MOTION PARALLAX AND ABSOLUTE DISTANCE

by

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SUMMARY PAGE

THE PROBLEM

To determine whether absolute distance estimation can be improved by the use of motion parallax information, that is, by purposely introducing head movement.

FINDINGS

When using subjects who were without training, head movement improved their absolute distance estimation. Specific training in the use of motion parallax led to very accurate distance judgments. The presence of a textured background was found to be helpful, but subjects could also use motion parallax relative to a near reference object.

APPLICATION

The results have implications for the training of Navy divers. Since the usual distance information is deficient or distorted under water, distance perception would probably be improved if divers were taught to move their heads. Furthermore, for situations in which accurate distance estimation is important, specific training in the use of motion parallax might be of considerable value.

ADMINISTRATIVE INFORMATION

The investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4306.03-2050DXC9 - Evaluation of Sensory Aids and Training Procedures on Navy Divers' Visual Efficiency. The present report is No. 5 on that Work unit. It was approved for publication on 22 July 1971; and designated as Naval Submarine Medical Research Laboratory Report No. 673.

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ABSTRACT

The accuracy of absolute distance estimation based on monocular motion parallax was determined both before and after specific training. With the usual distance information eliminated, subjects either held their heads stationary, or rhythmically rotated their heads from side to side while judging the distance of stimuli placed 4-15 ft. away. Before training, head movement produced more accurate judgments than head fixed. After only 10 training trials, accurate judgments based on motion parallax were obtained. Results with a textured background were better than results with a white background, only when the subjects were not given any direct information about motion parallax. Good results were also obtained for motion parallax relative to a near reference object (2.5 ft. away). The results indicate that motion parallax can be useful for absolute distance estimation, and they suggest that motion parallax would be useful in the underwater environment, where the usual sources of distance information are absent or distorted.

MOTION PARALLAX AND ABSOLUTE DISTANCE

INTRODUCTION

The underwater environment is characterized by a decrement or distortion in the usual information for depth perception. As a result, stereoacuity is much worse under water than in air (Luria and Kinney, 1968), and large errors occur in absolute distance estimation (Luria, Kinney, and Weissman, 1967; Kinney, Luria and Weitzman, 1969; Ross, 1967; Ferris, 1971). In the context of our attempts to alleviate the poor visual performance under water, the present experiments examined the use of monocular motion parallax to improve absolute depth perception.

Motion parallax has been defined by Graham (1965, p. 504) as follows: "When a subject's eyes move with respect to the environment, or when the environment moves with respect to the subject's eyes, a differential angular velocity exists between the line of sight to a fixated object and the line of sight to any other object in the visual field." If the observer rotates his head from side to side, objects more distant than the fixated object appear to move in the same direction as the head movement, at velocities dependent on their distances from the subject; similarly, objects closer than the fixated object move at velocities dependent on their distances, but they move in the opposite direction. Although Helmholtz (1962, pp. 295-297) believed that motion parallax information is useful for both relative and absolute depth perception, most of the relevant experiments have been concerned only with relative depth Tschermak, 1939; Graham, Baker, Hecht and Lloyd, 1948; Gibson, Gibson, Smith, and Flock, 1959; Smith and Smith, 1963). There seems to be no doubt that motion parallax is a useful (if not precise) source of information for perceiving relative depth. Even infants and newborn animals apparently use motion parallax (Cf. Walk, and Gibson, 1961; Bower, 1965).

A limitation of many of the motion parallax studies is that they were concerned with visual field movement in the absence of observer movement. Park (1964) has shown that visual field movement alone, passive observer movement, and active observer movement, in that order, are progressively more effective for relative depth perception. Park has also suggested that motion parallax cannot provide a basis for perceiving absolute depth. His negative results agree with those of Bourdon (1902). On the other hand, Dees (1966), in the only extensive attempt to use motion parallax for absolute distance, was able to train subjects to make accurate absolute distance estimates based solely on motion parallax. Unfortunately, Dees did not use actual observer movement, and the performance of his subjects before training was not reported. The present experiments were designed to re-examine the use of motion parallax for absolute distance. The observers actively moved their heads from side to side, and results before and after training are reported.

