

INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.
2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.
4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.
5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

76-2540

LONGRIDGE, Thomas Maxwell, Jr., 1943-
THE EFFECTS OF PREEXPOSURE PRACTICE AND VISUAL
FEEDBACK ON LOCUS OF ADAPTATION TO PRISMATIC
DISPLACEMENT.

The University of Arizona, Ph.D., 1975
Psychology, experimental

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE EFFECTS OF PREEXPOSURE PRACTICE AND
VISUAL FEEDBACK ON LOCUS OF ADAPTATION
TO PRISMATIC DISPLACEMENT

by

Thomas Maxwell Longridge, Jr.

A Dissertation Submitted to the Faculty of the
DEPARTMENT OF PSYCHOLOGY
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA

1 9 7 5

THE UNIVERSITY OF ARIZONA

GRADUATE COLLEGE

I hereby recommend that this dissertation prepared under my
direction by Thomas Maxwell Longridge, Jr.
entitled The Effects of Preexposure Practice and
Visual Feedback on Locus of Adaptation
to Prismatic Displacement
be accepted as fulfilling the dissertation requirement of the
degree of Doctor of Philosophy

Lawrence Whalen
Dissertation Director

29 July 1975
Date

After inspection of the final copy of the dissertation, the
following members of the Final Examination Committee concur in
its approval and recommend its acceptance:*

Robert Lansing
Neil R. Butler
Ronald Hoof
Peter Madison

July 14, 1975
July 23 '75
July 23, 1975
July 23, 1975

*This approval and acceptance is contingent on the candidate's
adequate performance and defense of this dissertation at the
final oral examination. The inclusion of this sheet bound into
the library copy of the dissertation is evidence of satisfactory
performance at the final examination.

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: *Thomas Maxwell Longridge*

ACKNOWLEDGMENTS

The author is grateful to Drs. Lawrence Wheeler and Neil R. Bartlett for their encouragement and helpful advice in the planning and conduct of this dissertation. Special thanks is extended to Mr. Charles Davison, whose experience, skill, and limitless patience contributed immeasurably to the construction of a sound apparatus.

TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF ILLUSTRATIONS	vi
ABSTRACT	vii
INTRODUCTION	1
METHOD	13
Subjects	13
Apparatus	13
Experimental Design	17
Procedure	18
RESULTS	25
DISCUSSION	46
REFERENCES	52

LIST OF TABLES

Table	Page
1. Analysis of Variance of Mean Adaptation Scores	26
2. Intercorrelation Matrix	44
3. Multiple Linear Regression Analysis	45

LIST OF ILLUSTRATIONS

Figure	Page
1. Perspective View of Apparatus	14
2. Mean Adaptation in Degrees as a Function of Exposure Condition	29
3. Mean Adaptation in Degrees as a Function of Measure	31
4. Mean Adaptation in Degrees as a Function of Measure and Practice Condition	33
5. Mean Adaptation in Degrees as a Function of Measure and Exposure Condition	36
6. Mean Adaptation in Degrees as a Function of Order and Practice Condition	38
7. Mean Adaptation in Degrees as a Function of Exposure Condition and Practice Condition	40
8. Mean Adaptation in Degrees as a Function of Measure, Practice Condition, and Exposure Condition	41

ABSTRACT

The purpose of this experiment was to test several theoretical formulations concerning the nature of the adaptation which develops as a consequence of prismatic displacement. The effects of preexposure practice and exposure visual feedback on adaptation to a prismatically displaced visual field were studied on four dependent variables: (a) visual egocenter, (b) proprioceptive egocenter, (c) target pointing - exposed hand, and (d) target pointing - nonexposed hand. The results indicated preexposure practice increased adaptation in the visual measure and decreased it in the proprioceptive measure. Increased exposure visual feedback of limb position produced increased proprioceptive adaptation and decreased visual adaptation. Exposure conditions which limited the subject to proprioceptive cues increased visual adaptation and decreased proprioceptive adaptation. Of particular interest was the finding that under conditions of no visual feedback during exposure, preexposure practice was a sufficient condition for adaptation to occur. The results also indicated that adaptation in the target pointing-nonexposed hand measure could most parsimoniously be accounted for by the effects of adaptation in the visual

system. Finally, the results provided support for a linear component model of adaptation. The findings were discussed in the context of their theoretical implications.

INTRODUCTION

Adaptation to the prismatically displaced visual image has been a subject of interest since the earliest days of experimental psychology, having been studied in both the laboratories of Helmholtz (1862) and Wundt (1894). Renewed interest in the topic has occurred in recent years because of its usefulness as a tool for the study of basic perceptual processes. By interrupting the normal interaction between vision and other modalities, increased understanding of that process may be obtained. The existence of perceptual constancies despite distorted information from the external environment suggests adaptation to sensory discrepancy plays an important role in perception.

Evidence that adaptation to gross rearrangement of the perceptual environment could occur was dramatically revealed by the work of Stratton (1896, 1897), who studied the perceptual effects of wearing lenses which reinverted the visual image. Surprisingly, few other researchers devoted attention to this area until the work of Ivo Kohler (1964) and his associates at the University of Innsbruck became generally known. Like Stratton, these investigators studied the long term effects on perception of wearing distorting prisms and mirrors, and reported marked perceptual changes.

The present experiment is concerned with a considerably more circumscribed procedure than that employed in the latter research. Our interest here will be limited to optical transformations involving relatively brief lateral displacement of the visual field. Substantial adaptation effects can nevertheless be observed under such conditions with exposure periods as brief as three minutes (Harris, 1963).

The basic experimental paradigm of interest may be divided into three stages: preexposure, exposure, and postexposure. During preexposure, measures of task accuracy (e.g., target pointing) are taken without visual feedback of bodily movement. The subject is then exposed to a given degree and duration of prismatic displacement. During exposure typically he is required to engage in a specific motor task, and provided with visual feedback of his limb movements. Under such conditions the subject at first exhibits lateral localization errors in motor movements. However, the size of the error typically diminishes rapidly with duration and repeated trials. In postexposure the prismatic displacement is removed and measures of task accuracy are again taken without visual feedback of bodily movement.

The degree of adaptation achieved by the intervening exposure to a prismatically displaced visual field may be defined by the degree to which the postexposure measurements

relative to the preexposure measurements are biased in the direction opposite to the optical displacement. It may be measured in the limb exposed to view during prismatic exposure, as well as in the contralateral, nonexposed limb. In the latter case it is commonly referred to as intermanual transfer.

Adaptation may be thought of as a consequence of intermodality cue discrepancy, regardless of how this discrepancy is generated (Wallach, 1968). When the subject first views his hand through a prism, for example, a discrepancy exists between the visual and proprioceptive cues as to its location. Adaptation is the process whereby this discrepancy is reduced. After the subject has adapted, the seen and felt location of the prismatically viewed limb are again congruent. However, when the prism is then removed, and the subject is asked to point directly at a target without visual feedback of his limb, he points to one side of the target. The direction of his error will be opposite that of the prism induced displacement, a circumstance which provides a convenient methodology for measuring the magnitude of the adaptation. Current evidence suggests that within limits the larger the discrepancy, the greater the resulting adaptation (Dewar, 1970).

Canon (1966, 1970, 1971; Uhlarik and Canon, 1971) has formulated a model of adaptation which incorporates a process of reducing cue discrepancy by differential

attention to inputs from given modalities. One modality will be attended while other modalities providing discrepant information are not. Which modality is attended will be a function of task conditions as they relate to informational relevancy. Canon's model postulates the locus of adaptation between two conflicting modalities to be the one which is not attended. The latter will exhibit an adaptive shift so as to match the information in the attended modality, thus re-establishing perceptual congruency.

Usually where information from the visual and proprioceptive systems conflicts with respect to spatial orientation of a given stimulus, vision will dominate. For example, Hay, Pick, and Ikeda (1965) asked subjects to make judgments of the seen and felt locations of their visually displaced, stationary hand seen through a prism. The felt judgments were found to be identical to the seen judgments. Thus, when presented with erroneous visual cues and veridical proprioceptive cues concerning limb location, the discrepancy was resolved in favor of the visual cues. The investigators labeled this phenomenon, visual capture. Most of the subjects were not even aware of a discrepancy between the seen and felt locations. Visual capture occurred despite the fact that when tested by themselves, the proprioceptive cues provided for accurate localization. When simultaneously paired with visual feedback, however, a kind of perceptual fusion occurred in which judgments of

felt location matched the erroneous visual cues. The visual response, by comparison, showed no detectable change when the proprioceptive cues were added. Other investigators have replicated this effect (Neilsen, 1963; Pick, Warren, and Hay, 1969; Rock and Harris, 1967; Tastevin, 1937).

In the context of Canon's adaptational model, the preceding results are due to the occurrence of a proprioceptive shift which matches the attended modality, vision. It is assumed that vision predominates as the relevant modality because vision usually provides the most reliable and veridical cues to spatial localization. In the course of development, therefore, the individual learns to rely on such cues. Hence, visual capture readily occurs in perceptual discrepancies involving vision. However, Canon maintains that stimulus displays which are designed to elicit attention to nonvisual cues for localization feedback should not be expected to produce shifts to match the visual cues. Rather, a visual shift to match the relevant modality (e.g., proprioception, or audition) would be predicted.

In order to study this process, a means of independently measuring adaptive shift in a given modality is needed. One way to do so is to take pre- and postexposure measures of egocentric center using only cues from one modality at a time. To measure proprioceptive egocenter, the subject is asked to close his eyes and to point with a given arm to where he judges straight ahead to be, i.e., the

center of his midsagittal plane. To measure egocenter visually, the subject with head position fixed is asked to adjust a pinpoint spot of light against a homogenous field to the direction he judges to be straight ahead.

