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THE ROLE OF VISUAL CONTEXT IN MANUAL TARGET LOCALIZATION

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ABSTRACT

During space flight and immediately after return to the 1-g environment of earth, astronauts experience perceptual and sensory-motor disturbances. These changes result from adaptation of the astronaut to the microgravity environment of space. During space flight, sensory information from the eyes, limbs and vestibular organs is reinterpreted by the central nervous system in order to produce appropriate body movements in microgravity. This adaptation takes several days to develop. Upon return to earth, the changes in the sensory-motor system are no longer appropriate to a 1-g environment. Over several days, the astronaut must re-adapt to the terrestrial environment

Alterations in sensory-motor function may affect eye-head-hand coordination and, thus, the crewmember's ability to manually locate objects in extrapersonal space. Previous reports have demonstrated that crewmembers have difficulty in estimating joint and limb position and in pointing to memorized target positions on orbit and immediately postflight. The ability to point at or reach toward an object or perform other manual tasks is essential for safe Shuttle operation and may be compromised particularly during re-entry and landing sequences and during possible emergency egress from the Shuttle. An understanding of eye-head-hand coordination and the changes produced during space flight is necessary to develop effective countermeasures. This summer's project formed part of a study of the sensory cues used in the manual localization of objects.

To point or reach toward a target, a subject must determine the precise location of the object in extrapersonal space. The position of the target can be determined by using either an egocentric or allocentric reference frame. In an egocentric reference frame, the object is located in relation to the position of the subject's body . In an allocentric reference frame, the object is localized in relation to other objects in the external visual world. The goal of this summer's project was to determine the relative role of egocentric and allocentric cues in pointing movements.

In order to determine the relative importance of egocentric and allocentric cues, subjects were asked to point in the dark to the remembered position of a target. The target was initially seen either against a plain, dark background or against a featured background, that is as part of a rich visual scene. If egocentric cues are used primarily for pointing movements then the presence of the featured background should not affect pointing accuracy. In contrast, if allocentric cues are necessary for accurate pointing movements, then the presence of the featured background will improve pointing performance. The results from this study indicate that the presence of a featured background does not improve pointing accuracy. Therefore, egocentric as opposed to allocentric cues may be used primarily for pointing movements.

INTRODUCTION

During space flight and immediately after return to the 1-g environment of earth, astronauts experience perceptual and sensory-motor disturbances (Young *et al* , 1984) . For example, after flight, crewmembers encounter gait and postural instability. Even two days postflight, astronauts show increased dependence on visual cues to prevent falling (Kenyon and Young, 1986). Sensations of self or surround motion are experienced by crewmembers during voluntary head movements. These perceptual and sensory-motor changes result from adaptation of the astronaut to the microgravity environment of space. During space flight, sensory information from the eyes, limbs and vestibular organs is reinterpreted by the central nervous system in order to produce appropriate body movements in microgravity. This adaptation takes several days to develop. Upon return to earth, the changes in the sensory-motor system are no longer appropriate to a 1-g environment. Over several days, the astronaut must re-adapt to the terrestrial environment.

Alterations in sensory-motor function may affect eye-head-hand coordination and, thus, the crewmember's ability to manually locate objects in extrapersonal space. Previous reports have demonstrated that crewmembers have difficulty in estimating joint and limb position and in pointing to memorized target positions on orbit and immediately postflight (Watt *et al* 1985). The ability to point at or reach toward an object or perform other manual tasks is essential for safe Shuttle operation and may be compromised particularly during re-entry and landing sequences and during possible emergency egress from the Shuttle. An understanding of eye-head-hand coordination and the changes produced during space flight is necessary to develop effective countermeasures. This summer's project formed part of a study of the sensory cues used in the manual localization of objects.

