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THE EFFECT OF ACTIVE AND PASSIVE MOVEMENT WITHIN AND BETWEEN VISUAL AND KINESTHETIC MODALITIES ON A DISTANCE REPRODUCTION TASK

by

© JAMES DANIEL McCLEMENTS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effect of Active and Passive Movement Within and Between Visual and Kinesthetic Modalities on a Distance Reproduction Task" submitted by James Daniel McClements in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

This study's purpose was to examine the input and output ends of the black box as the location of the kinesthetic-visual performance discrepancy. There were three factors of experimental interest: input, output and range. The dependent variable was the difference between the standard and reproduction trials and was converted to accuracy and constant error scores. Standard deviations were also calculated for between S variability. The task was angular distance reproduction using a smoothly rotating handle.

The design was a treatment by subjects, factorial, complete block, mixed model with repeated measures. Three three-way analyses of variance were computed and Duncan's New Multiple Range test was calculated for the main effects in the primary analysis. A similar secondary analysis was completed for accuracy and constant error scores in which conditions were selected from the whole model to directly examine the effect of sensory modality, motor involvement and identical input-output.

It was concluded that there was no effect of muscular involvement or sensory modality at the input end of the black box. The type of output motor involvement affected the bias of the output response but did not affect the accuracy or variability of the response. There was no effect of sensory modality at the output end of the black box. It was also concluded that the range effect appears to be more complicated than what was originally postulated by Pepper and Herman (1970).

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TABLE OF CONTENTS

CHAPTER		PAGE
I	INTRODUCTION	1
	Black Box Model of Human Performance	5
	Purpose	6
	Definitions	6
	Problems	7
	Delimitations of the Study	8
II	RELATED LITERATURE	10
	Sensory Modality and Performance Disparity	10
	Summary	12
	Performance and Movement Distances	12
	Summary	14
	Sources of Kinesthetic Information	14
	Muscle-joint-skin	14
	Active-passive Movement	19
	Efference and Active Movement	20
	Summary	22
	Input-Output Paradigm	23
	Summary	24
III	PROCEDURES	25
	Motor and Visual Involvement	25
	Motor Involvement	25
	Visual Involvement	26
	Factors	27

CHAPTER		PAGE

Input and Output Factors 27

Range Factor 27

Dependent Variable 28

Accuracy Scores 28

Constant Error Scores 29

Standard Deviations 29

Experimental Design 29

Task 31

Apparatus 31

Apparatus Calibration 34

Order of Presentation and Starting Position . 35

Subjects 35

Method 35

Analysis 36

IV ANALYSIS 40

Hypothesis 40

Primary Analysis 40

Secondary Analysis 41

Identical Input-Output Analysis 42

Results 42

Primary Analyses 42

Secondary Analyses 50

Input-Output Paradigm 58

Identical Input-Output Analyses 59

Discussion 59

CHAPTER PAGE

	Input	59
	Output	65
	Summary of the Input and Output	69
	Range	69
	Input-Output Paradigm	71
	Identical Input-Output	72
V	SUMMARY AND CONCLUSIONS	74
	Summary	74
	Conclusions	77
BIBLIOGRAPHY		78
APPENDIX A		85
APPENDIX B		89
APPENDIX C		105
APPENDIX D		118

LIST OF TABLES

TABLE		PAGE
1	Critical F Values	43
2	Three Way Analysis of Variance Accuracy Scores	44
3	Three Way Analysis of Variance Constant Error Scores	44
4	Three Way Analysis of Variance Standard Deviations	45
5	Excerpts of Main Effects and Significant Interactions from a Five Way Analysis of Variance White-Black Conditions Accuracy Scores	52
6	Excerpts of Main Effects and Significant Interactions from a Five Way Analysis of Variance Active-Passive Conditions Accuracy Scores	52
7	Excerpts of Main Effects and Significant Interactions from a Five Way Analysis of Variance White-Black Conditions Constant Error Scores	53
8	Excerpts of Main Effects and Significant Interactions from a Five Way Analysis of Variance Active-Passive Conditions Constant Error Scores	53
9	Means and Differences Between Intra-Modality and Inter-Modality Performances	60
10	Two Way Analysis of Variance Identical Input and Output Accuracy Scores	61
11	Two Way Analysis of Variance Identical Input and Output Constant Error Scores	61

LIST OF FIGURES

FIGURE		PAGE
1	Black Box Model of Human Performance	5
2	Experimental Design	30
3	Side View of Apparatus	32
4	Experimenter's View of Apparatus	32
5	Block Diagram of Apparatus	33
6	Means for the Main Effects of Input for Accuracy Scores, Constant Error Scores and Standard Deviations	46
7	Means for the Main Effects of Output for Accuracy Scores, Constant Error Scores and Standard Deviations	47
8	Means for the Main Effects of Range for Accuracy Scores, Constant Error Scores and Standard Deviations	48
9	Means for the Main Effects of Light Output of the Active-Passive and White-Black Secondary Analysis for Accuracy Scores, Constant Error Scores and Standard Deviations	54
10	Means for the Main Effects of Motor Output of the Active-Passive and White-Black Secondary Analysis for Accuracy Scores, Constant Error Scores and Standard Deviations	55

FIGURE		PAGE
11	Means for the Main Effects of Range of the Active-Passive and White-Black Secondary Analysis for Accuracy Scores, Constant Error Scores and Standard Deviations	56
12	Means for the Main Effect of Identical Input-Output for Accuracy Scores, Constant Error Scores and Standard Deviations	62

CHAPTER I

INTRODUCTION

Man is a tremendously versatile organism. However his capacities are not limitless. The rate of skill acquisition and the level of performance are subject to the limitations of his nervous system, musculature and the characteristics of the activity. Human performance theory tries to analyse the processes involved in skilled performance, to study the development of skills, to identify the limiting aspects of performance, to dissect complex tasks into simpler components, to establish quantitative estimates of man's abilities in each of the basic functions, and to predict man's capabilities in performing complex skills. Human performance theory uses as an approach the study of information processing within man's nervous system and the communication between man and his environment.

One of the basic components of skill is perception, both of the information necessary to perform an act, and that of the act itself. One perceptual process is that of kinesthesis. The importance of kinesthesis has been expressed many times by both psychologists and physical educators. One of the more general quotations is that of Julian Smith's (1969):

> The continued study of kinesthesis... should prove valuable to those physical educators who want to learn more about the complex process of motor learning. Skill acquisition involves the continual use of kinesthetic feedback and memory to assist in the production of a consistent movement pattern. Thus a greater understanding of kinesthesis should help physical educators develop teaching techniques which make greater use of the detailed verbal and visual feedback needed to augment kinesthetic feedback and thus to maximize the performer's awareness of his own movement process.

Although the importance of kinesthesis has been expressed clearly, the exact nature of the phenomena has been clouded by jargon. Ellfeldt and Metheny (1958) stated:

> The current terminology of movement-kinesthesia is characterized by great diversity... . Anatomists, physiologists, neurologists and orthopaedists have studied structure and function; kinesiologists have identified principles of mechanics and dynamics; and those interested primarily in sports, dance work have all developed special terminologies. This concern with specifics has created a kinesiological Tower of Babel inhabited by specialists speaking in different tongues, unable to communicate adequately with each other about the general nature of the phenomena of movement and kinesthesia with which they are dealing.

To say the least, there have been many problems with respect to jargon in the literature on the topic of kinesthesis. Boring (1942) reported that Bell in 1826 was probably the first to describe a sixth sense which he called muscle sense. Bastian in 1880 first used the term kinesthesis to refer to a sense of movement involving the sensibilities of muscles, tendons, joints and skin. Sherrington in 1906 coined the term proprioception because kinesthetic sensations were mediated by proprioceptors as distinguished from interoceptors and exteroceptors. Others used position sense and appreciation of passive movement.

Physical educators have used the terms feel, internal feedback, kinesthesis, proprioception, muscle-tendon-joint sense, posture sense, position movement-sense and others. However, the two terms in most common usage were kinesthesis and proprioception. The term proprioception came from the classification of sensory receptors (interoceptors, exteroceptors and proprioceptors). The proprioceptors were defined as the muscle, tendon and joint receptors. The term proprioception was not considered appropriate in the context of the present study because of Mountcastle's (1966) work which questioned the role of the muscle and tendon receptors as sources of conscious kinesthetic information. The muscle spindles and tendon organs supply information but perhaps not to consciousness. This writer chose instead kinesthesis, because of its origin Greek, kinesis (motion) and asthesia (to perceive) which best described the phenomena to be studied. A third term, although not referred to very much, was that of somesthesis which referred to the various senses of the skin and the sense of movement.

Researchers in psychology and physical education have examined kinesthetic phenomena since the early 1880's. There have been two main trends of study. One of these was the anatomical and neurological aspect of kinesthesis. Recent works by Mountcastle and his associates (Mountcastle and Powell (1959), Rose and Mountcastle (1959) and Mountcastle (1966)) are good examples.