METHOD

Subjects

A total of 70 Navy enlisted men served as subjects. Each had normal vision and took part in only one experiment. None had any prior knowledge of the experimental situation.

Apparatus

The subject sat in a large room, facing a wall which was 19 ft. 5 in. away. The floor and ceiling were blocked from view by a black reduction screen having a large rectangular opening. The screen was 15.5 in. from the subject's eye; the viewing opening was 29 in. wide X 5 in. high (82° 36' X 17° 14'). A sheet of cardboard, painted black, was mounted behind the reduction screen, below the opening and parallel to the floor. It was not normally visible, but it prevented the subject from seeing the floor if he were to raise his head from its normal position. Two long, curved, partitions, draped with white sheets, were placed between the wall and each side of the reduction screen, thus enclosing the area between the screen and the wall.

The wall was covered with either solid white or textured paper. The textured background was constructed by affixing 1/2 inch squares of red tape to white paper, about 27 squares/sq. ft. The width of both backgrounds was 11 ft. (67° 54'), and the effective height was 17° 14', the height of the viewing opening. The backgrounds were illuminated by two strings of 60 w light bulbs which were mounted behind screens, parallel to the wall. One was along the floor and the other was near the ceiling, 34 in. and 30 in. from the wall, respectively. The brightness of the background was 25 ft-L.

The stimuli were 15 strips of wood, painted black, and varying in width from 1.75 - 7.5 in. When presented at the various observing distances, a constant retinal width of 2° 22' was maintained. The top and bottom edges of the strips were masked by the reduction screen, and thus the effective height was always 17° 14'. The basic test distances were 4, 5, 7, 9, 12 and 15 ft. Other distances were included during training sessions. Since the background lights provided the only illumination in the room, and since they were farther from the observer than the farthest stimulus distance, all stimuli appeared as silhouettes against the background. There was some stray illumination, however, due to reflection from the background.

Procedure

There were three phases to each experiment: The initial test (T_1), 10 training trials, and the final test (T_2). Each test distance was presented twice, in random order. The subject's task was to judge the absolute distance of the stimulus, to the nearest ft. or half-ft. Ten different distances were presented during training. Training consisted of the subject's being informed of the correct distance after each judgment. Between each judgment, the viewing opening was covered while a new stimulus was positioned.

All viewing was monocular. Depending on the experimental condition, either the white or the textured background was used. A second experimental variable was the presence or absence of motion parallax information. The subject either kept his head steady by leaning on a chin rest, or rotated his head rhythmically from side to side as he viewed the stimulus.

In the instructions, the subjects were asked to look directly at the stimulus and report how far from them it appeared to be. It was stressed that the task was purposely made difficult and that they should not be concerned if they had some difficulty.

The two judgments of each subject at each distance were averaged, and the median judgments for each group were plotted as a function of physical distance. In addition, power-function exponents (Stevens, 1957) were computed.

EXPERIMENT 1

Method

The variables examined were textured vs white background, and head fixed vs motion parallax. Ten subjects were assigned to each of the four treatment combinations. After T_1, subjects in the motion parallax groups were informed of the nature of motion parallax and were encouraged to use this information in determining their judgments.

Results

The median distance estimates are shown graphically in Figure 1. For textured background, the value of motion parallax is apparent (see Figure 1A). With head fixed, there was very little distance discrimination before training. Training produced some improvement, due mainly to an increase in the magnitude of all judgments. Performance with head movement was much better than with head fixed, both before and after training. Before training, there was considerable underestimation. When questioned after T_1, only one of the ten subjects reported that they noticed the relative movement between stimulus and background. Judgments after training were very accurate.