To point or reach toward a target, a subject must determine the precise location of the object in extrapersonal space. The position of the target can be determined by using either an egocentric or allocentric reference frame. In an egocentric reference frame, the object is located in relation to the position of the subject's body (Paillard, 1991; Blouin *et al.*, 1993). Egocentric cues include the direction of gaze and proprioceptive information on the position of the limbs. In an allocentric reference frame, the object is localized in relation to other objects in the external visual world. Thus, the egocentric system is dependent upon internal signals while the allocentric system is dependent upon external cues. The goal of this summer's project was to determine the relative role of egocentric and allocentric cues in pointing movements.

In order to determine the relative importance of egocentric and allocentric cues, subjects were asked to point in the dark to the remembered position of a target. The target was initially seen either against a plain, dark background or against a featured background, that is as part of a rich visual scene (Figure 1). If egocentric cues are used primarily for pointing movements then the presence of the featured background should not affect pointing accuracy. In contrast, if allocentric cues are necessary for accurate pointing movements, then the presence of the featured background will improve pointing performance. The results from this study indicate that the presence of a featured background does not improve pointing accuracy. Therefore, egocentric as opposed to allocentric cues may be used primarily for pointing movements.

METHODS

Subjects:

Ten subjects, four males and six females, ranging in age from 20 to 50 years, were tested. Six of the subjects were right-handed while four were left-handed.

Experimental setup:

In order to measure pointing accuracy, subjects were seated in a chair located one meter from the center of a screen. The target was illuminated on the center of the screen at eye-level.

A laser for pointing was mounted onto a plastic sleeve which then fit over the subject's index finger . The laser was secured with Velcro straps, and its position on the finger was adjusted along the vertical axis. The subject wore the laser on the preferred hand and held the controls for the laser in the opposite hand. For each test, subjects practiced pointing with the laser at the target on the screen and adjusted the position of the laser along the vertical axis until they were confident that the laser beam projected in the direction that they perceived to be pointing.

The target was initially displayed on a computer monitor and then projected onto the viewing screen using an overhead projector equipped with a special display panel (Proxima Corporation, San Diego CA.). The display panel possessed an auxiliary scanning device that was used to record the laser beam spot on the display screen when the subject pointed with the laser at the remembered target position. The display window has a resolution of 640 units horizontal by 480 units vertical. Software was written both to momentarily display a target on the screen and then dynamically record the coordinates of the laser spot (Figure 2).

Experimental protocols:

After the position of the laser beam was adjusted on the finger, the subject was asked to fixate on but not point at the target on the screen. The lights were then extinguished and the subject was asked to point in