The other trend has been the psychophysical study of behaviour. Some researchers, (Young, 1945; Witte, 1952; Roloff, 1954; Russel, 1954; Scott, 1955), tried to define a general kinesthetic sense using correlational studies. Other using correlational studies tried to correlate kinesthesis with specific sport abilities and skills, (Mumby, 1953; Ryan and Foster, 1967); rate of learning, (Clapper, 1954; Phillips, 1941; Roloff, 1954); and general motor ability tests, (Start, 1964; and Rosentswieg, 1965). This research on kinesthetic tests was rejected as inadequate by Henry (1953) who attempted to test the factor of force in kinesthesis.

The research on kinesthesis in physical education to this point had been characterized by descriptive techniques. According to Wilberg (1969), there had been a lack of theoretical meaningfulness. As Forscher (1963) expressed it: "... useful edifice(s) ... were buried under an avalanche of random bricks." In fact, Forscher further stated: "It became difficult to find a suitable plot for construction of an edifice, because the ground was covered with loose bricks."

More recent work by Posner (1966, 1967), Norrie (1967, 1968, 1969), Wilberg (1969), Moyst (1969), Hughes (1969), Stelmach (1970) and McClements (1969) were concerned with factors involved in kinesthetic short-term memory. Wilberg (1969) stated that, "... skill areas can be dissected... the importance of such a dissection laying in the ability of the selected parts (variables) to predict, within well defined limits the undissected skill." Wilberg (1969) further stated that problems concerning non-verbal storage in short-term memory had not been well examined. Kinesthesis was not well defined. The primary concern of the short-term memory studies (particularly Posner (1966, 1967) and Wilberg (1969)) was a differential storage in short-term memory.

One common finding among the above studies was that the visual reproduction of the independent variable studied (force, torque, distance, etc.) was superior to the kinesthetic reproduction (operationally defined as non-visual reproduction) (Posner and Konick (1966), Wilberg (1969), Hughes (1969), Moyst (1969) and McClements (1969)). Wilberg (1969) commented:

> The assumption often implied in a formal definition or construct is that the performer actually attended to the available input information. Unfortunately for the coach or instructor the kinds of information the student attended to are not always obvious.

Black Box Model of Human Performance

A very simple model of human performance is that of the black box (See Figure 1). The model consists of input, central processing and

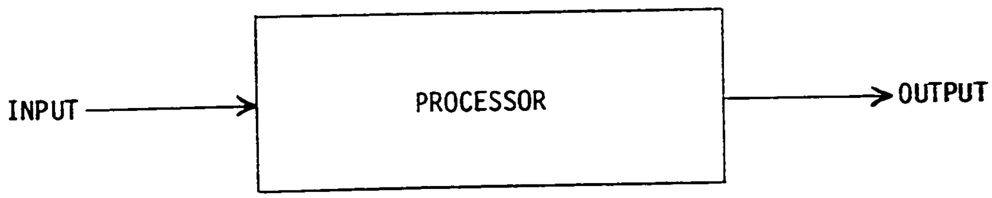

FIGURE 1

BLACK BOX MODEL OF HUMAN PERFORMANCE

output. The input portion of the model represented the information that is made available to the performer. Processing is a label applied to all the things the performer does to the information. Finally, output is the finished product or the response the performer produces as a result of the input and processing. In the above quotation by Wilberg (1969) the assumption was that Ss did not attend to the information input. However, what if the difference between the visual and kinesthetic conditions were not solely at the input end of the black box?

It was in fact the writer's 'black box' level of hypothesis that there may be three possible reasons or sources of this discrepancy:

1. perceptual or sensory input
2. processing or storage
3. motor output

Storage has been examined previously by researchers such as Posner

(1966, 1967) and Wilberg (1969) and the processing was, to make an understatement, difficult to examine.

I. PURPOSE

The purpose of this study was to try and determine if the difference between visual and kinesthetic performance was at the input or output end of the black box. An often unstated but basic assumption of previous research has been that the discrepancy has been at the sensory or input end of the black box. There is no evidence available to prove this assumption. However, it is important to the understanding of human motor performance that this assumption be examined.

II. DEFINITIONS

Reproduction accuracy. The accuracy of reproducing an angular distance presented by a handle turning on a standard trial.

Efferent information. The information available to the performer from the impulses to the motor effectors.

Afferent information. The information available to the performer from the impulses from sensory receptors.

Range effect. Shorter distance errors overshoot the standard distance and longer distance errors undershoot the standard distance in a standard distance reproduction task.

Active movement. Twisting of a handle initiated and controlled by the S.

Passive movement. Twisting of a handle initiated and controlled by E, however the S gripped the handle.

Kinesthesis. Wilberg operationally defined kinesthesis: "That particular form of non-visual information generated by the gripping and twisting of a handle."

Environmental cues. Those visual cues that were available to the S from the background or surroundings that augment the visual cues directly related to the handle.

III. PROBLEMS

1. Sensory modality comparisons recently received considerable attention in the literature. One comparison was that of vision and kinesthesis. The superiority of vision over kinesthesis seemed to depend on the definition of visual and kinesthetic modalities. Vision was found to be equal to kinesthesis if vision excluded the surrounding information of the environment and/or kinesthesis included increasing force. In this study visual cues with or without environmental cues were compared to kinesthesis.

2. The second problem was active versus passive movement of the limbs. The majority of the studies have shown that active movement was more accurate than passive movement for reproduction tasks. The differential effect of these conditions was attributed to the active movement having efferent information as well as the afferent information from the passive movement. Posner and Konick (1966) found that the addition of a motor movement to vision did little to change performance on a location

task. In this investigation, active, passive, and observe conditions were compared with each other.

3. The third dimension of range was included to prevent confounding due to a range effect. In distance reproduction studies, the distance moved was directly related to absolute error. If algebraic error was used in the analysis, a range effect was found.

4. The major purpose of the study was concerned with the input-output of the modalities as sources of information. This writer's interest was to try to determine if the difference between the modalities was at either the input or output end of the black box. The difficulty lay in the fact that there was no known way to directly measure how much information the perceptual or sensory processes provided the organism. It was proposed, therefore, to vary the amount or quality of the input or output information available to the Ss. If the error was all at the input end, there would be a significant input main effect. Similarly, there would be a significant output main effect if the error was at the output end. The purpose of the study was to determine if the discrepancy between visual and kinesthetic performance was at the input or output end of the black box or if both the input and the output contributed to error.

IV. DELIMITATIONS OF THE STUDY

1. The study was delimited by the number, sampling and ages of the Ss.

2. The study was delimited because the raw data was read only to

the nearest whole degree.

3. The study was delimited by the fact that the amount of information available for input and output could only be indirectly determined.

4. The study was delimited because although information could be made available to the S, there was no method of determining whether or not the S made use of it.

CHAPTER II

RELATED LITERATURE

In this chapter the relevant literature directly related to the research problem has been reviewed. The initial review concerns the disparity between visual and kinesthetic performances. Studies on distance factors in kinesthetic performance were included next, to prevent any conclusions from being narrowed by the range effect. Tracing of sources of kinesthetic information from the muscle-joint-skin receptors through the active-passive behavioural studies and the efferent studies were used to develop a partial explanation of kinesthesis. The input-output comparison paradigm was developed to study the visual kinesthetic disparity.

I. SENSORY MODALITY AND PERFORMANCE DISPARITY

The literature concerning the disparity between sensory modalities came mainly from deprivation studies in which the effects of one or more modalities were removed. Only the visual and kinesthetic sensory modalities are considered here.

Gibbs and Logan (1965) used visual, kinesthetic and combined input data to review the earlier conclusions that proprioceptive movement was less accurate than visual movement. They found that there was little difference in accuracy due to input source. They suggested that possibly accuracy of verbal and visual associations were tested and not proprioception or that accuracy may be dependent upon frequency of use. Levy

(1967) investigated positioning accuracy under conditions of minimal visual and kinesthetic information. Levy reported no difference in position accuracy if the output modality was identical to the input modality. Performance was hindered if the input-output modalities differed. Levy commented that limited visual information did not supplement kinesthetic information.

Robb (1967) examined the acquisition of arm movement patterns under conditions which varied in both type and frequency of feedback. She found that concurrent visual feedback was superior to concurrent proprioceptive feedback. Souder (1969) examined a possible relationship between upright perception in a two dimensional space and movement accuracy. Souder found that without complete visual field reference in the environment, movement accuracy deteriorated.

Kinesthetic distance, force or position reproduction accuracy has been used as a dependent variable in many studies of short-term memory. In the studies investigated below only the immediate reproduction results were reported. The results in some cases were directional only in that significance or lack of significance on the primary main effect was not generally reported. Posner and Konick (1966) calculated rate of information loss and reported that initial retention of visual image was superior to that of kinesthesis. Posner (1967) found that initial visual accuracy was superior to initial kinesthetic accuracy but this difference was not significant. In a series of studies that investigated factors in kinesthetic short-term memory, Wilberg (1969), Moyst (1969), Hughes (1969) and McClements (1969), all found initial visual reproduction superior to initial kinesthetic reproduction. In the same series, Carre (1969) reported no difference between the visual and kinesthetic modality.