Based on pre- and postexposure differences in the egocentric measures, the visual shift and proprioceptive shift engendered by a given experimental procedure can be determined. It should be noted, however, that the term "visual shift" in the present context refers to a change in the judged direction of gaze (e.g., straight ahead), rather than to a change on the basis of retinal loci. Such a change is itself proprioceptive in nature, and thus the expression is somewhat of a misnomer. It refers to a change based on proprioceptive feedback within the visual system, whereas "proprioceptive shift" is reserved for proprioception not directly tied to the visual system. This distinction should be kept in mind in all subsequent reference to proprioceptive and visual shift.

A test of Canon's model can be made by varying the availability of informational feedback from vision and/or proprioception and observing the resultant visual and proprioceptive shifts. One means of doing so involves the use of continuous versus terminal displays (Howard, 1968). In continuous displays the subject (S) can view his entire limb movement and thus can rely on vision to guide his limb to the target. In terminal displays only the endpoint

of the subject's limb movement is visually available (e.g., the tip of his finger); and correction of localization based on visual feedback is not permitted. Thus in the continuous display condition the subject is expected to attend primarily to vision to make his response, while in the terminal display condition he is expected to rely primarily on proprioception.

Canon's model makes differential predictions as to the locus of adaptation resulting from these two display conditions. Since in the continuous display condition vision is the attended modality, the model predicts the adaptive shift, if any, will occur with a proprioceptive locus. On the other hand, with terminal displays, in which the subject must rely primarily on proprioception as the attended modality on which to base his response, the adaptive shift, if any, would be expected to occur in the visual system. These predictions have been tested using pre- and postexposure measures of egocentric center. In general the results to date support the model's predictions (Choe and Welch, 1974; Uhlarik and Canon, 1971).

However, in addition to obtaining a significant visual shift in the terminal display condition, a lesser but nevertheless statistically significant proprioceptive shift is obtained. Uhlarik and Canon (1971) attribute the latter to the fact that in the terminal display condition the subject is not limited to only proprioceptive information, but

also receives visual feedback at the termination of movement (in order to generate the requisite cue discrepancy). The evidence with respect to visual capture indicates that when vision and proprioception provide conflicting cues, the tendency to attend to the visual cues is very strong. According to Uhlarik and Canon (1971):

The existence of significant proprioceptive-motor shifts in the terminal display condition may seem anomalous, but it should be noted that the model holds attention to be the critical variable in determining the nature of the adaptation developing. The display or exposure condition variable is seen as playing a role only insofar as it influences the source of information to which S attends during the exposure period In view of the evidence regarding what has been termed visual dominance or capture, it might be anticipated that Ss in the terminal display condition, where exposure circumstances were expected to force attention to proprioceptive cues would, in fact, attend to visual inputs at least a portion of the time To the extent that attention was at times paid to visual cues, adaptation with a proprioceptive locus would be predicted (p. 238).

Thus, although visual and proprioceptive shift differences have been established using terminal versus continuous displays, comparison of shifts under the two conditions does not provide for an unconfounded test of Canon's model because vision operates in both. Although terminal displays emphasize attention to proprioception during movement, it is still necessary to have visual feedback at the termination of movement in order to provide the necessary cue discrepancy for adaptation to occur.

Recently, however, Wallace (1974) has demonstrated that preexposure practice may serve to provide the necessary cue discrepancy to produce adaptation, even without visual feedback during exposure. Level of preexposure practice was varied by having subjects point at one target more frequently than another. During exposure subjects pointed an equal number of times at all targets. Greater adaptation was observed in the postexposure measurement for the target receiving more preexposure practice. No difference in this result was found between subjects receiving visual feedback of limb position during exposure and subjects not receiving such feedback.

Wallace's results suggest an ideal means for a direct, unconfounded test of Canon's model. Theoretically, given the requisite cue discrepancy necessary for adaptation to occur, if the subject is provided with no visual feedback of limb position, and is thus forced to attend exclusively to proprioceptive cues for localization feedback, no proprioceptive shift should be expected. Instead, whatever adaptation does occur should be localized in the visual system. Presence or absence of preexposure practice can be used to vary the saliency of the proprioceptive cues during exposure. Thus, preexposure practice in pointing at targets should increase the attention directed to proprioceptive feedback of limb position during prismatic exposure. This in turn should produce increased visual shift, and decreased

proprioceptive shift, relative to a zero practice configuration.

The present experiment involves the manipulation of both preexposure practice and visual feedback during exposure as a means of testing Canon's model concerning locus of adaptation. In addition a test of the model's predictions with respect to the occurrence/nonoccurrence of intermanual transfer will be made. Contradictory results have been obtained concerning this measure. Various investigators have observed transfer of adaptation to the nonexposed arm (Cohen, 1967; Craske, 1967; Howard, 1968). Others have failed to find evidence of such transfer (Hamilton, 1964; Harris, 1963). Since a change in the visual system would be expected to result in shifts in localization of visually observed targets no matter which limb is used in making the localization, Canon's model predicts that any condition which induces visual shift should produce intermanual transfer. This study will include a test of the predicted isomorphism. However, "target pointing - nonexposed arm" will be substituted for the term "intermanual transfer." The latter expression begs the question since, as the preceding discussion implies, it remains to be demonstrated what, if anything, transfers.

In addition to the above, this experiment will provide a test of the additive loop hypothesis advanced by McLaughlin and Webster (1967) and Wilkinson (1971).

These investigators have proposed that the visual-motor loop is a linear system comprising a number of independent subsystems. Errors in the subsystem sum algebraically to produce the error in the total loop. Wilkinson has obtained evidence that prism induced change in target aiming performance is equal to the sum of the visual and proprioceptive shift, separately measured. The linear model can thus be viewed as complementing that of Canon. It relates the size of the adaptive shift in target pointing to the sum of the adaptive shifts occurring in given modalities. Since the present experiment involved the manipulation of conditions expected to produce adaptation due primarily to visual shift, or to proprioceptive shift, respectively, as well as to their combination, it offers a good opportunity for a test of the additive loop hypothesis.

In summary, the purpose of the present study was twofold. First, it was designed to test the effects of pre-exposure practice, and amount of visual feedback during exposure, in the context of Canon's model of adaptive loci. Given cue discrepancy in the informational feedback provided by vision and proprioception, conditions which tend to emphasize the cues from one modality should lead to decreased adaptation in that modality and increased adaptation in the other. Conditions leading to adaptation in the visual system should also produce shifts in target pointing - nonexposed hand. Second, this experiment provided a test

of the additive loop hypothesis concerning adaptation observed in target pointing. The magnitude of the total shift in the latter should be linearly determined by the sum of the individual visual and proprioceptive shifts.

METHOD

Subjects

Ninety-six male United States Air Force enlisted personnel between the ages of 17 and 21 served as subjects in the experiment. Right hand dominance was required of all subjects and was determined by asking S whether he was right or left handed, and by asking him which hand he employed for handwriting. In addition, only subjects with no medical history of astigmatism were selected.

Apparatus

A diagram of the apparatus is presented in Figure 1. It consisted of a 92.31 cm high, vertical, semicircular, black masonite screen curved to a radius of 65.39 cm. The center of the screen was approximately 82.05 cm from S's right eye. The lower one-third of the screen was transected by a 32.05 cm high horizontal plywood panel. The latter was supported by four 30.77 cm high legs resting on a 78.21 cm high table. The S was seated facing the vertical screen. Pointing localizations were made by reaching under the horizontal panel and touching the index finger on the top of a semicircular position transducer, described below.

The center portion of the horizontal panel contained a sliding section which could be adjusted to: (a) entirely

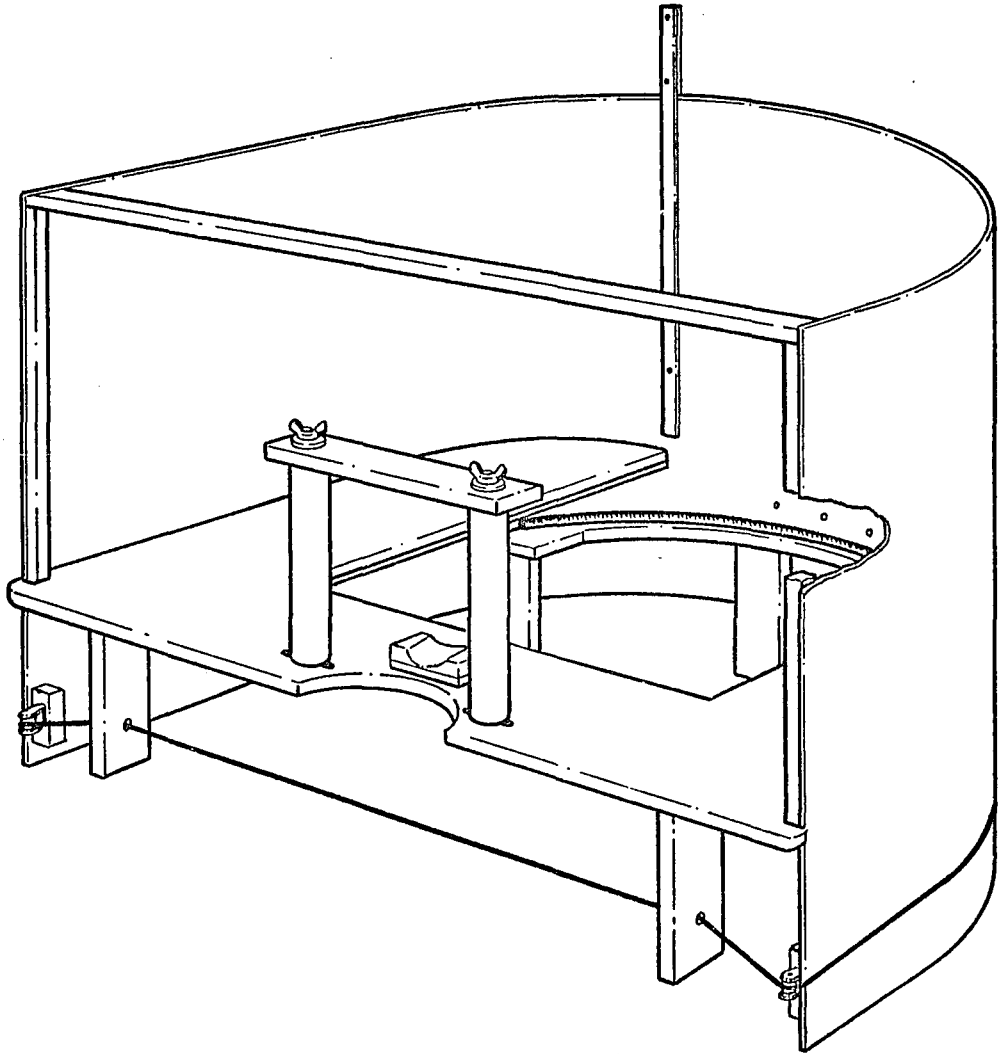


Figure 1. Perspective View of Apparatus.

