds of hours of underwater experience. It is also possible that divers might be assisted in adapting to the underwater distortion quickly by prior exposure to magnifying lenses in air.⁴ Such a technique would allow

divers to be trained out of water and, if effective, could be used to maintain a high level of performance throughout a diver's career.

Two experiments were designed to test these hypotheses. The first investigated the effect of either one or two sessions of exposure to magnifying lenses in air on subsequent exposure to underwater distortion. For comparison, a group was included which received all three sessions with exposure under water. The data from the first day of the latter group served as a control for the effect of the lenses.

The second experiment investigated the effect of many repeated exposures to the underwater distortion. Subjects participated in ten exposure sessions, spaced once a week for ten weeks. It was postulated that these subjects would show a decrease in the initial localization error upon entering the water (see McKay⁴ for comparable prism exposure data) and show a comparable decrease in the final localization error over the ten weeks.

EXPERIMENT 1

Procedure

A total of fifty Naval enlisted men volunteered for the experiment. Initially subjects were assigned randomly to each of the three groups. Later in the experiment an attempt was made to equate degree of previous underwater experience among the groups. The

majority of the subjects (42 men) had little or no previous experience under water.

Each subject was assigned to one of three groups. Each group returned for three successive days. Group I (WWW) spent all three days undergoing hand-eye practice in the water. Group II (LWW) was given one-day exposure to magnifying lenses (1-1/2X) in air and the following two days' exposure in the water. The third group (LLW) had two days' experience with the lenses before entering the water on the third.

Localization accuracy was tested using a hand-eye coordination table on which the subject marks the apparent location of various designated targets without being able to see his hand. The test has been described in detail previously;³ the final scores are an average of two marks at each of four target positions.

For all three groups the procedure each day was approximately the same. A pretest of localization accuracy was given on the hand-eye table in air without lenses. A second test was then given either in the water or with the lenses on, depending on the type of exposure scheduled for that day. The difference between localization on the pretest and localization on the second test is referred to as initial error.

The subject was next given practice in hand-eye coordination for ten minutes either in the water or while wearing the lenses. This practice consisted of one of several games (tic tac toe, Chinese checkers, American checkers, or a simple paper and pencil game

adapted for underwater use). Following this ten-minute exposure the subject was again tested on the hand-eye table while still in the water or wearing the lenses.

Subjects were then given a ten-minute test period during which they were encouraged to play Frisbee to allow the effect of the distortion to dissipate. After the rest period subjects again entered the water or put on lenses, and spent the next ten minutes practicing with a different game. A third water test was taken, followed by a second rest period, and a third practice session.

A final water, or lenses, test was given followed immediately by a final test in air without lenses. The difference between the pre-test and the final water test is referred to as final error; the difference between the pre-test and final air test is termed the after-effect. There were each day, therefore, a total of three exposure periods of ten minutes each, followed by tests of localization error. Two rest periods were interspaced between the exposures. Pre- and post-test localization was tested under normal conditions; that is, in the air without lenses.

Results

Table I presents the localization measures on the hand-eye table for all subjects in the various groups for the three days in the water.* The difference among the three groups on their

**Results of the magnifying lenses are not applicable to the present work and are, therefore, not included. These data may be obtained from the senior author upon request.*

Table I. Localization measures on test of hand-eye coordination for all subjects - Water data. Measures in inches.

Group	Initial Error	Error after			Final % Comp.	After-effect	
		10 min.	20 min.	30 min.		(in.)	%
First day in water							
<u>WWW</u> N=16	1.92	1.79	1.42	1.18	39%	-.63	33%
<u>LWW</u> N=20	1.54	1.20	0.99	0.86	44	-.91	59
<u>LLW</u> N=14	1.68	1.35	1.12	1.02	39	-.81	48
Average	1.71	1.45	1.18	1.02	41	-.78	47
Second day in water							
<u>WWW</u>	1.81	1.53	1.56	1.31	28	-.58	32
<u>LWW</u>	1.51	1.42	1.28	1.08	28	-.60	40
Average	1.66	1.48	1.42	1.20	28	-.59	36
Third day in water							
<u>WWW</u>	1.57	1.63	1.71	1.36	13	-.38	24

first day in the water are not significant, either for the initial error, final compensation, or after-effect. Similarly there was no difference between the WWW and LWW groups on their second day in the water. The largest amount of compensation occurred for all groups on their first day in the water, regard-

less of whether it was preceded by lenses or not.

For the WWW group, there was a significant decrease in initial error over the three days ($t=1.91$, $p<.05$), but no similar increase in compensation or after-effect. The comparable

decrease in initial error for the LWW group from the first to second day in the water was not significant.

Differences between subjects with no previous underwater experience and those with experience have been reported in earlier work.^{2,3} This difference is substantiated by the current data. On the first day in the water initial error for novices was 2.0 inches, for subjects with occasional experience

this error was 1.25", and for subjects with frequent experience it was 1.18". There was very little difference in final error (novices = 1.08, occasional = 0.90, frequent = 1.05).