Summary

In reproduction tasks, visual performance was superior to kinesthetic performance if environmental cues were included in the visual information. However, if the visual cues did not include environmental cues then performance deteriorated.

II. PERFORMANCE AND MOVEMENT DISTANCES

Weiss (1955) loaded a joystick for different displacements and forces, and commented that the extent of movement was a more useful cue than force or pressure. Smalheiser (1965) found that distance produced significant differences in the constant error response measure for backward and forward arm positioning. Posner and Konick (1966) noted that absolute error was a linear function of distance moved. Lloyd (1968) reported that the shorter distances were more accurate than the longer distances. McClements (1969) noted a linear relationship between the amount of error and the log (base two) of the distance.

Christina (1967) found that accuracy of reproduction increased as the size of the angle to be reproduced increased. Ellis et al (1968) had two conditions of movement, very short and very long. They reported that error with the longer movement was less than error with the short movement. Stelmach (1969) studied the retention of simple movement responses and found no effect due to the amplitude of movement.

Brown et al (1948) measured positioning reactions in the absence of visual cues. Their task involved linear distance reproduction in horizontal and vertical planes. They found a range effect, i.e., Ss overshot at shorter distances and undershot at longer distances and that the percentage error was greater at the short distances and decreased as the distances increased. Keele (1968) summarized an unpublished study that suggested there were different cues involved in the retention of long and short movements. Stelmach (1968) reported that the accuracy of reproduction using absolute error was a function of the amplitude of movement. However, when algebraic error was considered, a range effect was confirmed. Stelmach (1970) reported large overshoot errors at twenty degrees and negative errors increasing with the angle size from forty to one hundred degrees. Stelmach and Wilson (1970) examined the effect of motor interpolated tasks on short-term memory. They reported no effect due to movement distance for absolute errors. However, they did comment that there was a range effect but that it was not significant.

Pepper and Herman (1970) reviewed the data of Keele (1968), Posner (1967) and Posner and Konick (1966), and suggested that when their algebraic errors were analysed, a range effect was confirmed. Pepper and Herman's data was compatible with Adams and Dijkstra's (1966) data. Pepper and Herman produced only overshooting while Adams and Dijkstra (1966) reported only undershooting. Pepper and Herman explained that the two studies were in the extreme ends of the range effect.

Levy (1967) found that consistency scores increased with distance moved and reported data similar to the range effect for constant error scores.

Summary

An increase in the error as distance increased was found for movement distances when accuracy (absolute error) was analysed. However if constant error (algebraic error) was examined, a range effect of undershoot for long distances and overshoot of short distances occurred.

III. SOURCES OF KINESTHETIC INFORMATION

There have been three research approaches on the source of kinesthetic information. The earliest approach was identification of sensory receptors' roles (muscle-joint-skin). The second approach was concerned with the type of movement (active-passive). The third dealt with an efferent theory of kinesthesis.

Muscle-joint-skin

Boring (1942) reported that Bell (1926) was the first to accept muscle sense as a "sixth sense". Bell's rational was based on the removal of limb sensation (dorsal root fibers were cut) but with the muscle innervation left intact. Bell argued that precise movement depended on afferent muscle sensations in addition to efferent innervation. Boring (1942) further reported that there were no physiological correlates of muscle sense recognized until Kuhne named some previously deleted organs, muscle spindles. However Kuhne cautiously suggested that these receptors might be involved in muscle sense. Sherrington (1894) established that muscle spindles had a sensory function.

Boring (1942) also reported that Rauber (1865) associated Pacinian corpuscles with the tendons and ligaments surrounding the joints. Goldscheider (1889) and others, knowing that joints had sensitive organs concluded that these organs were responsible for knowledge of limb position and movement. Goldscheider claimed that these joint receptors were of more value than muscle or tactile sense.

Pillsbury (1901) passed an induction current through the elbow and wrist, and found that it decreased the joints' sensitivity (the just noticeable difference increased). Furthermore anaesthetization of the elbow and wrist caused a greater decrement. He replicated the study using the knee and ankle. From both of these studies he concluded that the source of information was in the muscles and tendons, and not in the joints as Goldscheider thought. Pillsbury based his conclusions on the fact that the electrical stimulation and anaesthesia of distal joints interfered with the just noticeable difference of proximal joints.

Winter (1912) reported that Angier (1905) agreed with Goldscheider in that the sensation of movement came from the joints and that neither arm position nor muscle condition had any effect. However Winter also reported that Strumpell (1903) attributed the sensation of movement to muscles. Winter utilized the same conditions as Pillsbury did and added electrical stimulation of the upper arm, lower arm and hand as well as four speeds. He also disagreed with Goldscheider, claiming that anaesthesia affected the muscles and the joint tendons but not the articular surface.

McCouch et al (1951) conducted two experiments on the problem of whether end organs for tonic neck reflexes lie in the muscles or the joints. The first experiment was to sever all muscle innervations of the upper three cervical segments of cats. The second was to sever all joint innervations of the same area. The reflexes were elicited without the muscle and skin sensations. However, there were no reflexes when the joint innervation was severed, and the muscle and skin innervation was impaired.

Mountcastle and Powell (1959) studied neural discharge patterns on the postcentral gyrus of monkey brains for movement and steady angles of joints. They found a precise relationship of the firing of a neuron to the joint position, and a second relationship between the frequency of firing and the speed of movement. The final or steady discharge rate was dependent upon the joint position with the highest rates at the extremities.

Similar joint movements produced more or less similar discharge patterns. Particularly in non-axial joints a large majority of the neuron were unidirectional and were inhibited when the joint was moved in the opposite direction. They found no excitatory interaction between skin and joint receptors. However, they did find an inhibitory effect of distal skin receptors on the proximal joint neurons, e.g., the hand on the shoulder.

Mountcastle and Powell (1959) did not observe any cortical neurons driven by the stretching of muscle tissue. The muscle spindle fibers go to the cerebellum and to the cerebrum. The frequency of discharge of muscle spindles was independent of the length of the muscles.

Davis (1966) studied the passive movement in joint receptors and concluded that acceleration was the most likely stimulus for movement. He also noted that the most sensitive area was the normal joint position and that the starting position and the direction of movement had a bearing on this sensitivity.

Gelfan and Carter (1967) investigated input from muscle spindles as a source of information for a conscious awareness of muscle length. They exposed the tendons and by pulling, shortened or lengthened the muscle length. His patients reported no experience of pulling or stretching muscles. They concluded that the information from stretch receptors was not consciously received.

Irvine and Ludvigh (1936) rejected the existence of position sense in eye muscles. They stated that there were no muscle spindles in the eye. They also argued that Ss with paralyzed eye muscles were unaware of their eye position and that persons with nystagmus could not determine whether their eyes were moving. Also under a condition of vestibularly induced nystagmus the Ss' eyes were perceived as stationary. Ludvigh (1952) argued that the above experiments were conducted in an abnormal situation. In an attempt to control this, he used a rotating mirror assembly which forced the Ss to judge whether they were looking right or left. He found that the eye did have some position sense but that it was very gross when compared to the ability of the organism to distinguish the direction of the eyes in relation to an object. It was also very gross when compared to the position sense of the hip joint.

He concluded that the muscle spindles of the extra-ocular muscles did not produce much acceptable information about eye position. He suggested that it is doubtful that the skeletal muscle spindles could mediate knowledge of limb position.

Merton (1961) designed an experiment, "... from the conviction the sense organs in muscles are not, in fact, designed to give accurate positional information." He investigated arm positioning (measured by pointing) and eye positioning (measured by after images). He found that the eye and the arm positioning errors were very similar. He attributed this relationship to the joint use of the hand and eye in human life.

Cohen (1958) studied the contribution of the tactile, musculo-tendinous and articular receptor in human shoulders. He used a control condition, a weight-added condition, a tape-covered shoulder condition and a tape-and-weight condition. He concluded that tactual and musculo-tendinous receptors made small contributions but the most important information came from the articular receptors. Cohen (1961) abolished proprioception from extra-ocular muscles by surgery, and used nerve blocks to abolish the power of accommodation by the cilary muscles and the first three cervical vertebrae. These three proprioceptive systems were abolished singly and in combination. The removal of proprioception from the extra-ocular muscles and accommodation had no effect. The removal of the neck proprioception caused widespread defects in balance and orientation and, therefore, motor co-ordination. Lee and Ring (1954) found that interference with skin sensation around a joint does not affect position sense for movements of that joint.

Norman and Kiker (1969) attributed the non-visual estimation of near space to a unitary sensory process or to a phenomena of sense of space that had components of visual, tactual, distance, duraction, vestibular cues as well as muscle and joint sense.