(Shown without sliding panel described in text)

preclude visual feedback of limb position, (b) allow only visual feedback of the tip of the finger at the termination of each pointing localization, or (c) allow full visual feedback of limb position during pointing localization.

The target pointing display consisted of three white circles mounted on the semicircular screen. Each was 6.5 mm in diameter and subtended a visual angle of 22.41 minutes. The middle target was centered against the black screen, separated by 6 degrees (9.30 cm) from the two laterally adjacent targets. The targets were in the same plane as the top of the position transducer, 5.77 cm below the horizontal panel and 26.28 cm above the table.

A single target identical in size to the preceding targets was utilized to obtain visual egocentric measures. It was located 45.19 cm above the table on a movable rod against the black screen. A taut horizontal string 6.4 cm above the table directly in front of S was attached to the rod by means of a pulley system on the rear side of the vertical screen. S simply moved the string to the right or the left to move the target across the black screen. Visual egocentric measures were obtained in degrees by noting where a pointer attached to the moving rod stopped against a scale on the rear of the vertical screen.

A plexiglass chinrest was centered on the leading edge of the horizontal panel. On both sides of the chinrest

were adjustable headbars which were employed to clamp S's head securely, precluding head movement.

The position transducer consisted of a 1.28 cm thick, semicircular, insulated metal rod curved to a radius of 65.39 cm. Twenty-six gauge nichrome wire was wound on the rod at 10.53 windings per linear centimeter, through an arc of 64.5 degrees. The wire was connected to a two volt regulated power supply. The position transducer was located 58.97 cm in front of the vertical screen. It was 26.28 cm high at its topmost edge, and was supported on a three-legged frame.

The pointing localization measures were obtained when S completed an electric circuit by touching a stylus to the position transducer. In completing the circuit a signal linearly proportional to the position of the stylus on the coil was produced. The signal was measured using a Fluke 8300A digital voltmeter, which could reliably discriminate differences as small as a single winding on the coil.

The stylus consisted of a cylindrical metal rod 3 mm in length and .4 mm in diameter, which was attached to a rectangular strip of plexiglass 5.5 x 2.0 x .3 mm in size. The latter was taped to the underside of S's index finger. Two styluses were employed, one each on the right and left index fingers, respectively. Thin wires connected the styluses to the digital voltmeter.

Standard commercial welder's goggles were employed, the left eye of which was occluded. The right eyepiece consisted of clear glass, and could be unscrewed to be replaced with another eyepiece identical to it except for the attachment of a 20 diopter glass wedge prism. The prism laterally displaced the visual field by 11.3 degrees.

Except for the white targets, chinrest, and headbars, the entire apparatus was painted flat black.

Experimental Design

A 3 x 2 x 2 x 2 x 2 x 4 repeated measures factorial design was employed. Pre- and postexposure differences in the mean scores on four dependent measures constituted the experimental data of interest in this study. Differences indicative of shifts in mean localization in a compensatory direction to the prism induced displacement were arbitrarily given positive signs. The dependent measures were: (a) M_1 - visual egocenter, (b) M_2 - proprioceptive egocenter, (c) M_3 - target pointing using the arm exposed during prismatic displacement, (d) M_4 - target pointing using the arm contralateral to that exposed during prismatic displacement.

Independent variables of interest were:

1. Exposure condition, three levels: (a) E_1 - zero visual feedback of limb position during prismatic displacement, (b) E_2 - terminal visual feedback of limb position during prismatic displacement, (c) E_3 - continuous

visual feedback of limb position during prismatic displacement.

2. Practice condition, two levels: (a) P_1 - no preexposure target pointing practice, (b) P_2 - 45 preexposure target pointing practice trials.

Control variables the effects of which were counter-balanced, and included in the analysis of variance, were:

1. Hand utilized for target pointing during prismatic displacement, two levels: (a) H_1 - right hand, (b) H_2 - left hand.

2. Prism orientation, two levels: (a) B_1 - base left (target displacement to the right), (b) B_2 - base right (target displacement to the left).

3. Order of egocentric measures, two levels: (a) O_1 - visual egocenter measured before proprioceptive egocenter, (b) O_2 - proprioceptive egocenter measured before visual egocenter.

Procedure

S was first seated at the front of the apparatus and the experimenter (E) adjusted the height of his chair so that the subject's head was level with the horizontal panel when placed in the chinrest. E adjusted the sliding horizontal panel so as to provide visual feedback of hand position at the termination of a pointing movement. Next E pointed out the exposure targets and demonstrated the form

in which S was to point at them. E instructed S that he was to keep his pointing arm horizontally level with the table and rest his contralateral arm with elbow bent, directly in front of him on the table. E instructed S that he was to bring his hand back to his chest between each pointing movement, and so demonstrated. E instructed S that he was to reach under the horizontal panel to lay his index finger on the top of the position transducer each time he pointed, and so demonstrated.

S was then told to place his head on the chinrest and to practice pointing at the central targets five times with his right hand. At the completion of such practice he was told to do the same with his left hand. E corrected any deviations from the prescribed pointing form during these practice trials.

Next E demonstrated the use of the horizontal string for adjusting the visual egocentric target. No practice on the latter was provided. E then taped the styluses to S's right and left index fingers. Five more practice trials with each hand were provided, with S touching the stylus on the top of the position transducer each time. Next E asked S to put on the welder's goggles and informed him that upon placing his head on the chinrest, the head bars would be tightened so as to preclude head movement. E tightened the bars securely, and requested S to attempt to move his head. E verified that no head movement was possible, and

instructed S not to attempt to move his head until the termination of the experiment.

E then adjusted the sliding horizontal panel so as to preclude S's vision of the central targets, and verified this adjustment by asking S whether he could see the targets. In this position the panel also precluded visual feedback of limb movement.

Preexposure, exposure, and postexposure instructions were all read by E from cards with the exception of pre-exposure practice and exposure target pointing sequences. Both the latter were presented by means of a tape recorder, as explained below.

Measurement by E began with the preexposure egocentric measures. For both the visual and proprioceptive egocentric measures, S was instructed to select the direction he felt to be directly in front of his nose. The order of the egocentric measures was counterbalanced. For half the subjects, visual egocenter was measured first. For the other half, proprioceptive egocenter was measured first. Four trials on each such measure were given, the means of which, respectively, constituted the experimental data. Proprioceptive egocentric measures were always taken with the same arm utilized during subsequent prismatic exposure. S was instructed to keep his eyes closed throughout the four proprioceptive trials. Of the four visual egocentric measures, two were initiated with the movable target at the

right edge of the visual field, and two were initiated at the left edge. A right-left-right-left order was employed. When not in use the visual egocentric target was moved out of view at the far right of the screen.

Immediately following the egocentric measures, E measured preexposure target pointing accuracy. For this purpose the sliding horizontal panel was adjusted so as to provide vision of the central targets without allowing any visual feedback of limb position. To make this adjustment, E asked S to inform him when he could barely see all three central targets while the sliding panel was slowly being moved back. E then further adjusted the panel 6.4 mm so that the targets were fully visible, and so verified by asking S whether he could completely see all the targets. In this position the sliding panel still precluded any visual feedback of limb position.

Nine preexposure target pointing trials were given per arm, three on each target in a random sequence read by E. The same sequence was employed for all Ss in both pre- and postexposure trials. Approximate intertrial interval was six seconds. E manually recorded the pointing localization as registered on the digital voltmeter when S touched the top of the position transducer. The mean of the nine trials constituted the experimental data for this measure. Target pointing accuracy was always measured first using

the arm to be employed during prismatic exposure and immediately thereafter using the contralateral arm.

Half the subjects were provided with preexposure target pointing practice, while half were not given such practice. For the former group, practice trials followed immediately upon preexposure target pointing trials. No change in visual feedback conditions was entailed. S practiced with the same arm employed during prismatic exposure. A total of 45 practice trials were administered, 15 on each target. Intertrial interval was 6 seconds. S pointed at the three central targets in a random sequence presented on a tape recorder. The same sequence was employed for all Ss.

Upon completion of preexposure trials, S was instructed to place both arms flat on the table in front of him, remain motionless, and keep his eyes closed until told to open them. E then replaced the right eyepiece of clear glass with one identical to it except for the attachment of a 20 diopter wedge prism. For half the Ss a base left prism orientation was employed, and for the other half, a base right orientation was used.

Prior to instructing S to open his eyes, E adjusted the sliding horizontal panel for the appropriate level of visual feedback during exposure. One third of the Ss received no visual feedback of limb position during exposure. One third saw only the tip of their finger at the

termination of each pointing movement. One third were provided with full visual feedback of limb position during pointing movements. For all conditions S was instructed not to correct for any apparent error in pointing direction upon termination of a pointing movement.

Upon instructing S to open his eyes, E verified that all targets were visible by asking S whether he could see all three. E then instructed S as to which hand to employ when pointing, following which a taped random sequence of targets was presented. The same sequence was employed for all Ss.