Table II shows the localization measures for only those subjects with no previous snorkel and mask experience in the three groups. Again decrease in initial error for the WWW group is suggested although it failed to reach

Table II. Localization measures on test of hand-eye coordination for subjects with no previous experience with mask and snorkel - Water data. Measures in inches.

Group	Initial Error	Error after			Final % Comp.	After-effect		
		10 min.	20 min.	30 min.		(in.)	%	
First day in water								
<u>WWW</u> N=11	1.93	1.66	1.27	1.04	46%	-.68	35%	
<u>LWW</u> N=11	2.23	1.54	1.36	0.98	56	-1.13	51	
<u>LLW</u> N= 6	1.89	1.38	1.03	1.17	38	-.51	27	
Average		2.02	1.53	1.22	1.06	47	-.77	38
Second day in water								
<u>WWW</u>	1.82	1.46	1.41	1.25	31	-.78	43	
<u>LWW</u>	1.69	1.52	1.42	1.15	32	-.73	43	
Average		1.76	1.49	1.41	1.20	31	-.76	43
Third day in water								
<u>WWW</u>	1.58	1.61	1.63	1.29	18	-.39	25	

significance and the decrease in initial error for the LWW group is significant over the two water days ($t=2.4$, $df=10$).

Amount of previous experience under water varied greatly among groups with the LLW group having the most and LWW the next greatest amount. The apparent advantage in adaptation shown by the lens groups in Table I is no longer evident in Table II, suggesting it was a product of their greater underwater experience.

Discussion

The data suggest that previous exposure to magnifying lenses is not effective in reducing either original or final error when subjects are subsequently exposed to the underwater distortion. These subjects perform the same in water as subjects who have had no previous experience at all. Previous exposure to magnifying lenses does not appear to be a valid technique for reducing localization errors under water.

Although the data suggest a decrease in initial error over days, the absolute amount of decrease is not impressive. Furthermore, there is no evidence to suggest a decrease in final error over the three days. Three days may simply not be enough exposure to generate meaningful amounts of compensation.

It is conceivable that many more repetitions of the exposure are necessary to generate a meaningful amount of adaptation. The second experiment was designed to answer this question.

EXPERIMENT II

Procedure

Six individuals volunteered to take part in the experiment. The four men were hospital corpsmen and the two women were graduate students employed by the laboratory.

Each subject returned on the same day each week for eleven weeks. The first week subjects were shown the apparatus, given a brief explanation of the experiment and preliminary tests of hand-eye localization were given in air and in the water using the hand-eye table. The difference between these air and water localizations were taken as the measure of the initial distortion perceived by the individual (Control).

Each week for the next ten weeks the procedure remained the same. It consisted of a pre-test on the hand-eye table in the air followed immediately by a test in the water.

For the next fifteen minutes the subject practiced one of several hand-eye tasks under water. A wide variety of tasks were included in an attempt to cover the whole spectrum of visual-motor responses that a diver might be expected to complete. These tests included Chinese and American checkers, constructing with an erector set, building forms with plastic snap-together blocks, completing a pipe frame test and a nuts and bolts test.

Following the first fifteen minutes of exposure the subject was given a

five-minute break out of the water. He then returned to the water for a second fifteen-minute exposure session during which he engaged in one of the other tasks. Order of presentation of tasks was counterbalanced across subjects across weeks.

Following the second fifteen minutes of exposure, final tests on the hand-eye table were given first in the water and then in the air.

Results

Table III presents the average error for the six subjects over a ten-week period. The decreases in localization error, both initial and final, were small and variable from week to week. The size of the after-effect, too, was small averaging 9% over the ten weeks, and was not correlated with the error measures.

In order to minimize the effect of random weekly fluctuations, the initial and final error data for each successive two weeks were averaged and plotted in Fig. 1. Both measures show a decrease in error over the course of the training period but the amount of improvement is not impressive.

Once again individuals varied widely in their responses to the underwater training. Figures 2 and 3 are examples of the extremes of behavior found.

Figure 2 compares the initial and final error for the only subject who showed good compensation throughout the experiment. This subject shows a progressive decrease both in initial and final error. At the end of the ten weeks

this subject had about a 1" initial error, compared to 3" initial error measured during the first session. At the end of the underwater training, he was displaying almost complete adaptation.

Figure 3 shows the data for a subject more representative of the other five. These subjects showed no progressive decrease in either initial or final error. For this subject the initial error was 2.2" on week one and 2.5" on week ten-- compensation averaged 20% but after ten weeks this subject still showed a final error of 1.8".

Discussion

After ten weeks of training most subjects still show an error of over 1-1/2 inches (70% of the initial error) in attempting to locate an object under water. This amount of adaptation does not compare favorably with other studies of adaptation using lenses^{4,5} and is no better than the previous underwater studies that have used considerably shorter adaptation periods.^{1,2,3}

The actual amount of final error from week one to week ten remained the same (1.75" - 1.80"). A *t*-test revealed no significant differences over the ten weeks (*t* = -.05, *df* = 5). This suggests that after ten weeks' experience under water, subjects were not able to do better than their final performance on the first day of exposure. Again we have been able to generate rapidly a small amount of compensation, and have been unable to further improve performance.