Active-passive Movement

Brown et al (1953) studied the passive movement sense in the metatarso-phalangeal joint. The joint and capsule were anesthetized. They found that the appreciation of active movement was unimpaired but the appreciation of passive movement was impaired. From these results they suggested that the source of sensation was in the joint capsule and not the muscle or tendons. However, active movement supplemented this sensation with sensations from the muscles and tendons. Provins (1958) did a supplement to Brown's work using a similar apparatus but examining the finger instead of the toe. He had both controlled and blocked with active and passive movement tasks. He found that active movement slightly improved performance in the control Ss but not when the joints were anesthetized. Both active and passive performance showed a decrement when blocking occurred. He disagreed with Brown in suggesting that the sensation of active and passive movement was based on the same source of information.

Lloyd and Caldwell (1965) studied the active and passive positioning of men's legs. They reported that the accuracy of positioning a limb was better for the active movement than the passive. The normal walking position of the legs with active movement provided the most accurate responses. They suggested two reasons. The first was that there may have been a practice effect, second was that there may have been more joint receptors in this area. They further suggested that the joint receptors may be a source of noise as well as relevant information. Lloyd (1968) found that active positioning was superior to passive positioning. However, he also found an increase in the muscle activity of the contralateral limb which may be confounding the passive condition. Levy (1967) found no difference in the active or passive manipulating of the arm carrying out a positioning accuracy task.

Efference and Active Movement

Brindley and Merton (1960) ran several tests to study position sense in the eye. The first was passive deviation of one eye by using forceps on the anaesthetized conjunctival sac. This caused no sensation or substantial reflex movement of the other eye. Simultaneous movements of both eyes did not cause kinesthetic sensation either. When the eyes were fixed and the organism actively tried to move his eyes, he always perceived his environment as moving. They concluded that there was no position sense dependent upon proprioception from extra-ocular muscles or muscle spindles. They attributed position sense of the eyes to what Helmholtz called 'a will to move'.

Festinger and Canon (1965) utilized the fact that proprioceptive input from eye muscles was poor to test their hypothesis that the human organism possessed "outflow" information based on nerve impulses from motor pathways. They attributed the phenomena of objects moving to the eye failing to reply to a command of efferent information. They cited von Holtz (1954) who proposed the idea of an efference copy (e.g. afferent information was matched to efferent information). A basic trial was used where visual information was available while pointing was used to determine optimal performance. Two other conditions, one involving saccadic eye movement, the other involving smooth eye movement were used. According to Festinger and Canon (1965) the saccadic eye movement should provide better efferent information than smooth eye movement. The target location was more accurate with the saccadic eye movement than with the smooth eye movement. Thus it was concluded that efferent information was available to the organism.

The above held true while the head was fixed, however, when the head was allowed to move, good kinesthetic information was no longer as important. The efferent information was as good as the kinesthetic information plus the efferent information, implying that there may be some redundancy. The performance for the head movement information never reached optimal level, but the performance for the head fixed saccadic movement did equal the optimal while the smooth movement did not.

Adams (1967) postulated a perceptual trace in short-term memory. It was this writer's view that Adam's perceptual trace could be a store of the efferent information. Lester (1968) reviewed the literature and concluded that awareness of position sense change may not be due to afference from proprioceptors but rather the monitoring of efference.

Higgins and Angel (1969) measured error correction time and proprioceptive reaction time using the same techniques. They found that the error correction time was well within proprioceptive reaction time. They rejected the explanation that the correction was only part of the motor plan and suggested that Ss can detect errors without peripheral or visual feedback. They concluded that Ss monitored their own feedback internally and compared actual motor commands with reference values and did error corrections based on this. This was interpreted as support for Festinger and Canon's theory that efferent information was available to the Ss.

Held and Freedman (1963) and Held (1965) found that active arm movements produced compensatory shifts in positioning a visually displaced arm. Passive arm movement did not produce this shift. They concluded that in the passive condition the crucial connection or correlation between motor output was lacking. Merton (1964) anaesthetized the thumb and wrist with a pneumatic tourniquet that did not affect the muscles. He found that the anaesthesized hand was insensitive to passive movement of the joints but was sensitive to active movement of the joints. He suggested that the limb muscles were similar to the eye and tongue muscles in that they were insentient (when stretched or allowed to shorten they gave rise to no conscious sensation). He attributed the component of the active movement to a sense of effort (a code sent out by the motor cortex representing instructions to perform movements; not specific instructions to muscles).

Summary

The muscle-joint-tactile research accepted the joint receptors as sources of kinesthetic information and rejected the muscle and skin receptors. However, efferent information of active movement was accredited for the superior performance of active over passive movement. An efferent theory of motor awareness was suggested and this may have been the reason for active movements' superiority over passive movement.

IV. INPUT-OUTPUT PARADIGM

Legge (1965) studied the visual and proprioceptive accuracy of aligning a pointer with a target under the effects of small doses of nitrous oxide. The doses of nitrous oxide were strong enough to produce analgesia (absence of pain) but not strong enough for anaesthesia (absence of sensation). He found a significant decrease in performance due to drug dosage. He found the visual target and pointer condition produced an almost perfect performance. Proprioceptive target and pointer conditions produced a performance slightly more variable than the visual target and pointer condition. Visual target and proprioceptive pointer produced large positive error while the visual pointer and proprioceptive target gave negative errors. He concluded that the integration of visual and proprioceptive information added an additional process.

Levy (1967) investigated the effects on positioning accuracy of visual and kinesthetic input and output information. His visual condition was a luminous rod on a dark background. He found the luminous rod did not add information if it was present or absent during both the input and output phases. He found performance was impaired if visual information was provided in one phase and not the other.

Connolly and Jones (1970) studied cross and intra-modal matching (visual and kinesthetic). Intra-modal matching was more accurate and less variable than cross-modal matching. The visual-visual performance was superior to the kinesthetic-kinesthetic. The kinesthetic-visual condition was more accurate than the visual-kinesthetic condition. They postulated a model that assumed separate visual and kinesthetic storage. They offered the more rapid decay of the kinesthetic as an explanation for kinesthetic output being inferior to visual output. They suggested that the transformation from one modality to the other may cause a greater error in cross-modality matching than intra-modality matching.

Summary

The intra-modality matching produced a superior performance when compared to inter-modality matching.

CHAPTER III

PROCEDURES

The three independent variables of input, output, and range, and the levels of these factors, were chosen, based on the review of literature, to study the problem of visual kinesthetic disparity. The motor and light involvement were discussed before the factors of input and output because the latter factors are made up of combinations of these involvements.

I. MOTOR AND VISUAL INVOLVEMENT

Motor Involvement

There are three types of motor involvement selected:

Active. The active motor condition was defined as the information available to the S from the gripping and twisting of the handle with active muscle involvement. The S controlled the rotation of the handle. For the input conditions, the S stopped rotating the handle when it hit the stop peg and the tone sounded. For the output conditions, the S attempted to reproduce the input distance.

Passive. The passive motor condition was defined as the information available to the S from the gripping and twisting of the handle with passive muscle involvement. The E controlled the rotation of the handle. For the input conditions, the handle stopped rotating when it hit the stop peg and the tone sounded. For the output conditions, the S gripped the handle. The E turned the handle and the S gripped the handle and verbally instructed the E on how far the handle was to be turned.

Observe. The observe motor condition was defined as the information available to the S from watching the handle without gripping or holding it. The E controlled the rotation of the handle and the S rested his arm. For the input conditions, the S watched the handle rotate until it hit the stop peg and the tone sounded. For the output conditions, the S watched the handle and verbally instructed the E on how far the handle was to be turned.

Each type of motor involvement was selected for its available sources of information. For the observe conditions, the information was limited to the visual components. The passive conditions should have had an afferent component in addition to whatever visual information was available. It was assumed that the active conditions should have had the same visual and afferent information as the passive condition and efferent information from active muscular involvement.

Visual Involvement

There were three types of visual information selected:

White light. The white light condition was defined as the information available to the S from watching the handle turn with a visible background.

Black light. The black light condition was defined as the information available to the S from watching the handle turn without a visible background.

No light. The no light condition was defined as the information available to the S from gripping and/or turning the handle without a visual aid.

Each type of visual involvement was selected for its available sources of information. For the no light conditions, the information available was limited to kinesthetic cues. The black light conditions separated the task visual information from the background information. The background information was available only under the white light condition which also included the task visual information.

The visual conditions were controlled by means of switches used by the E. The motor conditions required the S's co-operation.

II. FACTORS

Input and Output Factors

The three types of motor involvement and the three types of visual involvement discussed above were combined into the eight levels of the input and output factors: active with white light, active with black light, active with no light, passive with white light, passive with black light, passive with no light, observe with white light and observe with black light. The 'observe-no-light' combination was not used because there would have been no information available to the S.

Range Factor

There were two levels of range selected:

Short range. The short range was defined as distances from ten to thirty degrees in two-degree intervals.

Long range. The long range was defined as distances from sixty to eighty degrees in two-degree intervals.

The range effect was included as a factor to prevent confounding due to differential effects of long and short distances. The distances within the ranges were determined by using Fisher and Yates (1963) tables of random numbers, sampling with replacement.

III. DEPENDENT VARIABLE

The dependent variable was the difference between the input or standard trial and the output or reproduction trial. This difference was converted to accuracy scores and constant error scores. Standard deviations were calculated as a measure of between S variability.