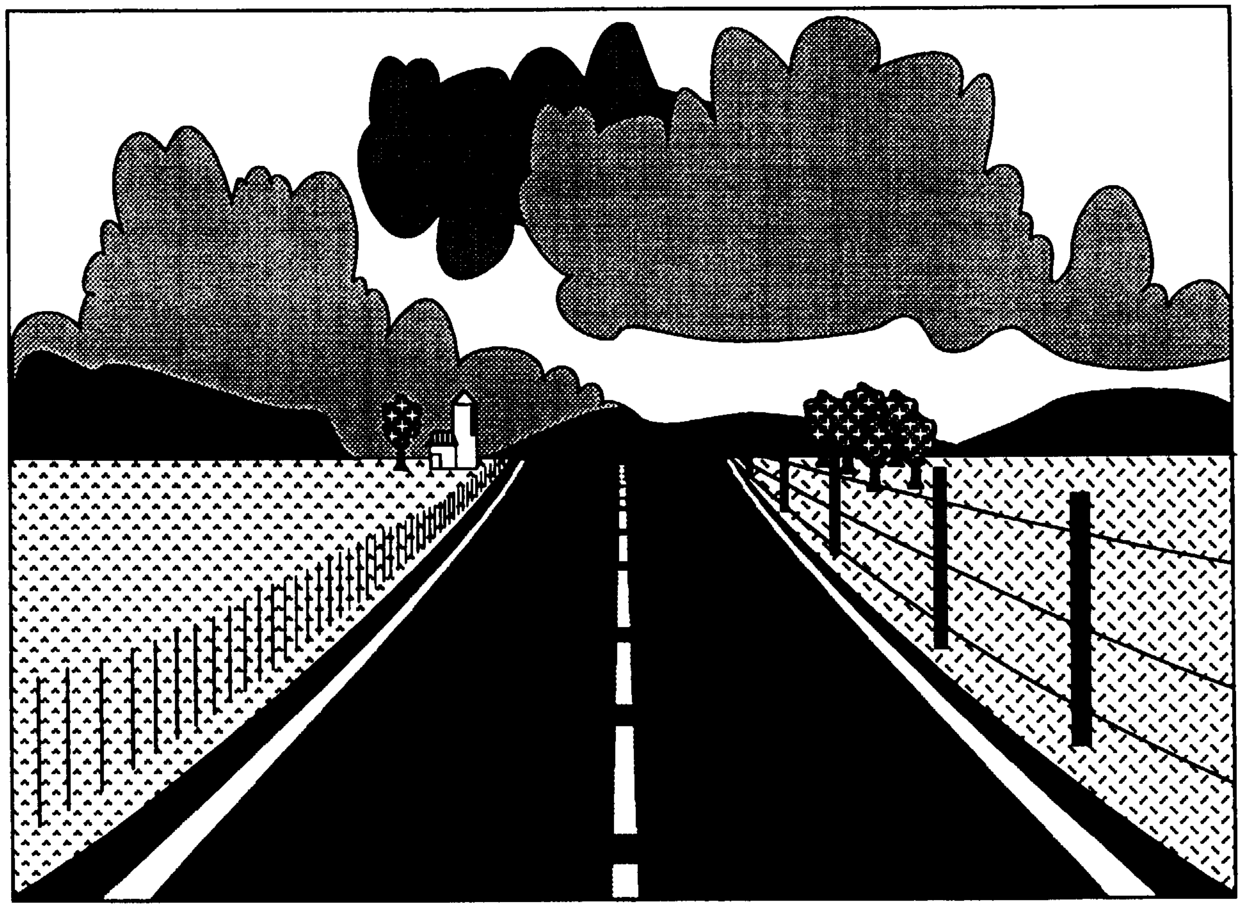

Figure 1.- The featured background. The target is seen here in the center of the visual scene.