Half the Ss used their right arm during prismatic exposure, while the other half used their left. Sixty exposure pointing trials were administered, 20 on each target. Intertrial interval was six seconds. Total exposure duration was 6 minutes, 40 seconds.

Upon completion of exposure trials S was again instructed to lay both arms flat on the table, remain motionless, and keep his eyes closed until told to open them. E removed the prism eyepiece and replaced it with the clear lens. E then adjusted the sliding horizontal panel so as to preclude vision of the central targets and limb movement.

Postexposure measures were then taken using the identical procedure and order employed during preexposure measurement. As during preexposure, postexposure egocentric

measures always preceded target pointing measures. Measurement of target pointing accuracy with the arm employed during exposure always preceded that taken with the contralateral arm.

RESULTS

Table 1 presents the results of the analysis of variance. Significant main effects included exposure condition (E), and measure (M). Significant interaction effects included measure by practice (M x P), measure by exposure (M x E), and order by practice (O x P). The practice by exposure (P x E) interaction was not significant, nor was the M x P x E triple interaction. None of the control variables were found to have significant effects other than the O x P interaction.

Comparisons between means were conducted using the method of Scheffé, except where otherwise noted (Edwards, 1972). Also, one-tailed t tests of the hypothesis that mean adaptation significantly exceeded zero in each treatment condition were made.

Figure 2 graphically presents mean adaptation in degrees as a function of exposure condition. Terminal exposure produced the highest mean adaptation, 6.58 degrees, an amount which did not significantly exceed the 5.53 degrees produced in the continuous exposure condition, $F(2, 48) = 3.35$, not significant (n.s.). Adaptation in both conditions was significantly greater than zero, $t(127) = 16.18$, $t(127) = 13.59$, respectively, $p < .01$. The .94

Table 1. Analysis of Variance of Mean Adaptation Scores.

Source of Variation	df	MS	F
O Order of egocentric measures	1	.65	<1
B Prism orientation	1	.67	<1
H Hand exposed	1	.09	<1
P Practice condition	1	72.83	3.44
E Exposure condition	2	1148.42	54.29**
O x B	1	.44	<1
O x H	1	.02	<1
B x H	1	.03	<1
O x P	1	89.64	4.24*
B x P	1	.21	<1
H x P	1	8.66	<1
O x E	2	7.30	<1
B x E	2	5.66	<1
H x E	2	12.58	<1
P x E	2	50.06	2.37
O x B x H	1	.03	<1
O x B x P	1	.85	<1
O x H x P	1	32.68	1.55
B x H x P	1	10.84	<1
O x B x E	2	6.36	<1
O x H x E	2	11.26	<1
B x H x E	2	.33	<1
O x P x E	2	33.21	1.57
B x P x E	2	2.48	<1
H x P x E	2	22.12	1.05
O x B x H x P	1	59.06	2.79
O x B x H x E	2	2.82	<1
O x B x P x E	2	26.56	1.26
O x H x P x E	2	15.45	<1
B x H x P x E	2	.74	<1
O x B x H x P x E	2	5.09	<1
Error Between, S (OBHPE)	48	21.15	

Table 1 continued.

Source of Variation	df	MS	F
M Measure	3	299.10	14.16**
M x O	3	.74	<1
M x B	3	.53	<1
M x H	3	.20	<1
M x P	3	88.88	4.21*
M x E	6	537.75	25.46**
M x O x B	3	.27	<1
M x O x H	3	2.40	<1
M x B x H	3	.63	<1
M x O x P	3	20.13	<1
M x B x P	3	.49	<1
M x H x P	3	1.10	<1
M x O x E	6	12.84	<1
M x B x E	6	5.38	<1
M x H x E	6	1.13	<1
M x P x E	6	6.82	<1
M x O x B x H	3	.21	<1
M x O x B x P	3	1.87	<1
M x O x H x P	3	19.48	<1
M x B x H x P	3	22.23	1.05
M x O x B x E	6	11.11	<1
M x O x H x E	6	1.60	<1
M x B x H x E	6	13.10	<1
M x O x P x E	6	6.56	<1
M x B x P x E	6	15.14	<1
M x H x P x E	6	18.85	<1

Table 1 continued.

Source of Variation	df	MS	F
M x O x B x H x P	3	22.41	1.07
M x O x B x H x E	6	3.85	<1
M x O x B x P x E	6	20.49	<1
M x O x H x P x E	6	10.02	<1
M x B x H x P x E	6	11.60	<1
M x O x B x H x P x E	6	9.70	<1
Error Within, S(OBHPE)M	144	21.13	

* $p < .05$

** $p < .01$

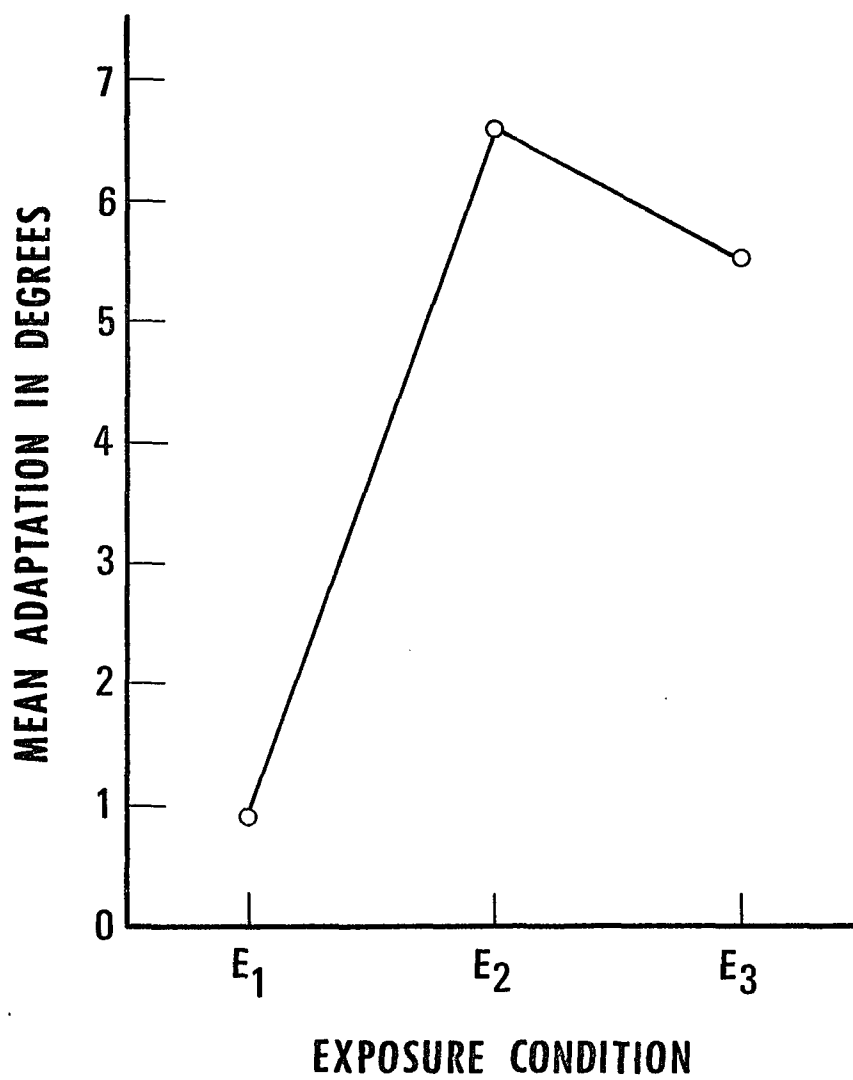


Figure 2. Mean Adaptation in Degrees as a Function of Exposure Condition.

degrees mean adaptation observed in the zero exposure condition was also significantly greater than zero, $t(127) = 2.32$, $p < .05$, but was significantly less than that observed in the terminal and continuous exposure conditions, $F(2, 48) = 96.05$, $F(2, 48) = 63.53$, respectively, $p < .01$.

Figure 3 graphically presents mean adaptation as a function of measure. Mean adaptation in the target pointing - exposed hand measure was 6.82 degrees. This was significantly greater than the mean of 4.41 degrees exhibited by the proprioceptive egocentric measure, $F(3, 144) = 13.14$, $p < .01$, the mean of 3.22 degrees exhibited by the visual egocentric measure, $F(3, 144) = 29.47$, $p < .01$, and the mean of 2.95 degrees exhibited by the target pointing - nonexposed hand measure, $F(3, 144) = 34.02$, $p < .01$. No significant differences in mean adaptation were observed between visual egocenter and proprioceptive egocenter, $F(3, 144) = 3.28$, n.s., between visual egocenter and target pointing - nonexposed hand, $F(3, 144) < 1$, nor between proprioceptive egocenter and target pointing - nonexposed hand, $F(3, 144) = 4.88$, n.s. A test of the difference between mean adaptation in the target pointing - exposed hand measure and the algebraic sum of the visual and proprioceptive egocentric measures was conducted; the difference was not significant, $F(3, 144) < 1$. The least adaptation was observed in the target pointing - nonexposed hand measure, an amount which was nevertheless found to be significantly