With the white background (see Figure 1B), the same differences between the head fixed and motion parallax groups were obtained. A direct comparison of the results for the two backgrounds (Figures 1C and 1D) indicates that, except for smaller T_1 estimates for white background with head fixed, the results for the two backgrounds are very similar. Only one of the subjects in the white background, motion parallax group was aware of stimulus movement during T_1.

Power-function exponents for the four groups are listed in the first two rows of Table 1. Since very small values are indicative of very poor distance discrimination, and values close to 1.0 usually represent good distance discrimination, the values obtained are consistent with the graphical results discussed above.

Discussion

With head fixed, the experimental arrangement eliminated virtually all distance discrimination. A particular subject tended to perceive the stimulus at a particular distance regardless of the physical distance. The slight distance discrimination at the nearer

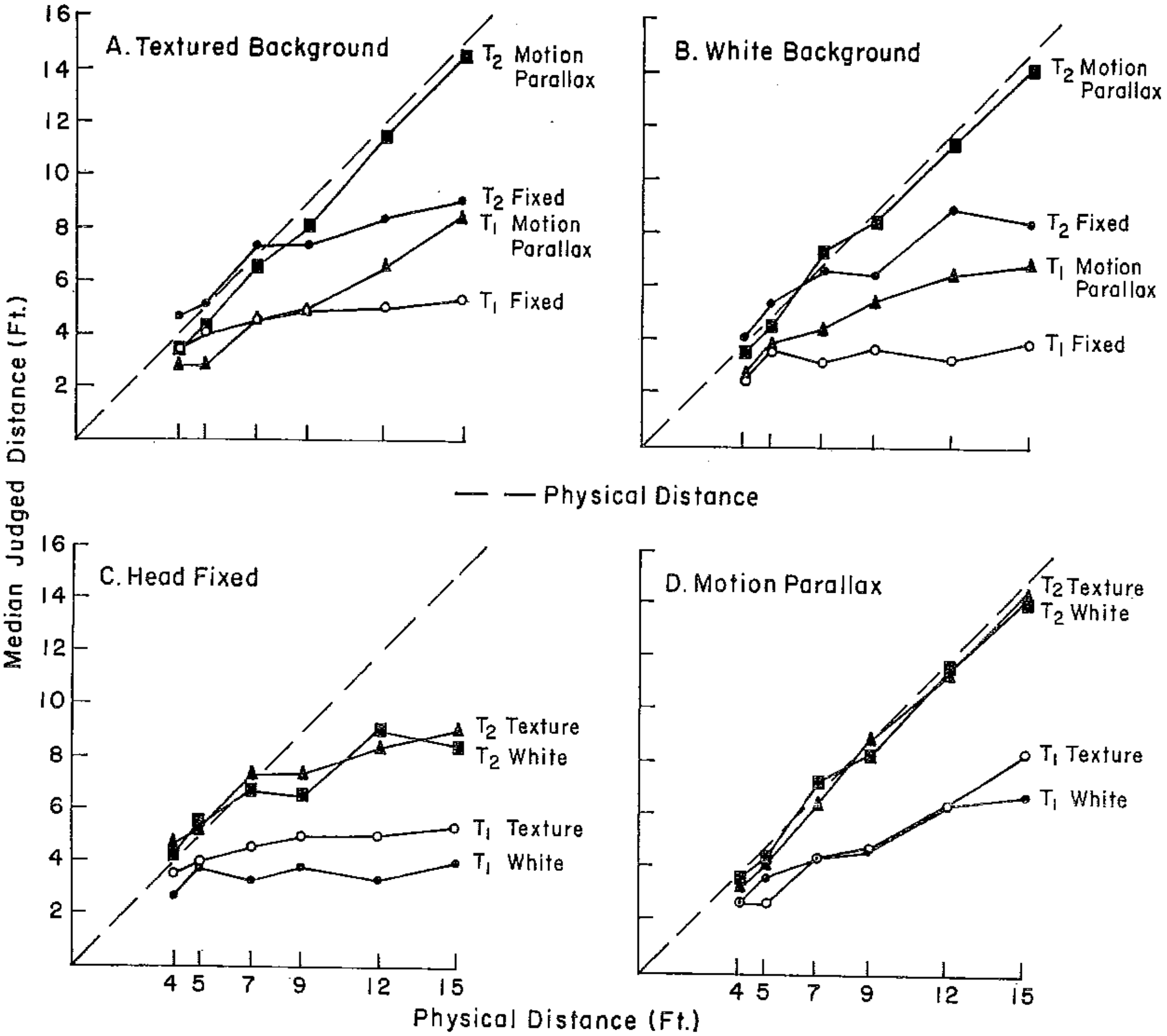

Fig. 1. ***Median distance estimates for T_1 and T_2 in Experiment 1: Head fixed vs. motion parallax, textured (A) and white (B) background groups; textured vs. white background, head fixed (C) and motion parallax (D).***

distances was probably due to accommodation. The very low power-function exponents before training are consistent with the results for "reduced cues" obtained by Künnapas (1968). Training led to some improvement, indicating that some residual distance information remained. Besides comments such as "how it looked," some subjects reported that they based their judgments on size differences. Even though retinal size was constant, the more distant, physically wider, stimuli appeared wider. Since the subjects did not know that the stimuli differed in physical size, the perceived size differences were an