Accuracy Scores

Accuracy scores were calculated as the absolute differences between the input and output trials. It was used as a measure of central tendency which had only scalar qualities. It differed from the constant error scores in that it reflected only the magnitude of error without regard for directional bias. It was the best estimate of the response accuracy or size of error.

Constant Error Scores

Constant error scores were calculated as the algebraic difference between the input and output trials. It was used as a measure of central tendency which had vector qualities reflecting both magnitude and direction of error. It was the best estimate of the average bias of the response, that is, whether the response was short or long and by how much.

Standard Deviations

Standard deviations of the constant error served as a variable error score. It was a measure of consistency or variability between Ss. It would have been better to have an estimate of each Ss' variability but this was impossible as there was only one entry per S per cell.

IV. EXPERIMENTAL DESIGN

The experimental design selected had to allow the analysis of the main effects of input, output and range as well as their interactions. The experimental design selected was a treatment by subjects, factorial, complete block, mixed model with repeated measures. The subjects, who were chosen, were treated as separate blocks. The levels of the three factors of experimental interest, input with eight levels, output with eight levels and range with two levels, were selected, and thus were fixed factors. The input and output factors had identical levels (see Figure 2).

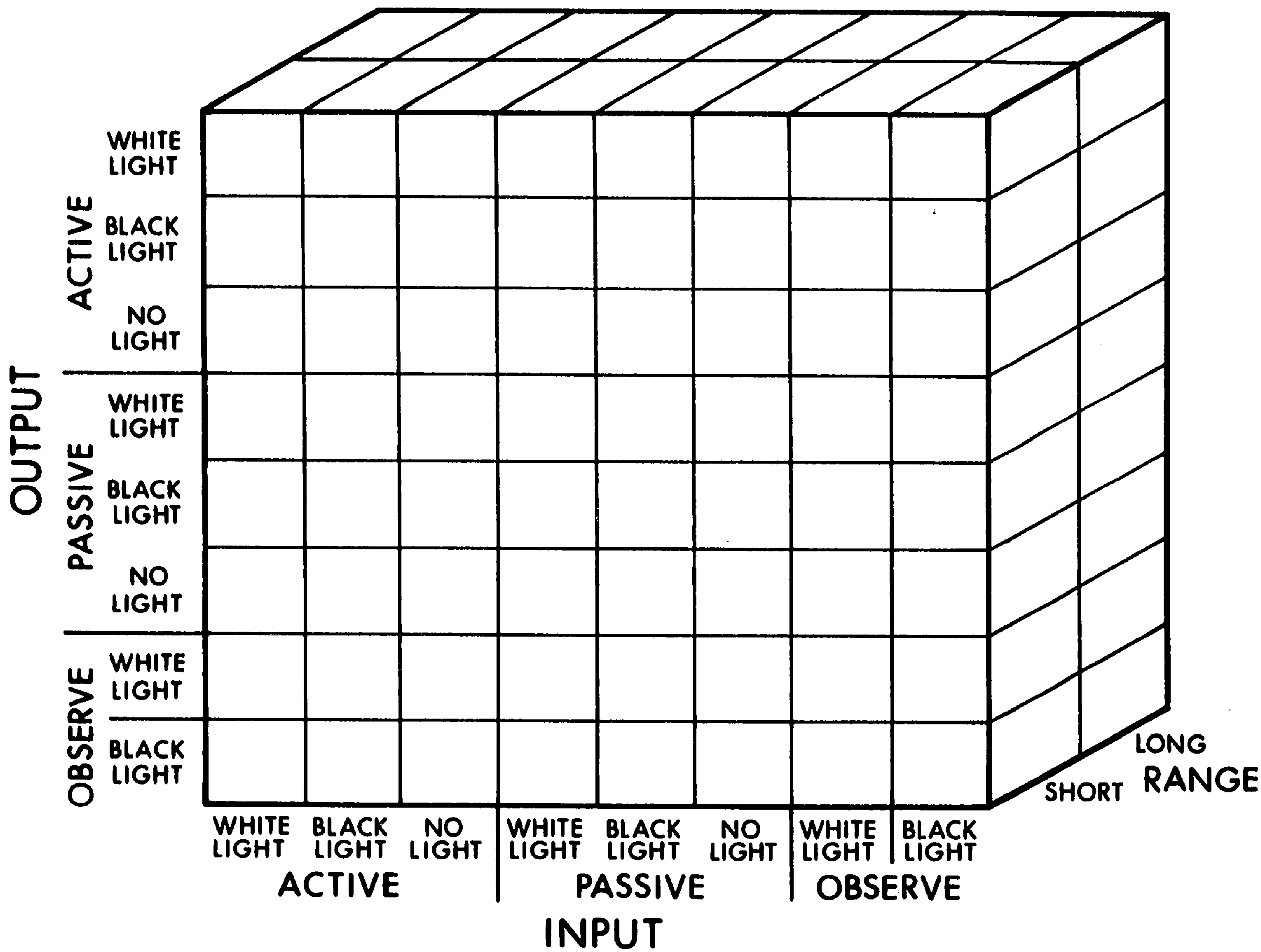

FIGURE 2 EXPERIMENTAL DESIGN

V. TASK

The task was the reproduction of an angular distance utilizing a rotary action of the wrist and forearm. The subjects were presented with a standard angular distance under specified light and motor conditions and were asked to immediately reproduce the input standard distance under the same or a new combination of light and motor conditions. The extent of movement was the only thing being reproduced.

VI. APPARATUS

The apparatus utilized was a smooth rotating handle (see Figures 3, 4, and 5). The _S_ placed his arm in a box which contained the handle, a white light system and a black light system. A pointer was attached to the handle. Both the handle and the pointer were painted with luminous green paint. The entire inside of the box was painted with flat black paint. All the _S_ could see under maximum light conditions were the handle, the pointer, his arm and hand, and the flat black background. With the black light, the _S_'s saw only the handle and the pointer. The _S_'s head was in a tunnel to prevent any light entering the box from the _Ss_ side.

On the _E_'s side of the apparatus, a pointer was firmly attached to the spindle of the handle. The spindle passed through the center of a 360-degree protractor. One hundred holes were drilled for the stop peg at two-degree intervals on the circumference of the protractor. These holes were all within the _S_'s range of movement.

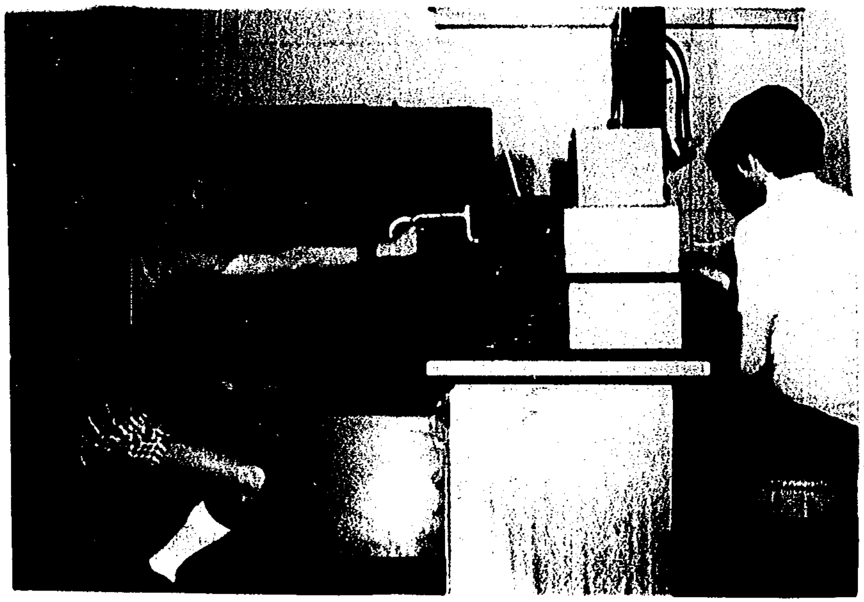

FIGURE 3

SIDE VIEW OF APPARATUS

(side of tunnel removed)