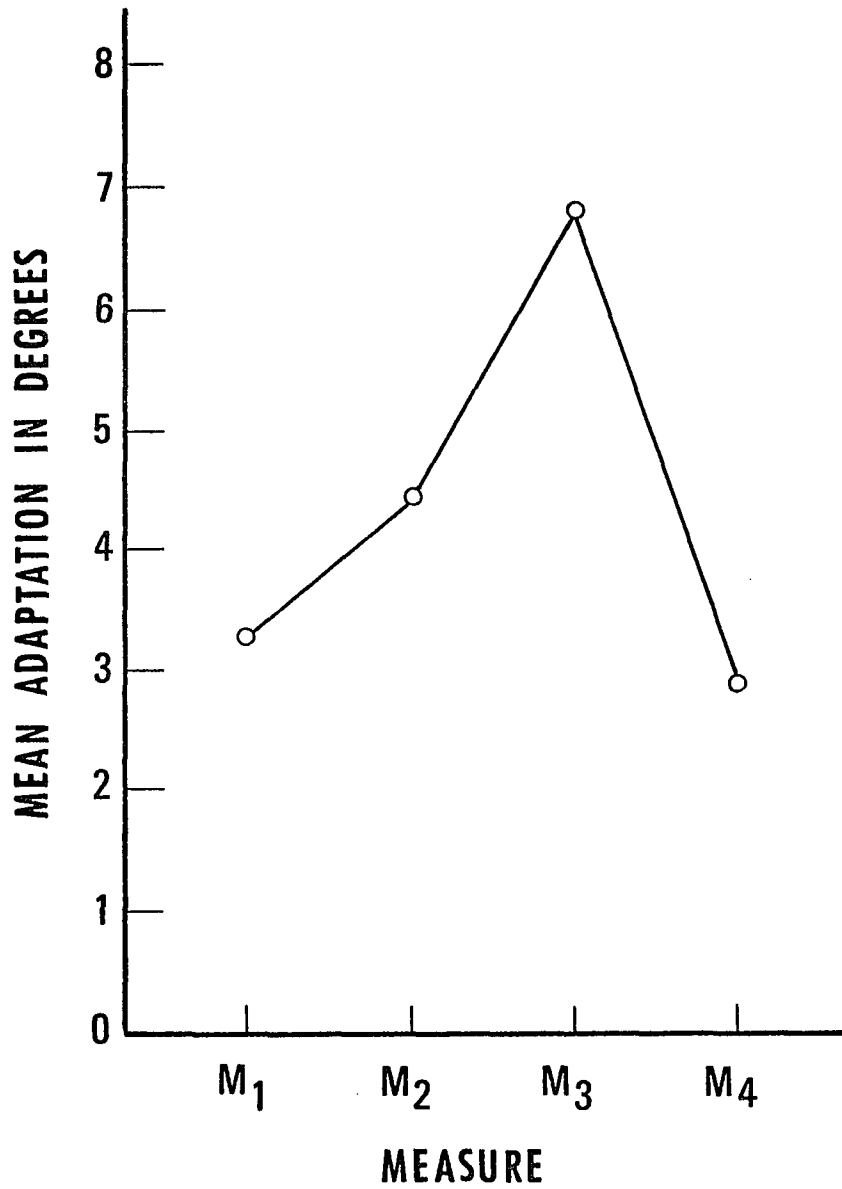


Figure 3. Mean Adaptation in Degrees as a Function of Measure.

greater than zero, $t(95) = 6.28$, $p < .01$. Thus all of the measures exhibited levels of adaptation significantly greater than zero.

Figure 4 graphically portrays mean adaptation as a function of measure and practice condition. The significant interaction is due entirely to the differential effects of level of practice on proprioceptive egocenter versus the other three measures of adaptation. Thus, no significant interaction was obtained in comparing the effects of practice on visual egocenter, target pointing - exposed hand, and target pointing - nonexposed hand, $F(3, 144) < 1$. Conversely, an orthogonal breakdown of the differential effects of practice on the visual and proprioceptive egocentric measures was highly significant, $F(1, 144) = 9.94$, $p < .01$, accounting for 79 percent of the total variance in the overall $M \times P$ interaction.

The means in the zero practice condition for the visual egocenter, proprioceptive egocenter, target pointing - exposed hand, and target pointing - nonexposed hand measures were 2.12 degrees, 5.41 degrees, 5.98 degrees, and 2.14 degrees, respectively. The 2.12 degrees obtained in the visual egocentric measure was significantly greater than zero, $t(47) = 3.20$, $p < .05$. Thus all of the measures exhibited a significantly greater than zero level of adaptation in the zero practice condition.

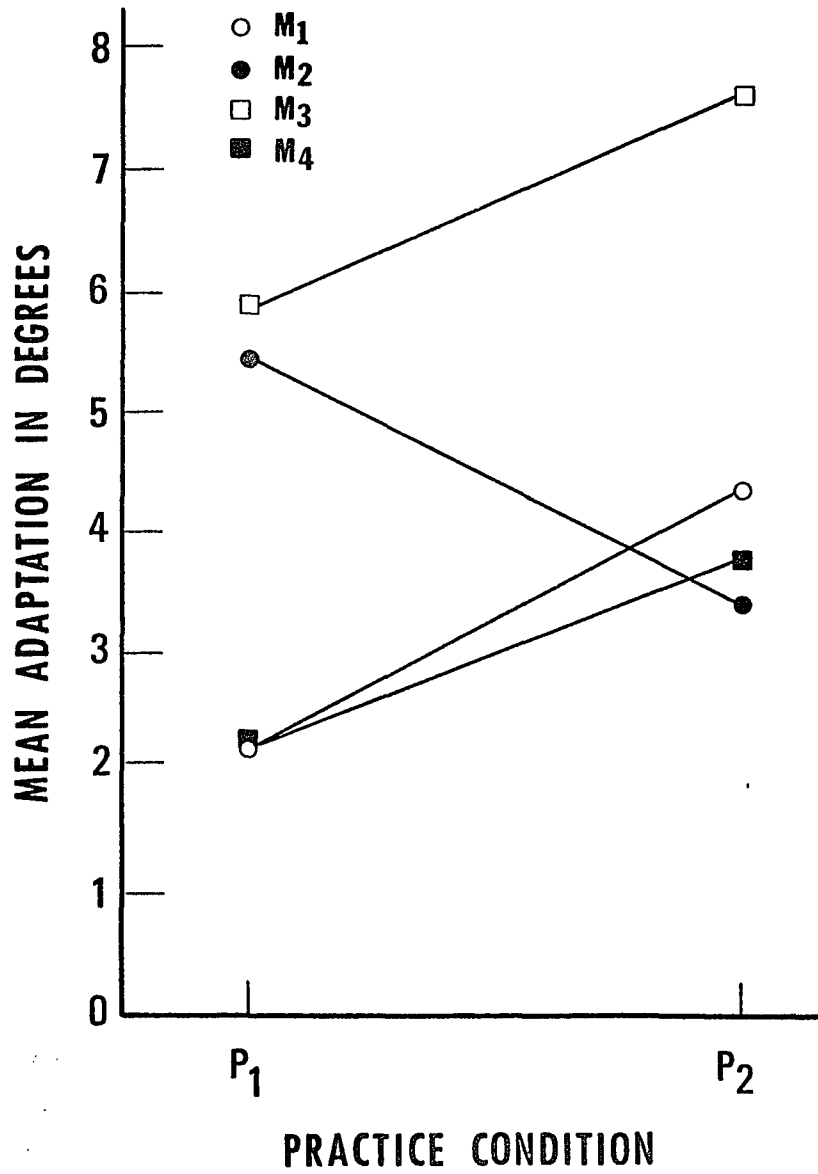


Figure 4. Mean Adaptation in Degrees as a Function of Measure and Practice Condition.

The means for the four measures in the with-practice condition, taken in the precedingly referenced order, were 4.31 degrees, 3.42 degrees, 7.66 degrees, and 3.75 degrees, respectively. The mean of 3.42 degrees exhibited by the proprioceptive egocentric measure was significantly greater than zero, $t(47) = 5.16$, $p < .01$. Thus all of the measures exhibited a significantly greater than zero level of adaptation in the with-practice condition.

All of the measures except proprioceptive egocenter exhibited greater adaptation in the with-practice than in the zero practice condition. A test of the main effect of practice, without the effects on the proprioceptive egocentric measure included, was significant, $F(3, 144) = 11.37$, $p < .01$. Individual tests for each of the measures indicated that visual egocenter exhibited significantly more adaptation in the with-practice condition than in the zero practice condition, $F(3, 144) = 5.48$, $p < .05$, while proprioceptive egocenter exhibited significantly less adaptation in the with-practice condition, $F(3, 144) = 4.50$, $p < .05$. The difference between practice conditions failed to achieve significance in the case of the target pointing - exposed hand measure, $F(3, 144) = 3.21$, n.s., and target pointing - nonexposed hand measure, $F(3, 144) = 2.94$, n.s. The difference between egocentric measures was significant in the zero practice condition, $F(3, 144) = 12.29$, $p < .01$, but not in the with-practice condition, $F(3, 144) = .90$, n.s.

Figure 5 graphically portrays mean adaptation as a function of measure and exposure condition. Two of the measures, visual egocenter and target pointing - nonexposed hand, were not differentially affected by exposure condition. A comparison of the interaction effect of exposure and the latter two measures was not significant, $F(6, 144) < 1$. Thus the interaction effect was limited to the proprioceptive egocenter and target pointing - exposed hand measures.