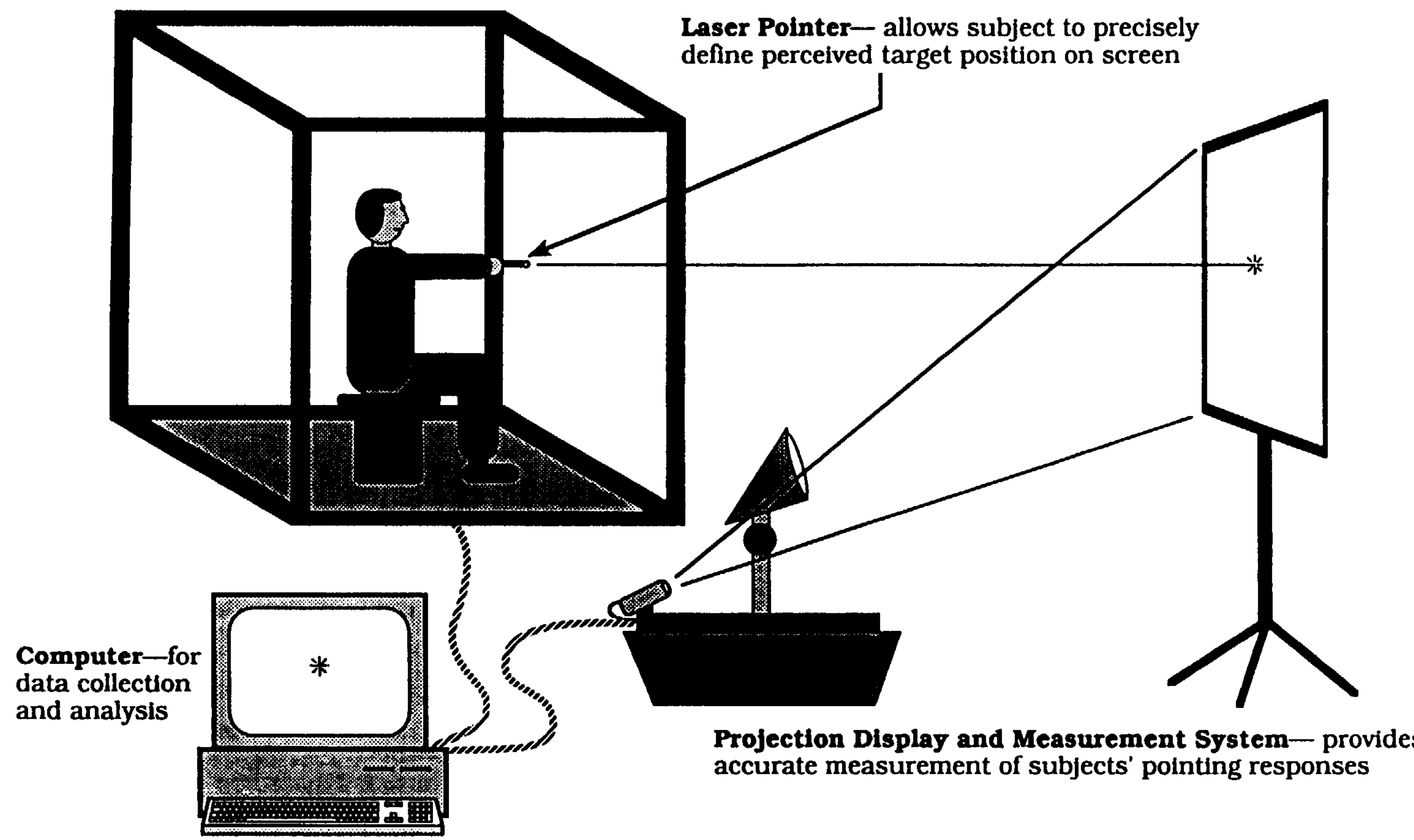

Figure 2.- The experimental set-up.

the dark at the screen to the remembered position of the target. After pointing, the subject lowered his or her arm, the screen was re-illuminated and the target again appeared on the screen for another pointing trial. This procedure was repeated thirty times.

Four different variations of the pointing task were run. For each type of test, the same ten subjects were used. The four variations are described below:

1.) The target consisted of a bright spot always positioned at the center of the screen. The target was seen against a plain, dark background.

2.) The target consisted of a bright spot always positioned in the center of the screen. The target was seen against a featured background, that is within a visual scene (Figure 1). The scene, a landscape of a farm, road and sky, was designed to give the subject cues as to what was up and what was down. The road bisected the scene, and the images on either side of the road were not identical so that the scene contained asymmetrical right and left halves.

3.) The target consisted of a bright spot that was randomly positioned on the screen for each of the thirty trials. The target was seen against a plain background.

4.) The target consisted of a bright spot that was randomly positioned on the screen for each of the thirty trials. The target was seen against a featured background.

For the ten subjects, the order of the tests was always 1 through 4. The time between each test was at least four days. The rationale for the design of the four types of tests is given below.

The subjects were asked to point in the dark so as to eliminate any vision of their limbs while pointing. Vision of the limbs would provide a cue for pointing that is not purely egocentric or allocentric and would thus confound interpretation of the experimental results. By pointing in the dark, the subjects also received minimal feedback of how accurately they had pointed.

If the target was seen against a plain background (tests 1 and 3), then the subject relied on egocentric cues, ie the direction of the gaze and the position of the arm, to help determine where to point. If the target was seen against a featured background (tests 2 and 4), then the subject could use allocentric as well as egocentric cues to help determine where to point. Allocentric cues would include the relationship of the target to other images on the screen.