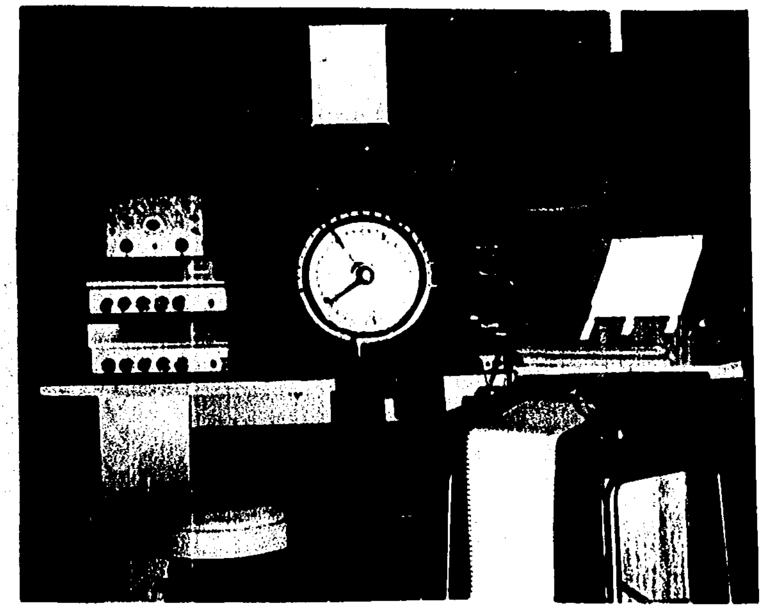

FIGURE 4

EXPERIMENTER'S VIEW OF APPARATUS

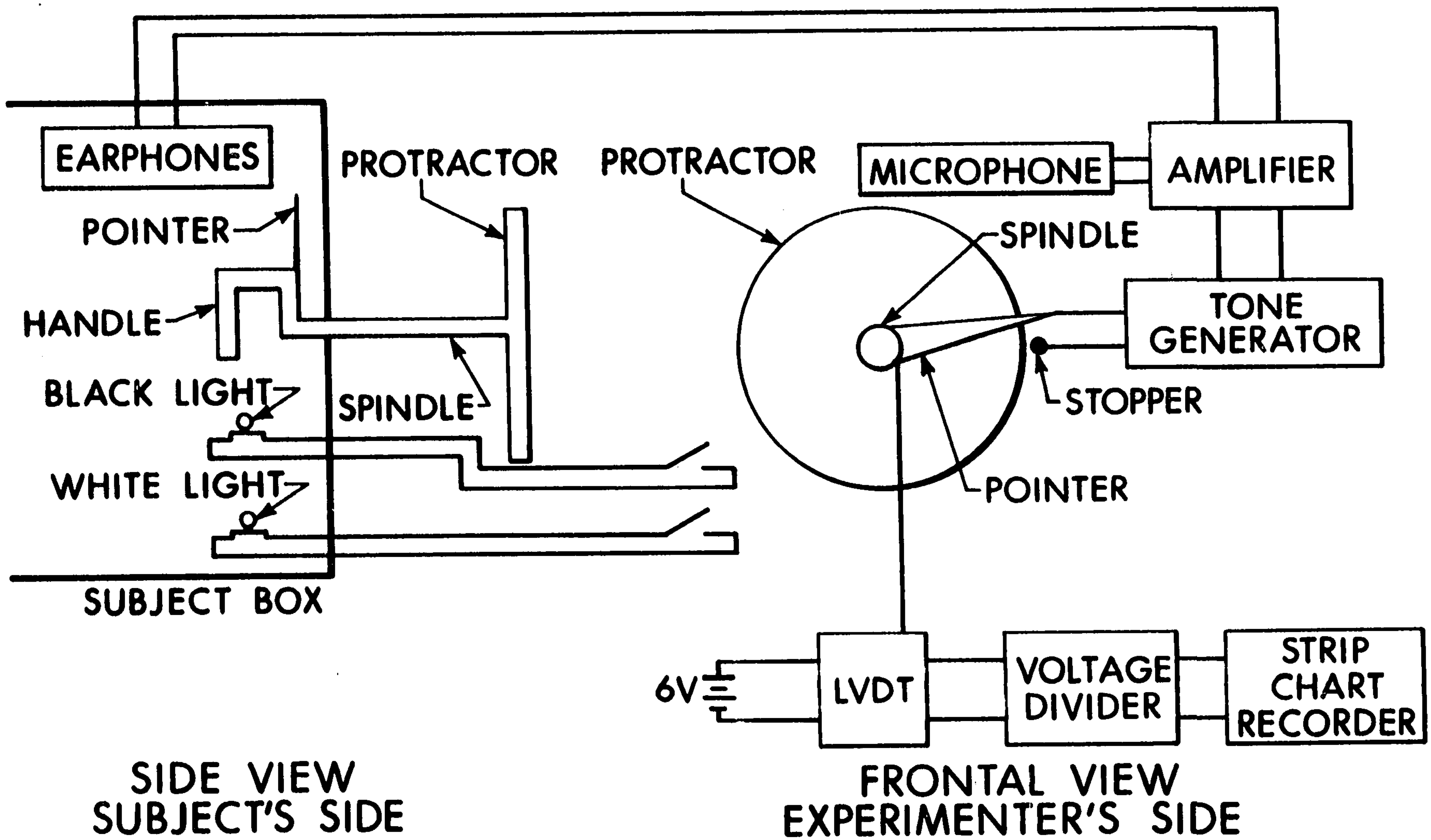

FIGURE 5 BLOCK DIAGRAM APPARATUS

Attached to the spindle was one side of a normally open contact switch. The other side of the switch was connected to the stop peg. On the completion of the input trial, the spindle touched the stop peg and an electric circuit was completed. When this circuit closed, a signal tone was produced from a pure tone generator. An EICO Model 377 auditory tone generator was connected to a Bogen 'Challenger' Model CHB20A amplifier and a set of Telex Model ST-20 headphones. An Electro-voice 644 Sound Spot microphone was also connected to the amplifier and used by the E to communicate with the S.

Also connected to the spindle was a short piece of cord which was fastened to the armature of a Sanborn DCDT, D.C. Differential Transformer Displacement Transducer. The transducer had a six-volt D.C. battery as a power source. The output was stepped down from a six volt scale by a voltage divider to a 100 mv scale to be compatible with the Sargent Model SRG strip chart recorder. The latter was used to record the input and output distances.

VII. APPARATUS CALIBRATION

Calibrations were conducted on three consecutive days. Measurements were taken at ten-degree intervals from zero to two hundred degrees in a random order with five repetitions per day. The largest range of the fifteen readings at any one interval was one degree. The largest range of the means of the five repetitions for the three days for any one interval was 0.16 degrees. As the apparatus could only be read to one degree accuracy, a tolerance of one degree between readings was considered acceptable.

The data collected for calibration was not quite linear throughout the entire range of movements. The experimental data was corrected for this nonlinearity using a computer program written by this writer before the statistical analysis was initiated.

VIII. ORDER OF PRESENTATION AND STARTING POSITION

The order of presentation for each S was independently determined by sampling without replacement from Fisher and Yates (1963) random number tables. The starting positions for both the input and output conditions were drawn with replacement from the same tables. The only restriction was that the chosen distance could not be completed outside the S's range of movement.

IX. SUBJECTS

All twenty Ss were volunteers between twenty and thirty years of age. One half of the Ss were City of Edmonton firemen and the other half were graduate students in physical education at the University of Alberta.

X. METHOD

The Ss were tested in three thirty-minute sessions. The S was positioned in an adjustable chair facing the handle. The task involved three phases: an instruction phase, an input phase and an output phase. Before every trial, there was an instruction phase during which the S was told which levels of input and output he was to receive. During the input phase, the S was asked to attend to the input distance using the input as defined by the conditions given during the instruction phase. After a short delay during which the E prepared the output conditions, the S attempted to reproduce the distance as the output phase. The handle always turned counterclockwise.

Immediately before the first session instructions were read to the S (see Appendix 1). Following this, there was a training period to familiarize the S with the apparatus, the techniques and the conditions.

The start and stop positions for both the input and output phases were marked on the strip-chart recorder. These were later transferred to data sheets and then IBM cards.

XI. ANALYSIS

Cochran's Test for Homogeneity of Variance was calculated on the variances of the accuracy and the constant error scores.

To answer the main problem of the thesis, three primary analyses of variance were calculated. They were three eight by two by eight analyses of variance for accuracy, constant error and standard deviations. Duncan's New Multiple Range Test was used as the test on the means for the main effects and on the simple main effects of the significant interactions.

It was decided 'post hoc' that two six by two by six analyses of variance be used as secondary analyses to aid the discussion of the primary analyses. The first of these two secondary analyses was calculated to aid the discussion of the effect of motor involvement and included only the white and black light conditions for the active, passive and observe motor conditions. The active and passive conditions with no light were disregarded because there was no equivalent condition for the observe conditions.

The second secondary analysis was calculated to facilitate the discussion of the effect of sensory modality and included only the white, black and no light conditions for the active and passive motor conditions. The observe conditions were ignored because there was no equivalent for the no light condition.

For each of the above nine analyses, each S appeared in each cell once and was treated as a block. As a result, the between Ss sum of squares was partitioned out. Any significant Ss by treatment interactions were assumed to be spurious because of only one entry per cell. Their sums of squares and degrees of freedom were pooled to obtain a single estimate of error. This was done in order to attempt to obtain a better estimate of the population variance. If these interactions were not all negligible, the estimate of the error based on pooled interactions would be larger and thus the test would become even more conservative.

In addition to the primary and secondary analyses, two eight by two analyses were calculated for the identical input-output conditions. The identical input-output conditions were used in previous studies thus these analyses allowed the comparisons of this study to the previous ones. Duncan's New Multiple Range Test was used as the test on the means for the main effects and the simple main effects of the significant interactions.