In the zero exposure condition mean target pointing - exposed hand exhibited the most adaptation, 1.31 degrees, but that amount was not significantly greater than zero, $t(31) = 1.61$, n.s. Thus in the zero exposure condition none of the measures exhibited significant adaptation. In the terminal exposure condition the least adaptation was exhibited by the proprioceptive egocentric measure, 1.72 degrees, an amount which was not significantly greater than zero, $t(31) = 2.12$, n.s. Target pointing - exposed arm exhibited the greatest mean adaptation, 9.97 degrees, a highly significant amount, $t(31) = 12.27$, $p < .01$. The latter was not found to be significantly different from the 7.67 degrees mean adaptation exhibited by the visual egocentric measure, $F(6, 144) = 4.01$, n.s., nor the 6.94 degrees exhibited by the target pointing - nonexposed arm measure, $F(6, 144) = 6.95$, n.s. Each of the latter two measures exhibited a significantly greater than zero level

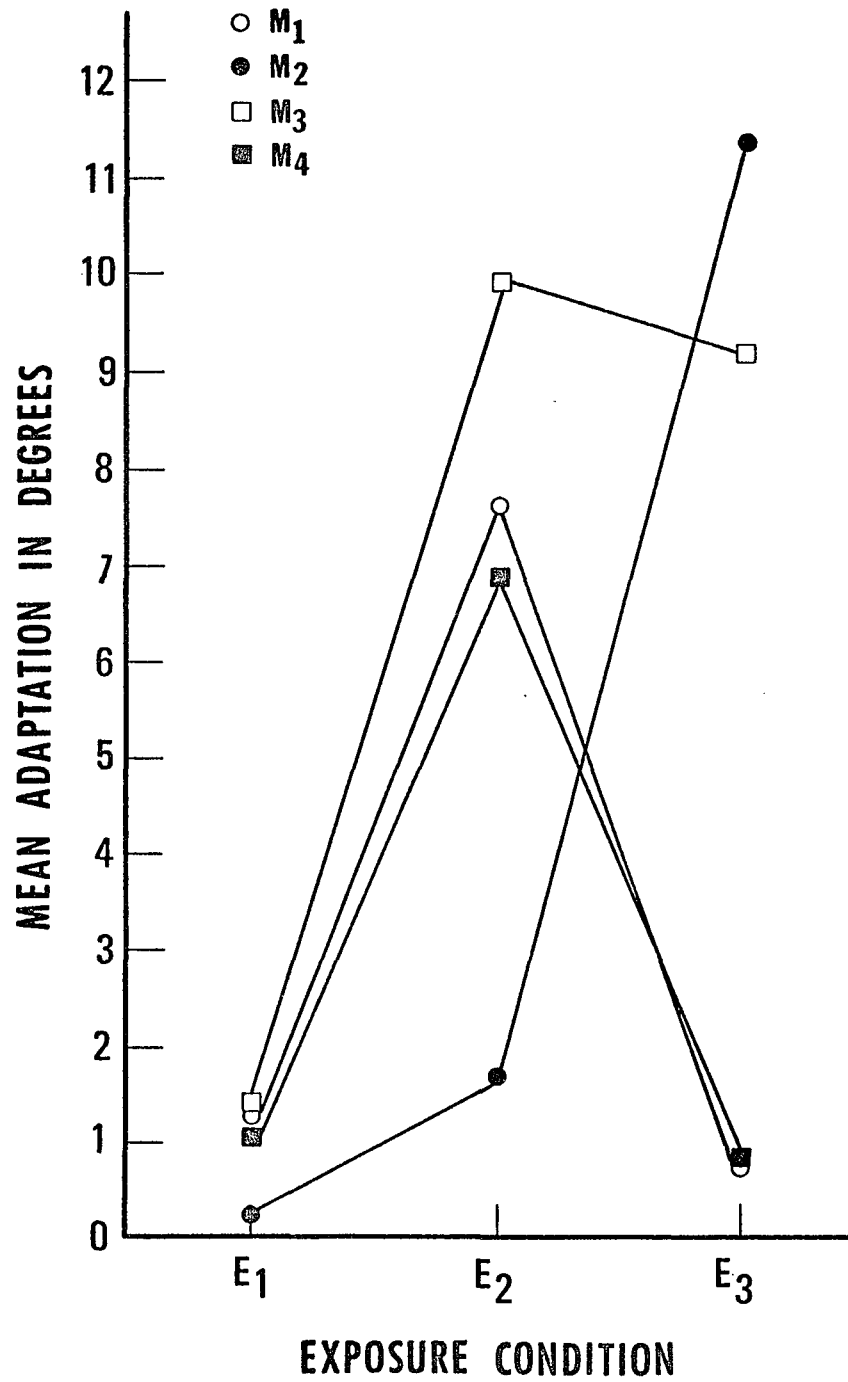


Figure 5. Mean Adaptation in Degrees as a Function of Measure and Exposure Condition.

of adaptation, \underline{t} (31) = 9.44, \underline{t} (31) = 8.54, respectively, $p < .01$, but did not differ significantly from one another, \underline{F} (6, 144) < 1.

In the continuous exposure condition the proprioceptive egocentric measure exhibited the most adaptation, 11.33 degrees, a highly significant amount, \underline{t} (31) = 13.94, $p < .01$. Mean adaptation in the target pointing - exposed arm measure was 9.17 degrees, also significantly greater than zero, \underline{t} (31) = 11.29, $p < .01$, but not significantly different from the proprioceptive measure, \underline{F} (6, 144) = 3.53, n.s. Not significantly greater than zero were the .72 degrees mean adaptation exhibited by the visual egocentric measure, \underline{t} (31) = .89, n.s., and the .87 degrees exhibited by the target pointing - nonexposed hand measure, \underline{t} (31) = 1.07, n.s.

Figure 6 graphically presents mean adaptation as a function of order and practice (O x P). Presence or absence of practice was found to have differential effects on O_1 (visual egocenter measured before proprioceptive egocenter) and no effect on O_2 (proprioceptive egocenter measured before visual egocenter). The 3.39 degrees mean adaptation exhibited in the O_1 condition under a zero level of practice was significantly less than the 5.23 degrees exhibited by O_1 in the with-practice condition, \underline{F} (1, 48) = 7.67, $p < .01$. Conversely, in the O_2 condition the mean levels of adaptation

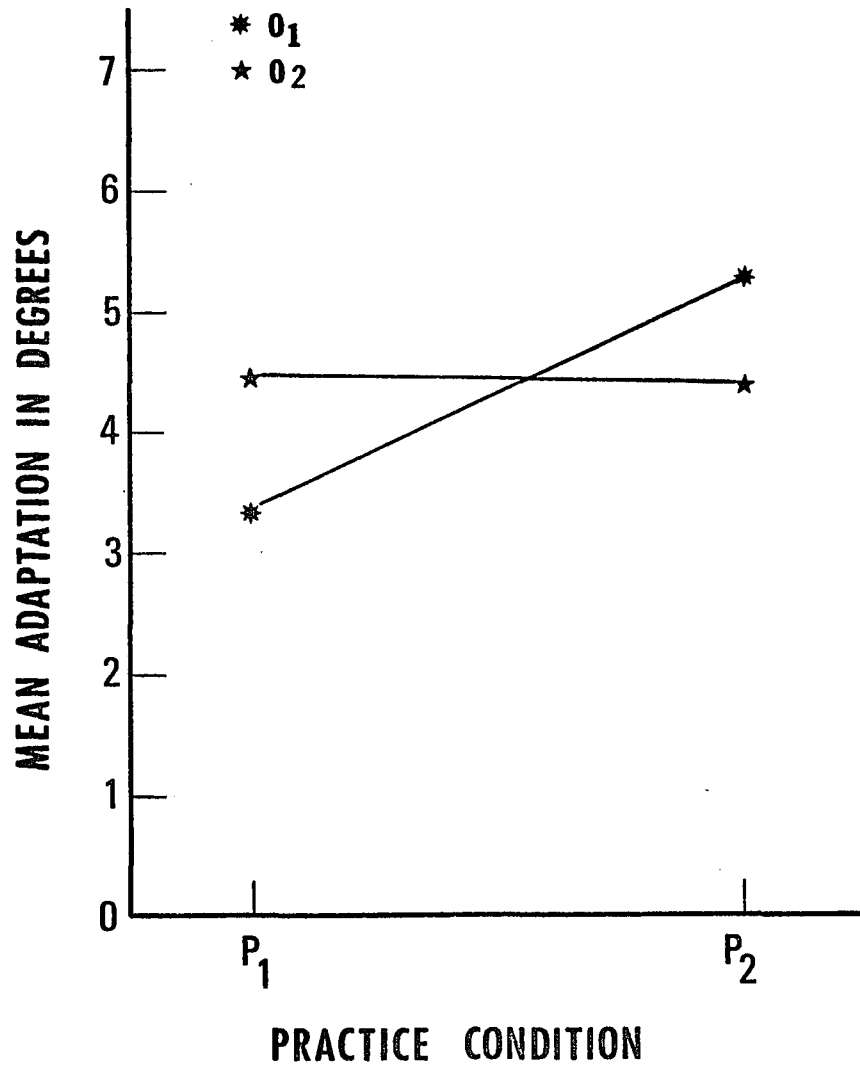


Figure 6. Mean Adaptation in Degrees as a Function of Order and Practice Condition.

for the zero practice and with-practice conditions were nearly identical, 4.44 degrees versus 4.34 degrees, respectively, $F(1, 48) < 1$.

Figure 7 presents adaptation as a function of exposure and practice. While the overall $E \times P$ interaction was not significant, an orthogonal breakdown of the differential effects of practice on the zero exposure and continuous exposure conditions was significant, $F(1, 48) = 4.06$, $p < .01$. A test of the difference in level of adaptation between practice conditions with zero exposure indicated significantly more adaptation occurred in the with-practice condition, $F(1, 48) = 4.67$, $p < .05$. The mean level of adaptation in the zero exposure/zero practice condition was .06 degrees, which was not significantly greater than zero, $t(63) = .11$, n.s. The 1.82 degrees mean adaptation exhibited in the zero exposure/with-practice condition did, however, significantly exceed zero, $t(63) = 3.17$, $p < .01$. No other significant differences were observed.

Figure 8 presents adaptation as a function of measure, exposure, and level of practice. The absence of a significant triple interaction indicates that the significant $M \times P$ interaction was of similar form across exposure conditions, and the significant $M \times E$ interaction was of similar form across practice conditions, as is evident in Figure 8. As indicated earlier, the $E \times P$ interaction was significant for the zero and continuous exposure conditions.