Table 1. Power-Function Exponents

Condition	Textured Background T_1	Textured Background T_2	White Background T_1	White Background T_2
Motion Parallax	.93	1.11	.65	1.04
Head Fixed	.32	.51	.19	.52
Motion Parallax-Uninformed	.80	.99	.85	.93
Near Reference				
Head Fixed			.45	-
Motion Parallax			-	1.03

inappropriate basis for judging physical distance.

An unexpected result of the experiment was that the presence or absence of a textured background had no important effect on the usefulness of motion parallax information. A possible explanation for this result is, that once the subject was looking for relative movement, there was enough noticeable texture on the white background to permit maximal performance. Hence, adding additional texture would have no important effect. This possibility was tested in the next experiment.

EXPERIMENT 2

Method

Two additional motion parallax groups were tested, one for each background. There were 10 subjects in each group. In contrast to the previous experiment, these subjects were not informed about the nature of motion parallax prior to the training trials. The training procedure was otherwise the same as in the previous experiment.

Results

The results (See Figure 2A) indicate that the presence of a textured background made a considerable difference, when the subjects were not told about motion parallax. Training produced considerable improvement for the textured background, but a relatively small improvement for the white background. When questioned after the experiment, three subjects in the "texture" group and no subjects in the "white" group reported that they used motion parallax information. Comparison with the motion parallax results of Experiment 1 (see Figures 2B and 2C) indicates that, except for T_2 with a white background, the results for the two experiments are very similar. Power-function exponents for the "uninformed" groups are listed in the third row of Table 1.