If the target was always located at the center of the screen (tests 1 and 2) , then with repeated trials, the subject may be able to use the memory of his or her arm position during each trial to help determine where to point. If the target was found at a different locations with each trial (tests 3 and 4) , then a memory of the arm position used in the former trial will be less useful in determining where to point.

Data analysis:

The resultant deviation in centimeters of the position of the laser beam from actual target position on the screen was determined for each trial. This deviation was considered the pointing error. The values of pointing error for all thirty trials were then averaged. Mean values of pointing error were compared between the four types of tests for a single subject using a Student's unpaired, two-tailed T test. A p value of less than 0.05 indicated a significant difference between the means.

RESULTS

The pointing error from subject to subject ranged from an average of 3.5 cm to 37 cm. No consistent difference was seen between the four left-handed and six right-handed subjects.

The mean pointing error was compared for each subject between tests in which the target was presented at a central spot on the screen against either a plain or featured background (Figure 3). For four of the subjects, the pointing accuracy improved when the target was seen against a plain background; for two of the subjects, pointing accuracy improved when the target was seen against a featured background, while for two subjects, no significant difference was seen in tests using a plain or featured background . Thus, the featured background generally produced no improvement in pointing performance. Since the test involving a plain background was always performed before the test using a featured background, the improvement with a featured background for two of the subjects may simply reflect improvement from practice. When a second test was run on the two subjects using a plain background, no significant difference was seen between the second test using a plain background and the test using a featured background (pointing error for subject G, plain background, test 2: 8.34+/-0.69; featured background: 7.58 +/- 0.73; pointing error for subject H, plain background, test 2: 10.39+/-0.76, featured background: 11.26+/-1.21).

Mean pointing error was also compared for each subject between tests in which the target was randomly located on the screen for each trial either against a plain or featured background (Figure 4). No difference between a plain and featured background was seen in pointing accuracy for six of the ten subjects. Two subjects performed more accurately using a plain background while two subjects performed more

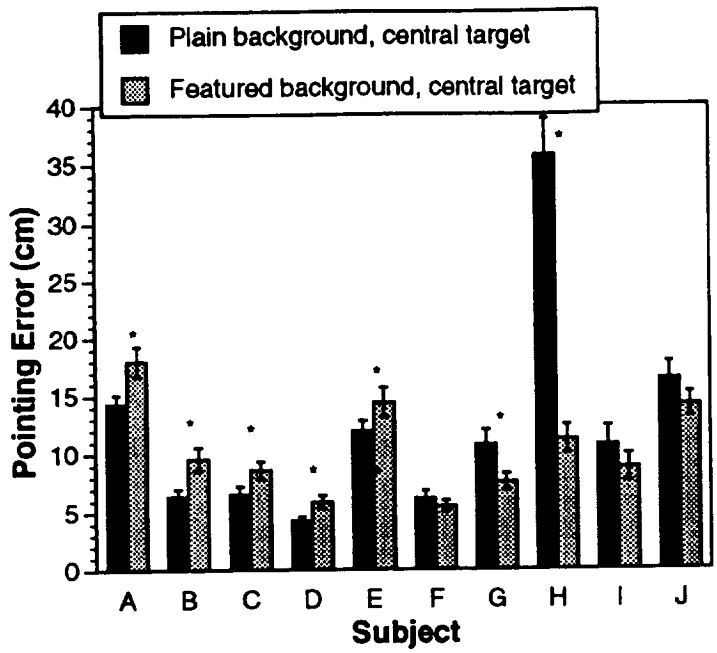

Figure 3.- Error in pointing at a central target seen by the subject against a plain or featured background. Data represent mean +/- S.E.M. of thirty trials. Asterisks indicate significant difference.