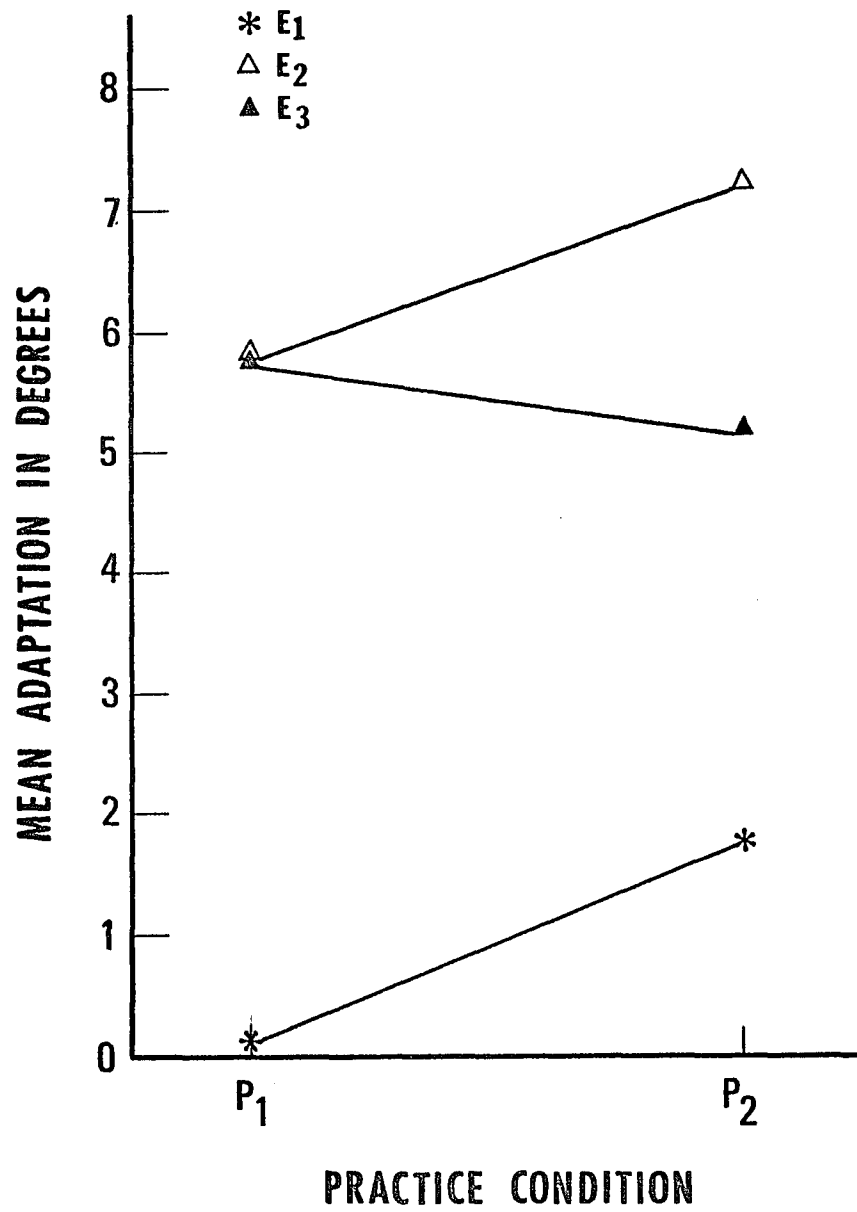


Figure 7. Mean Adaptation in Degrees as a Function of Exposure Condition and Practice Condition.

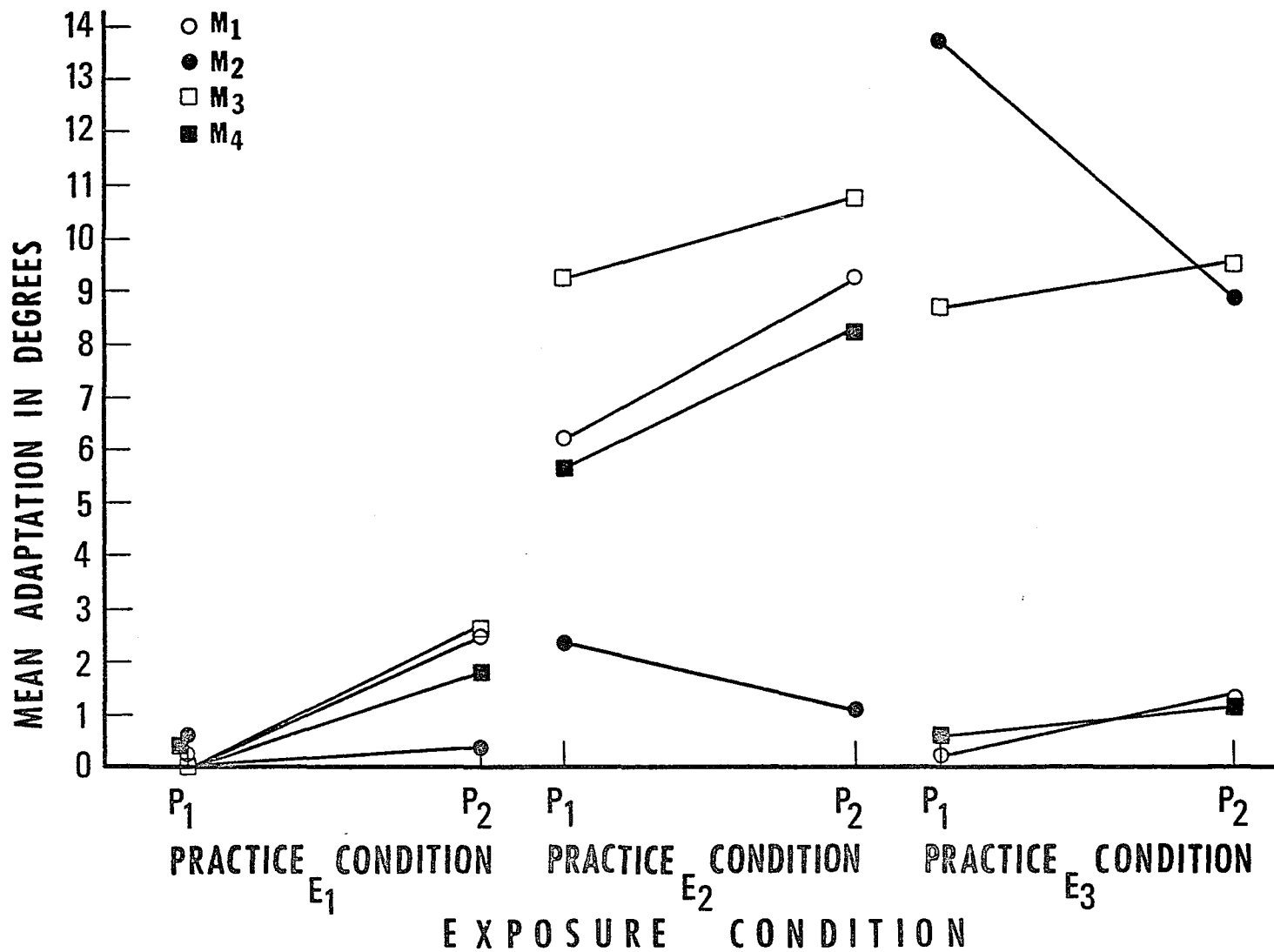


Figure 8. Mean Adaptation in Degrees as a Function of Measure, Practice Condition, and Exposure Condition.

Therefore, the E x P interaction was also of similar form across measures, for the latter two conditions.

Of particular interest in Figure 8 is the difference in mean adaptation exhibited by each of the four dependent measures across the two levels of practice in the zero exposure condition. Negligible adaptation was observed in the zero practice condition in all four measures. In the with-practice condition, two measures exhibited significantly greater than zero levels of adaptation. These were visual egocenter, $t(15) = 2.15$, $p < .025$, and target pointing - exposed hand, $t(15) = 2.29$, $p < .025$. Target pointing - nonexposed hand fell short of significance, $t(15) = 1.71$, $t_{.05} = 1.75$. Adaptation in the proprioceptive egocentric measure remained not significantly greater than zero in the with-practice condition, $t(15) = .19$, n.s.

The results with respect to the terminal and continuous exposure conditions in Figure 8 are expressive of the findings already cited concerning main effects and two factor interactions. However, it was noted that in the terminal exposure condition proprioceptive egocenter achieved significantly greater than zero adaptation at the zero practice level, $t(15) = 2.06$, $p < .05$. The absence of a significant value for the proprioceptive measure at the with-practice level, $t(15) = .88$, n.s., accounts for the failure of that measure to achieve significance when averaged across practice levels in the terminal exposure condition.

It was also noted with respect to Figure 8 that in the continuous exposure condition, significantly less adaptation was evident in the proprioceptive egocentric measure at the with-practice level than at the zero practice level, $F(3, 144) = 8.54, p < .05$.

Table 2 presents the intercorrelation matrix for the four dependent variables. A significant negative correlation was obtained between visual egocenter and proprioceptive egocenter, $r(94) = -.28, p < .01$. The highest observed correlation was that between visual egocenter and target pointing - nonexposed hand, $r(94) = .58, p < .01$. The latter measure did not correlate significantly with either proprioceptive egocenter or target pointing - exposed hand.

Table 3 presents the results of a multiple linear regression analysis in which the two egocentric measures were employed to predict adaptation in the target pointing - exposed hand measure. The weighted linear combination produced a substantial increase in accountable variance. The multiple correlation, $R(93) = .57, p < .01$, accounted for 33 percent of the variance in the criterion. Considered individually, visual egocenter accounted for only 13 percent and proprioceptive egocenter only 10 percent of the variance in the target pointing - exposed hand measure. The multiple regression was found to be significantly linear in form, $F(2, 93) = 22.52, p < .01$.

Table 2. Intercorrelation Matrix.

	M ₁	M ₂	M ₃	M ₄
Visual Egocenter (M ₁)	-	-.28*	.36*	.58*
Proprioceptive Egocenter (M ₂)		-	.32*	-.16
Target Pointing - Exposed Hand (M ₃)			-	.17
Target Pointing - Nonexposed Hand (M ₄)				-

* $p < .01$, $df = 94$.

Table 3. Multiple Linear Regression Analysis.