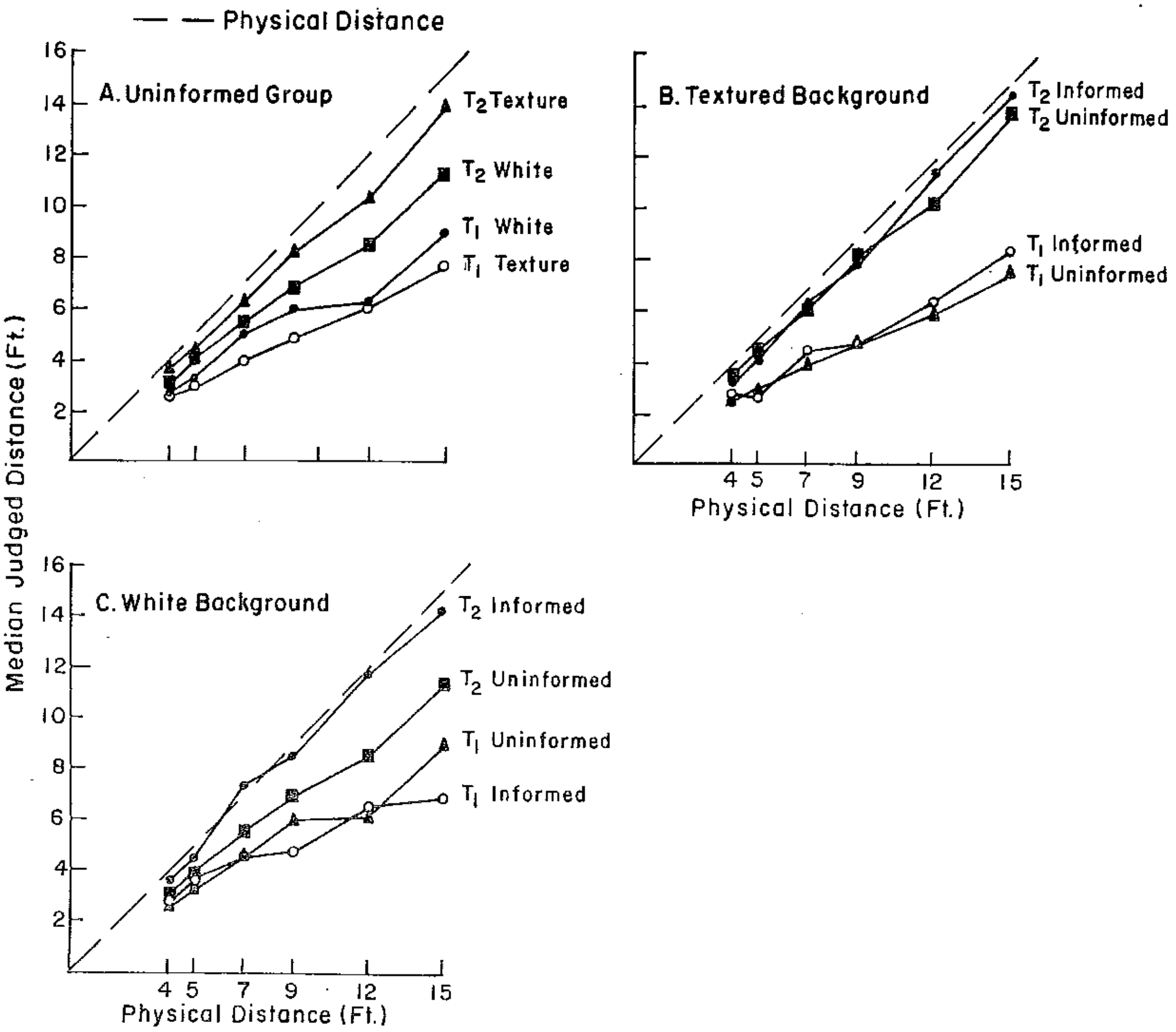

Fig. 2. Median distance estimates, based on motion parallax, for T_1 and T_2 in Experiment 2: Uninformed group, textured vs. white background (A); Uninformed group vs. informed group (from Experiment 1), textured (B) and white (C) backgrounds.

EXPERIMENT 3

Method

In the first two experiments, the parallax movement was relative to a background which was more distant than the stimulus. This experiment examined motion parallax relative to an object nearer than the stimulus. A 3/4 in. wide vertical black strip (1° 26') was mounted behind the viewing opening, 30 in. from the observer and 3° 56' to the left of the test stimuli. The white background was used. A group of 10 subjects was tested with head fixed (T_1), informed about motion parallax (relative to the near strip) and trained with head movement, and then retested with head movement (T_2).