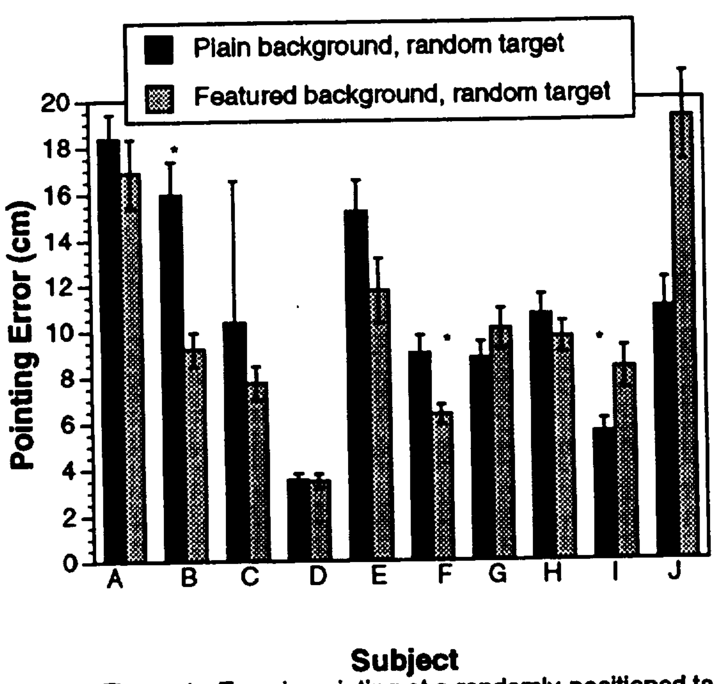

Figure 4.- Error in pointing at a randomly-positioned target seen by the subject against a plain or featured background. Data represent mean +/- S.E.M. of thirty trials. Asterisks indicate significant difference.

accurately using a featured background. As with the tests involving a centrally-located target, the featured background generally did not improve pointing accuracy.

As can be seen in figure 5 and 6, subjects pointed with similar accuracy when the target was centrally-located for all trails as when the target was located at a different position on the screen for each trial. When the target was seen against a plain background (Figure 5), three subjects performed more accurately when pointing at a centrally-located target while three subjects pointed more accurately when the target was randomly-located. No significant differences between centrally- and randomly- located targets were seen for four subjects. When the target appeared against a featured background (Figure 6), one subject performed more accurately with a randomly-located target while two pointed more accurately at a centrally-located target. For the other seven subjects, no significant differences were seen.

DISCUSSION

The experiments performed in this study were designed to test whether or not subjects use egocentric or allocentric cues in pointing at a target. If allocentric cues are used, then the placement of the target in a featured background should enhance pointing accuracy over that seen when the target is placed in a plain background. However, subjects pointed with similar accuracy whether the target was placed in a plain or featured background. This result was seen whether or not the target was located in the same central spot or at a different location with each pointing trial.

One concern in the interpretation of these experiments is the ability of the subjects to perform consistently from day to day. For example, the subjects may learn during the first test how to point more accurately and, therefore, perform better on the second test for reasons unrelated to the changes in target position or type of background. The learning that occurs from test to test is minimized by the fact that the subjects receive no visual feedback during trials of how accurately they pointed. In every test, the subjects pointed in the dark to a remembered location of the target. Furthermore, the test using a featured background was always performed after the test using a plain background. If the subjects had learned to point more accurately from the first test with a plain background, then they should all perform more accurately in the second test using a featured background. Yet, eight out of the ten subjects did not point more accurately on the second, featured-background test. Two subjects did perform more accurately. When they were retested using a plain background, they pointed with the same accuracy as they had in the test with the featured background. Thus,