Criterion: Target pointing - exposed hand (M_3)					
	<u>Regression Coefficient</u>	<u>Standard Error of Regression Coefficient</u>	<u>Partial Correl. Coefficient</u>	<u>Sum of Squares</u>	<u>Proportion of Variance</u>
Predictors: Visual Egocenter (M_1)	.82	.15	.50	442.71	.132
Proprioceptive Egocenter (M_2)	.38	.07	.47	652.70	.194
Multiple correlation coefficient:	.57*				
Coefficient of determination:	.33				
Standard Error of Estimate:	4.93				
Intercept:	2.36				
Test of linearity:					
<u>Source of variance:</u>	<u>df</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>	
Due to regression	2	1095.41	547.71	22.52**	
Deviation from regression	93	2261.51	24.32		
Regression Equation:	$M_3 = 2.36 + .82M_1 + .38M_2$				

* $p < .01$, $df = 93$.

** $p < .01$, $df = 2, 93$.

DISCUSSION

The results are consistent with Canon's theoretical formulation with respect to locus of adaptation. The experimental hypotheses concerning the effects of practice were supported. Significant adaptation occurred in all three exposure conditions and in all four of the measures employed. The M x P and M x E interactions were significant. The M x P x E interaction was not significant. A significant O x P interaction occurred.

Of critical concern were the interactions with the measures factor, in particular with respect to the two egocentric measures. The results indicated that practice had an inverse effect on the adaptation observed in those two measures. That is, practice increased the adaptation observed in the visual egocentric measure, and decreased it in the proprioceptive egocentric measure. This finding is consistent with Canon's hypothesis that given cue discrepancy in the informational feedback provided by two modalities, experimental conditions which influence the attention accorded a given modality have predictable effects on locus of adaptation. The expected effect of practice was to increase attention to proprioception, thus producing less

adaptive shift in that modality, and more adaptation in the visual modality, relative to a zero practice condition. The results were consistent with this expectation.

The results with respect to egocentric measure and exposure condition in general replicate Canon's findings. Averaged over practice condition, terminal exposure produced a significant visual shift and an insignificant proprioceptive shift. The opposite relationship was observed with continuous exposure, i.e., a significant proprioceptive shift and an insignificant visual shift were produced.

Uhlarik and Canon (1971) obtained a significant though much reduced proprioceptive shift in the terminal exposure condition, relative to continuous exposure. The present experiment obtained identical results when no pre-exposure practice was provided. However, with administration of preexposure practice the level of proprioceptive adaptation in the terminal exposure condition declined, and was not significant. This finding may be theoretically attributed to the increased attention to proprioception elicited by preexposure practice. When averaged across practice levels in the terminal exposure condition, adaptation in the proprioceptive measure was not significant.

The significant negative correlation obtained between egocentric measures provides further support for the theoretical relationship between attention and adaptive loci

discussed above. That is, the results indicated that to the extent adaptation increased in one egocentric measure, it decreased in the other.

A powerful test of the effect of preexposure practice is provided in the zero exposure condition. Two key elements characterize this condition: (a) the absence of a simultaneous conflict between the visual and proprioceptive cues concerning limb position, and, (b) the fact that the subject is forced to rely exclusively on the proprioceptive cues for feedback concerning limb position. In the absence of a cue discrepancy there is no reason to expect any adaptation to occur as a result of prismatic displacement. The results confirm this expectation - in the zero exposure/zero preexposure practice condition, no adaptation was observed. However, when preexposure practice was administered in the zero exposure condition, significant adaptation was observed in two measures, visual egocenter and target pointing - exposed arm. (No difference over practice levels occurred in the proprioceptive measure for this condition, while target pointing - nonexposed arm fell just short of significance.)

This finding is consistent with Wallace's (1974) observation that preexposure practice is a sufficient condition for adaptation in target pointing to occur despite absence of visual feedback of limb position during prismatic exposure; it extends that observation to include adaptation

in the visual egocentric measure. The result is also consistent with Canon's model. Attention fully devoted to proprioception would be expected to produce adaptation with a visual locus, and no proprioceptive adaptation.

The results with respect to adaptation in the non-exposed hand support Canon's prediction of an isomorphism between that measure and visual shift. In all experimental combinations employed, the adaptation evident in the target pointing - nonexposed hand measure closely tracked that of the visual egocentric measure. A highly significant correlation between them was observed, while no significant relationship with the proprioceptive measure or target pointing - exposed hand measure was observed. It would appear, therefore, that adaptation in the target pointing - nonexposed hand measure can most parsimoniously be accounted for by attributing it to the effects of adaptation in the visual system. Since adaptation in the latter would have effects common to both arms, the process does not seem to be one of transfer between arms.

The results also lend support to the linear component model of adaptation advanced by McLaughlin and Webster (1967) and Wilkinson (1971). In the present study a significant multiple linear regression was observed between the weighted linear combination of egocentric measures and the target pointing - exposed arm measure. The obtained multiple correlation coefficient of .57 compares favorably

with the correlation of .64 obtained by Wilkinson. The finding that the algebraic sum of the egocentric measures equals the change in target pointing performance corroborates Wilkinson's results.

The variable of order of presentation of egocentric measures was not of direct interest in this study. Because of earlier research which suggested it might have an influence (Uhlarik and Canon, 1971), its effects were counter-balanced in the design. The significant $O \times P$ interaction confirmed this expectation. The effects of practice in this interaction were limited to the condition in which the visual egocentric measure preceded the proprioceptive egocentric measure. In that condition those effects led to increased adaptation when practice was provided and decreased adaptation when it was not. The results with respect to the $M \times P$ interaction indicated that the effect of practice is to increase visual adaptation. This would appear to account for the greater adaptation observed when visual egocenter was the first to be measured in the with-practice condition.

It would seem that either adaptation related to the visual egocentric measure is much more subject to rapid decay over time, or to the dissipating effects of intervening activity, or both, than is the proprioceptive measure. No difference between practice conditions was

evident when visual egocenter was measured after proprioceptive egocenter. Thus some of the beneficial effects of practice on visual adaptation are soon lost when that measure is not immediately sampled following exposure.

Additional research concerning factors influencing the course of decay in adaptation exhibited by egocentric and target pointing measures is needed.

REFERENCES

- Canon, L. K. Adaptation to simultaneous displacement of the visual and auditory fields. Proceedings of the 74th Annual Convention of the American Psychological Association, 1966, 1, 13-14.
- Canon, L. K. Intermodality inconsistency of input and directed attention as determinants of the nature of adaptation. Journal of Experimental Psychology, 1970, 84, 141-147.
- Canon, L. K. Directed attention and maladaptive "adaptation" to displacement of the visual field. Journal of Experimental Psychology, 1971, 88, 403-408.
- Choe, C. S., and Welch, R. B. Variables affecting the intermanual transfer and decay of prism adaptation. Journal of Experimental Psychology, 1974, 102, 1076-1084.
- Cohen, M. M. Continuous versus terminal visual feedback in prism aftereffects. Perceptual and Motor Skills, 1967, 24, 1295-1302.
- Craske, B. Adaptation to prisms: Change in internally registered eye-position. British Journal of Psychology, 1967, 57, 329-335.
- Dewar, R. Adaptation to displaced vision: Amount of optical displacement and practice. Perception and Psychophysics, 1970, 8, 313-316.
- Edwards, A. L. Experimental design in psychological research. New York: Holt, Rinehart and Winston, Inc., 1972.
- Hamilton, C. R. Intermanual transfer of adaptation to prisms. American Journal of Psychology, 1964, 77, 457-462.
- Harris, C. S. Adaptation to displaced vision: Visual, motor, or proprioceptive change? Science, 1963, 140, 812-813.

- Hay, J. C., Pick, H. L., and Ikeda, K. Visual capture produced by prism spectacles. Psychonomic Science, 1965, 2, 215-216.
- Helmholtz, H. von. Treatise on physiological optics. Translation from the 3rd German edition; J. P. C. Southall (Ed.), Vol. III, New York: Dover, 1962.
- Howard, I. P. Displacing the optical array. In S. J. Freedman (Ed.), The neuropsychology of spatially oriented behavior. Homewood, Ill.: Dorsey Press, 1968.
- Kohler, I. The formation and transformation of the perceptual world. (Translated by H. Fiss) Psychological Issues, 1964, 3(4).
- McLaughlin, S. C. and Webster, R. G. Changes in straight-ahead eye position during adaptation to wedge prisms. Perception & Psychophysics, 1967, 2, 27-44.
- Neilsen, T. I. Volition: A new experimental approach. Scandinavian Journal of Psychology, 1963, 4, 225-230.
- Pick, H. L., Jr., Warren, D. H. and Hay, J. C. Sensory conflict in judgement of spatial direction. Perception & Psychophysics, 1969, 6, 203-205.
- Rock, I. and Harris, C. S. Vision and touch. Scientific American, 1967, 216, 96-107.
- Stratton, G. M. Some preliminary experiments on vision without inversion of the retinal image. Psychological Review, 1896, 3, 611-617.
- Stratton, G. M. Upright vision and the retinal image. Psychological Review, 1897, 341-360, 463-481.
- Tastevin, J. En partant de l'experience d'Aristote. L'Encephale, 1937, 1, 57-84, 140-158.
- Uhlarik, J. J. and Canon, L. K. Influence of concurrent and terminal exposure conditions on the nature of perceptual adaptation. Journal of Experimental Psychology, 1971, 91, 233-239.
- Wallace, B. Preexposure pointing frequency effects on adaptation to prismatic viewing. Perception & Psychophysics, 1974, 15, 26-30.

- Wallach, H. Informational discrepancy as a basis of perceptual adaptation. In S. J. Freedman (Ed.) The neuropsychology of spatially oriented behavior. Homewood, Ill.: Dorsey Press, 1968.
- Wilkinson, D. A. Visual-motor control loop: A linear system? Journal of Experimental Psychology, 1971, 89, 250-257.
- Wundt, W. M. Principles of physiological psychology. Translated from the 5th German edition by E. B. Titchener. New York: The MacMillan Co., 1904.