It should be noted that the number of subjects was small, and variability was high. While one subject was finally

Table III. Localization measures on test of Hand-Eye Coordination over ten weeks of underwater training. Measures in inches.

Week	Mean Initial Error	% decrease over Control	Mean Final Error	% decrease over:		Mean After-Effect	% of Control	% same week initial error
				Control	same week initial error			
Control	2.33							
1	2.15	8	1.75	25	19	-.31	13	14
2	2.18	7	2.22	5	0	-.04	2	2
3	2.13	9	1.98	15	8	-.10	4	7
4	2.19	6	1.50	36	32	-.28	12	13
5	1.87	20	1.24	47	34	-.42	18	22
6	2.03	9	1.64	30	19	-.03	1	1
7	1.92	18	1.69	28	12	-.16	7	8
8	1.83	22	1.51	35	18	-.36	15	20
9	1.75	25	1.62	30	8	-.30	13	17
10	1.97	16	1.80	23	9	-.08	3	4
Mean	2.00	14	1.70	27	16	-.21	9	11

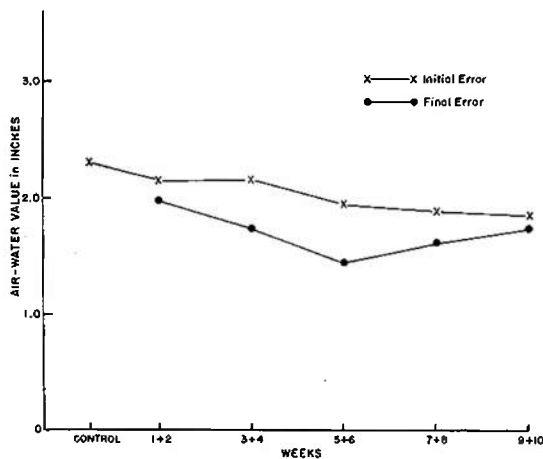


Fig. 1. Localization measures averaged for each successive two-week period.

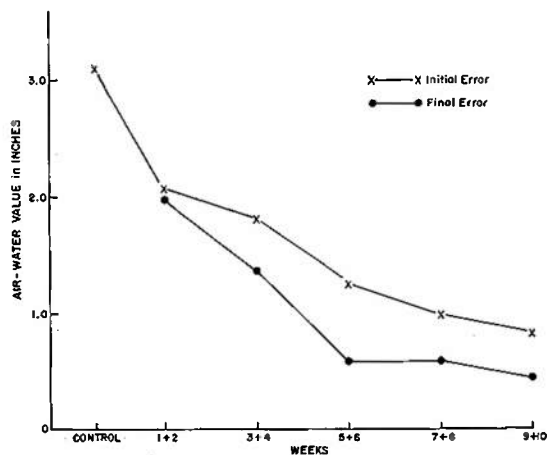


Fig. 2. Localization measures for one subject with good compensation.

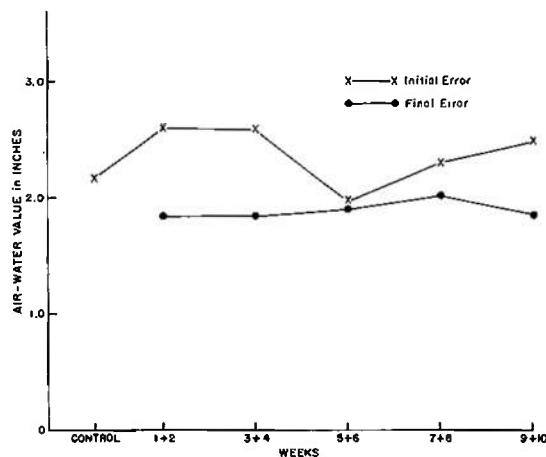


Fig. 3. Localization measures with a subject with little compensation.

able to compensate for the distortion almost completely, the other five had considerably less success.

This great difference between subjects suggests that it might be possible to choose candidates for SCUBA training on the basis of a variety of performance tests, including the results of training sessions in hand-eye coordination. Such a battery might include skill with tools, measures of physical stamina, general dexterity, swimming ability, etc. The broader the range of skills assessed, the more valid the battery results would be.

CONCLUSIONS

In keeping with previous work, we find that a small amount of adaptation is easy to achieve. Neither previous experience with lenses nor considerable repetition of exposure-sessions generated

significantly larger amounts of adaptation than previous studies. At the present time, it appears that prolonged exposure, over the course of many years may be necessary to achieve full adaptation in most subjects. Alternatively it may be possible to choose candidates for SCUBA training on the basis of their performance on a variety of tests, including, but not limited to, tests of ability to adapt to the visual distortion.

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