There were several problems that stemmed from the use of a repeated measures design: one was the possibility of a carry-over or learning effect, the other possibility was a fatigue effect. Greenhouse and Geisser (1959) stated that the scores must, "... in addition to being normally distributed have equal variances and be mutually independent or, at most have equal correlations." As the repeated measures design used the same group of Ss in every condition, each cell had the same and the treatment scores may have been correlated. Thus the Greenhouse and Geisser conservative degrees of freedom were used on the primary analysis.

The primary analyses were made conservative as the study was primarily exploratory in nature. The conclusions were based on the very conservative primary analyses with a rejection level of 0.01 to reduce the probability of a Type I error. The purpose of the secondary analysis was to aid in the discussion of the results. It was not felt necessary to be as stringent as the primary analysis as this study was designed to provide direction for future research. The writer did not want to ignore smaller differences that aided the discussion of the complex primary analysis as long as these differences made theoretical sense. The rejection level for the secondary analysis was set at 0.05 and normal degrees of freedom were used. Significance for the 0.05 level and normal degrees of freedom were also reported and discussed for the primary analysis.

All the analyses of variances were calculated using a Fortran IV ANOV80 program (a N-way analysis of variance program that utilizes the IBM Scientific Subroutine Package) obtained from the Department of Educational Research and modified slightly by this writer. The conversion of the raw data to a linear scale, the calculation of the dependent variables, the descriptive statistics and the range tests were calculated by using Fortran IV programs written by this writer. The programs were computed on the IBM 360/67 computer at the University of Alberta Computer Center.

CHAPTER IV

ANALYSIS

The analysis was divided into two segments. The first segment was the primary analysis which was very conservative and on which the conclusions were drawn. The second segment was the secondary analysis which consisted of two subdivisions, one concerned mainly with motor involvement, the other concerned with sensory modality. The purpose of the secondary analysis was to aid in the discussion of the primary analysis.

I. HYPOTHESIS

Primary Analyses

Four hypotheses were formed on the primary analyses:

1. H_1: There would be no effect due to the eight input conditions for the accuracy scores, constant error scores or standard deviations.

2. H_2: There would be no effect due to the eight output conditions for the accuracy scores, constant error scores or standard deviations.

3. H_{3a}: Short distance accuracy scores < Long distance accuracy scores.

   H_{3b}: Short distance constant error scores < Long distance constant error scores.

H_{3c}: Short distance standard deviations = Long distance standard deviations.

Hypotheses One and Two were stated in the null form because they were purely exploratory in nature. Predictions could have been made only for the identical input-output components of the analysis. However there were not enough observations per cell to allow prediction on these conditions. Hypothesis Three was made in three parts because of differential effects which depended upon the dependent variable analysed. Hypothesis Three (a) was formed on the basis of Posner (1966, 1967), Posner and Konick (1966) and McClements' (1969) conclusions that performance was inversely related to movement distance. Hypothesis Three (b) was formed as a result of Pepper and Herman (1970) who reported on short distances Ss tended to overshoot, while long distances they tended to undershoot. Hypothesis Three (c) was stated in the null form because there was no information available about variance.

Secondary Analyses

Five hypotheses were formed for the secondary analyses:

1. H_4: Active input = Passive input = Observe input for accuracy scores and constant error scores.

2. H_5: Active output = Passive output = Observe output for accuracy scores and constant error scores.

3. H_6: White light input = Black light input = No light input for accuracy scores and constant error scores.

4. H_7: White light output = Black light output = No light output for accuracy scores and constant error scores.

5. H_{8abc}: Identical to H_{3abc} above.

Hypotheses Four, Five, Six and Seven were stated in the null form as they were all exploratory in nature. There was no change in the range factor from the primary to the secondary analyses, thus hypothesis Eight should be identical to hypothesis Three.

Identical Input-Output Analysis

Hypotheses were not formed for this analysis because of the small number of entries per cell.

II. RESULTS

Cochran's Test for Homogeneity of Variance for the accuracy score variance (C = 0.0274) and constant error score variance (C = 0.0218) was not significant at the 0.05 level.

Primary Analyses

Three three-way analyses of variance for accuracy scores, constant error scores and standard deviations were calculated and are summarized in Tables 2, 3, and 4 respectively. The graphs for the accuracy scores, constant error scores and standard deviations are illustrated as follows: the input main effect in Figure 5; the output main effect in Figure 6, and the range effect in Figure 7. The cell means, Duncan's New Multiple Range Tests on main effects and graphs of the significant interactions

TABLE 1

CRITICAL F VALUES

	Critical F - normal df[1]			Critical F - conservative df[2]		
	df	0.01 level**	0.05 level*	df	0.01 level**	0.05 level*
Primary Analysis	1,2413	6.66	3.85	1,19	8.18	4.38
	7,2413	2.66	2.02	1,19	8.18	4.38
	19,2413	1.92	1.60	19,19	2.97	2.14
	49,2413	1.55	1.37	1,19	8.18	4.38
	1,49	7.18	4.04	1,1	4,052.00	161.00
	7,49	3.03	2.21	1,1	4,052.00	161.00
	49,49	1.95	1.61	1,1	4,052.00	161.00
Secondary Analysis	1,1349	6.66	3.85			
	2,1349	4.62	3.00			
	1,304	6.73	3.88			
	7,304	2.71	2.04			

1. The symbol '*' will be used to denote significance for normal degrees of freedom.
2. The symbol 'x' will be used to denote significance for the Greenhouse and Geisser (1959) conservative degrees of freedom used only in the primary analysis.

TABLE 2

THREE WAY ANALYSIS OF VARIANCE
ACCURACY SCORES

Source	df	Conservative df	Mean Squares	F
Range (R)	1	1	17362.84	389.60xx
Output (O)	7	1	110.94	2.49*
R x O	7	1	66.35	1.49
Input (I)	7	1	21.18	0.47
R x I	7	1	82.41	1.85
O x I	49	1	47.17	1.06
R x O x I	49	1	38.63	0.87
Subjects	19	19	309.27	6.94xx
Error	2413	19	44.56	

TABLE 3

THREE WAY ANALYSIS OF VARIANCE
CONSTANT ERROR SCORES

Source	df	Conservative df	Mean Squares	F
Range (R)	1	1	3834.24	36.23xx
Output (O)	7	1	1194.85	11.29xx
R x O	7	1	208.75	1.97
Input (I)	7	1	158.39	1.49
R x I	7	1	130.44	1.23
O x I	49	1	80.13	0.76
R x O x I	49	1	110.16	1.04
Subjects	19	19	555.55	5.24xx
Error	2413	19	105.84	

xx significant at the 0.01 level Greenhouse and Geisser
* significant at the 0.05 level

TABLE 4

THREE WAY ANALYSIS OF VARIANCE
STANDARD DEVIATIONS

Source	df	Conservative df	Mean Squares	F
Range (R)	1	1	1403.30	359.58**
Output (O)	7	1	2.85	0.73
R x O	7	1	5.72	1.46
Input (I)	7	1	6.31	1.62
R x I	7	1	4.64	1.19
O x I	49	1	3.64	0.93
Error	49	1	3.90	