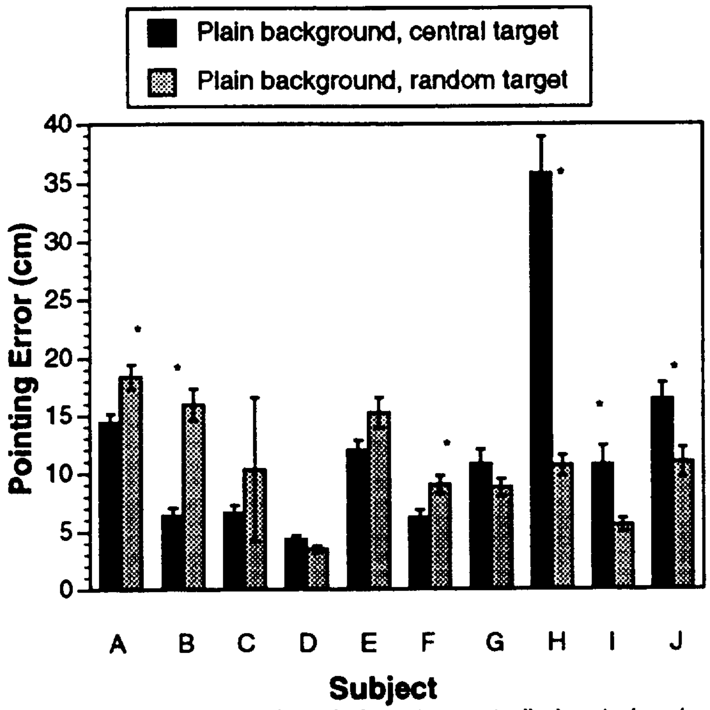

Figure 5.- Error in pointing at a centrally-located and randomly-located target seen by the subject against a plain background. Data represent mean +/- S.E.M. of thirty trials. Asterisks indicate significant difference.

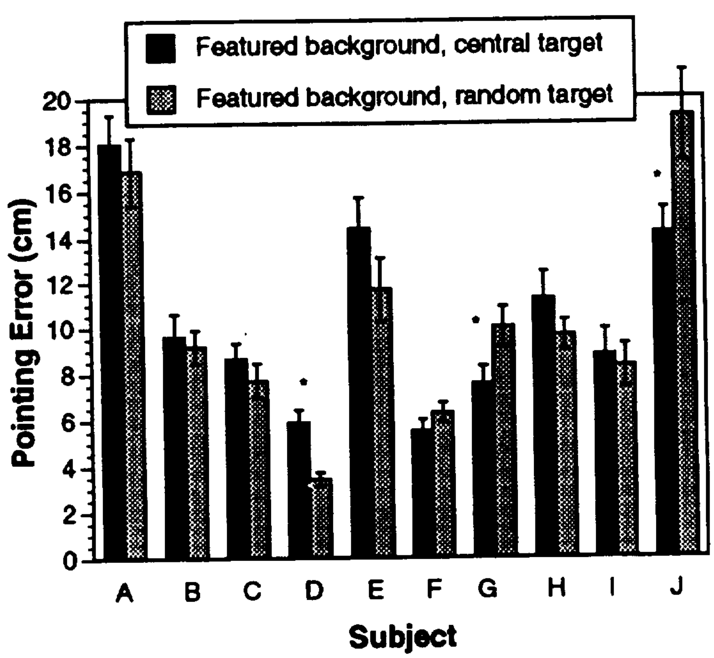

Figure 6.- Error in pointing at a centrally-located and randomly-located target seen by the subject against a featured background. Data represent mean +/- S.E.M. of thirty trials. Asterisks indicate significant difference.

the improvement seen in these two subjects when tested with a featured background may result more from learning how to point more accurately than from the presence of a featured background.

These data strongly indicate that a featured background does not improve pointing accuracy over that seen using a plain background. Thus, egocentric cues, such as the direction of gaze and the position of the limbs, play a much greater role in pointing accuracy than allocentric cues. Subjects determine where to point by the relationship of the target to themselves as opposed to the relationship of the target to other images in the external visual field.

Similar results have been reported by Blouin *et al*., (1993). These investigators determined that humans point with equal accuracy when the target was seen either in a dark room or in a lighted structured environment. In their experiments, the subject observed the target while pointing. In contrast, in the experiments reported here, the subjects pointed to a remembered location of the target.