Results

The data demonstrate the effectiveness of motion parallax with a near reference. In Figure 3, the results are compared with the corresponding results from Experiment 1. With head

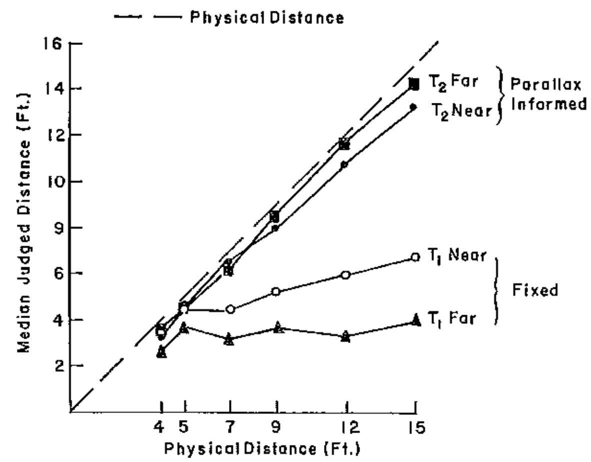

Fig. 3. Median distance estimates for T_1 (head fixed) and T_2 (motion parallax, informed) based on a near reference object (Experiment 3) and a far reference background (Experiment 1, white background).

fixed, distance perception with the near reference strip was initially poor, but somewhat better than when the strip was not present. Training with head movement and the near reference led to substantial improvement. The judgments were almost as accurate as with the far reference. The power-function exponents are listed in Table 1.

GENERAL DISCUSSION

These experiments have demonstrated that prior to any training, absolute distance perception is better with head movement than with head fixed. This result is inconsistent with the view of Park (1964) that motion parallax is not useful for perceiving absolute distance. It is significant that the head movement condition was superior, even though almost all of the subjects reported that they were not aware of the motion parallax information. The visual system is apparently capable of using, to some extent, information which is added when the head is rotated from side to side. The present research leaves open the question of precisely what added information is utilized.

The experiments also demonstrate that training subjects to use motion parallax information can lead to accurate distance estimation. This result extends the work of Dees (1966) to include the situation in which the visual field movement results from active head movement. It is of interest that whereas Dees' subjects achieved maximal performance after four presentations of each test distance, the subjects in the present experiments performed well after only 10 trials in which no distance was presented more than once. The rapid learning in the current research possibly reflects an advantage of active head movement over visual field movement with head fixed. Another result of interest concerns the importance of a textured background and of specifically informing the subjects about motion parallax. When directly informed, the subjects performed similarly regardless of the background. Apparently, only minimal differentiation within the background is necessary when the subject is consciously responding to motion parallax information. On the other hand, a textured background led to more accurate performance when the subjects were not informed of the nature of motion parallax.

There is an important practical limitation to training subjects to use motion parallax based on motion relative to a background. Unless the background is always located at infinity, as was the case in Dees' (1966) experiment, or unless the finite distance of the background is permanently fixed, as in Experiments 1 and 2, the proper scaling of motion parallax as a function of stimulus distance will vary with differences in the distance of the background. Consequently, training in the use of motion parallax with a particular background distance is probably of limited practical value. This limitation was the reason for examining the use of a near reference object in Experiment 3. An observer can always place a near object, such as an outstretched finger, in front of him. Since the subjects successfully used motion parallax with a near reference, the practical limitation of depending on a background can be eliminated. This result is particularly important in regard to the underwater environment, where water turbidity may often eliminate the presence of a definitely localized background. The potential value of motion parallax under water will be directly examined in future underwater experiments.

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13. ABSTRACT

The accuracy of absolute distance estimation based on monocular motion parallax was determined both before and after specific training. With the usual distance information eliminated, subjects either held their heads stationary or rhythmically rotated their heads from side to side while judging the distance of stimuli placed 4-15 ft. away. Before training, head movement produced more accurate judgments than head fixed. After only 10 training trials, accurate judgments based on motion parallax were obtained. Results with a textured background were better than results with a white background only when the subjects were not given any direct information about motion parallax. Good results were also obtained for motion parallax relative to a near reference object (2.5 ft. away). The results indicate that motion parallax can be useful for absolute distance estimation, and they suggest that motion parallax would be useful in the underwater environment, where the usual sources of distance information are absent or distorted.

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