Further evidence for an egocentric bias in pointing is seen in the experiments of Stark and Bridgeman (1983). These investigators tested the role of eye position during pointing. They pressed on the subjects eyes during a pointing task in order to send to the central nervous system incorrect information about the position of the eyes. If the target was seen against a featured background, the subjects *perceived* the location of the object correctly. However, they *pointed* to the wrong location in the direction incorrectly given by the eye position signal (Paillard, 1991).

A surprising result from the experiments reported here is that subjects performed with equal accuracy when pointing at target that was centrally-located for each trial as when pointing at a target that was in a different position with each trial. Before each test, the subjects adjusted the position of the laser on their finger by pointing at a centrally-located target at the screen. During this adjustment period, the subjects received visual feedback of how accurately they had pointed. Thus, one might suspect that the subjects would perform better in subsequent tests involving a centrally-located target. Moreover, in tests where the target was located at a central position with each trial, the subject may remember the arm and hand position used in the former trial and use this information as a cue for where to place the arm and hand when pointing in the subsequent trial. Since the majority of subjects performed with equal accuracy in tests involving centrally- and randomly-located targets, other cues, such as eye position, may be more important in determining where to point. This result merits further investigation.

This summer's study not only provided information on the role of egocentric and allocentric cues in manual localization of targets but also provided information for the design of future experiments. One of the major goals of the laboratory is to determine the role of vestibular signals in manual pointing movements. Vestibular input from the otoliths and semicircular canals provides information on head movements and the position of the head with respect to gravity and thus contributes to the perception of the position of the body in space. While on orbit and following return to earth, astronauts' vestibular responses change. These changes may affect goal-directed pointing movements. To determine the role of the vestibular system in pointing movements, subjects will be asked to point to objects following transient rotational or linear displacement (Bloomberg *et al.*, 1991). One question in the design of these experiments is whether to place the target in a plain or featured background. The results of this summer's experiments indicate that maximal pointing accuracy can be obtained when the target is placed against a plain, dark background.

During space flight, signals from proprioceptive and vestibular receptors are re-interpreted by the central nervous system. As a result, the egocentric reference frame is altered. Immediately postflight, crewmembers are more dependent than preflight on visual or allocentric cues for maintaining balance and locomotion. The relative importance of egocentric and allocentric cues in pointing movements and other manual tasks may also change postflight. Different results from those reported here may be seen if this study was performed on crewmembers shortly after their return to earth.

REFERENCES

1.) Bloomberg J, Jones GM, Segal B (1991) Adaptive modification of vestibularly perceived rotation. *Exp. Brain Res.* 84: 47-56.

2.) Blouin J, Bard C, Teasdale N, Paillard J, Fleury M, Forget R, Lamarre Y (1991). Reference systems for coding spatial information in normal subjects and a deafferented patient. *Exp. Brain Res.* 93: 324-331.

3.) Kenyon RV, Young LR (1986). MIT/Canadian vestibular experiments on Spacelab-1: 4. Pstural responses following exposure to weightlessness. *Exp. Brain Res.* 64: 335-346.

4.) Paillard J (1991). Motor and representational framing of space. In: Paillared J (ed.) *Brain and Space.* New York: Oxford Univ. Press, pp. 163-182.

5.) Stark L and Bridgeman B (1983). Role of corollary discharge in space constancy. *Perception and Psychophysics.* 34: 371-380.

6.) Watt DGD. Money KE, Bondar RL, Thirsk RB, Garneau M, Scully-Power P (1985). Canadian medical experiments on shuttle flight 41-G. *Can Aeronaut. Space J.* 31:215-226.

7.) Young LR, Oman CM, Watt DGD, Money KE, Lichtenberg BK (1984). Spatial orientation iin weightlessness and readaptation to earth's gravity. *Science.* 225: 205-208.