** significant at the 0.01 level

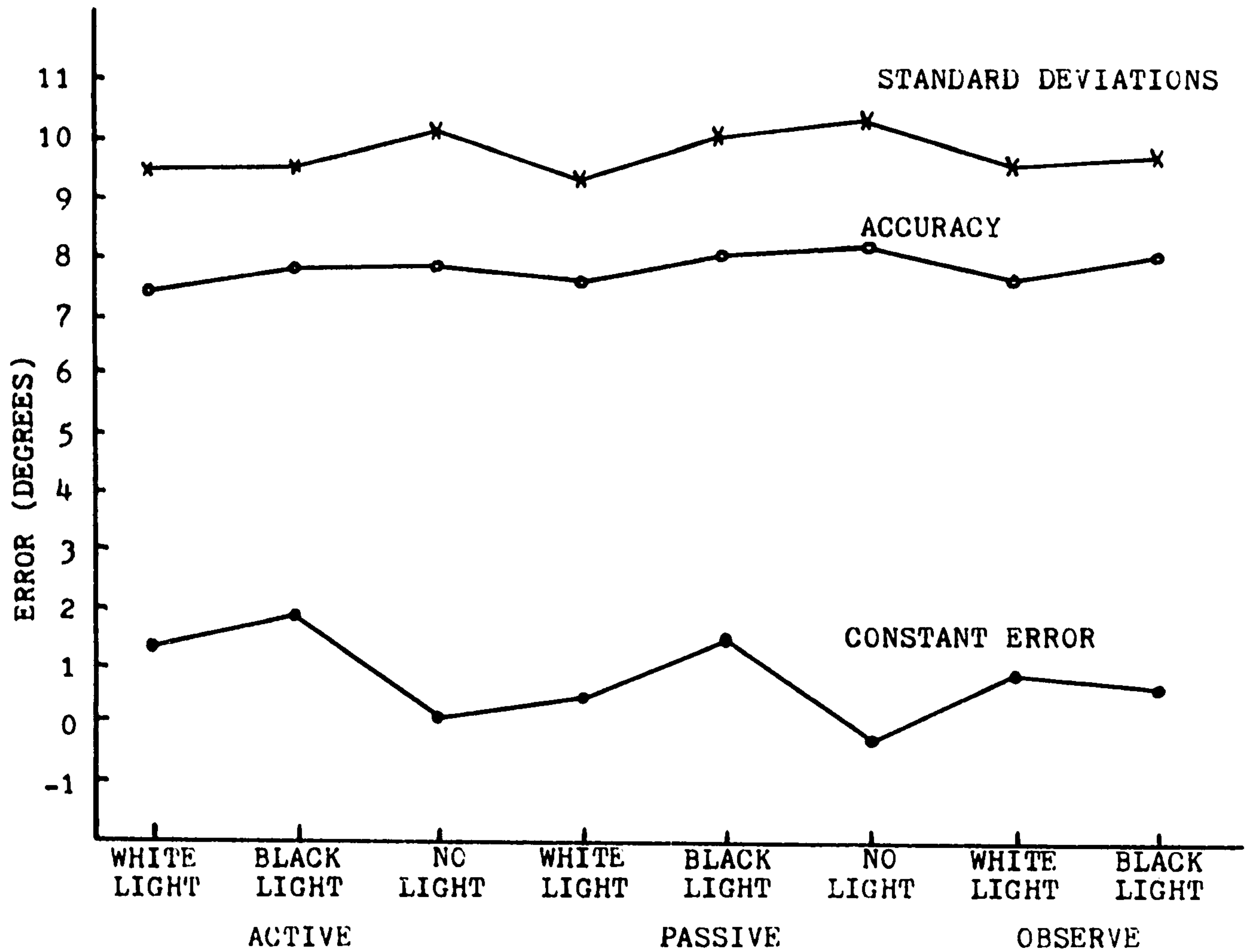

FIGURE 6

MEANS FOR THE MAIN EFFECTS OF INPUT FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

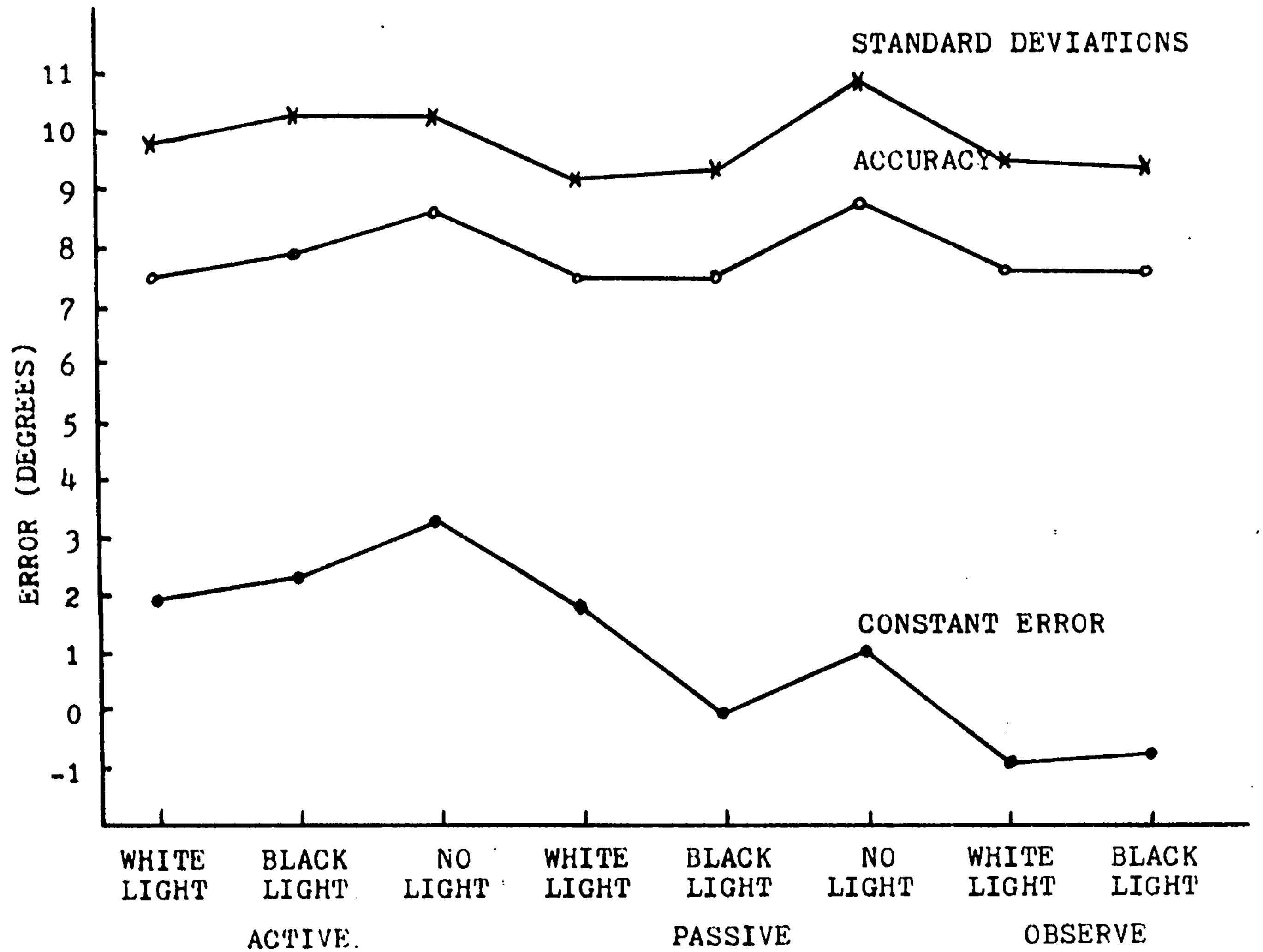

FIGURE 7

MEANS FOR THE MAIN EFFECTS OF OUTPUT FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

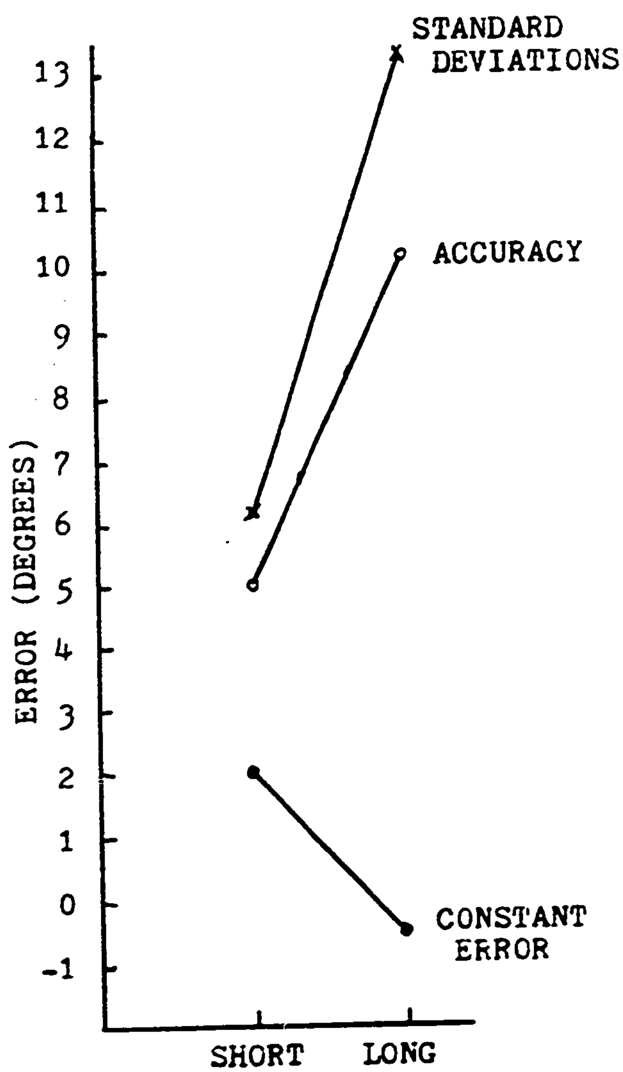

FIGURE 8

MEANS FOR THE MAIN EFFECTS OF RANGE FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS are found in Appendix B. The subject main effects were significant at the 0.01 level[1] for the accuracy and constant error scores (using Greenhouse and Geisser's (1959) conservative degrees of freedom). Subjects was not a factor in the standard deviation analysis.

Input (Hypothesis One). The input main effect was not significant for the accuracy score, constant error score or standard deviation analyses. For the constant error range test (Appendix B, Table 23), the active black light was significantly larger than the passive no light condition at the 0.05 level.

Output (Hypothesis Two). The output main effect was significant at the 0.05 level (normal or maximum degrees of freedom) for the accuracy score analysis. In the range test (Appendix B, Table 22), the passive no light condition was significantly larger at the 0.05 level than the other output conditions except for the active no light and black light conditions. The active no light condition was significantly larger than the observe and passive black light conditions and also the passive white light conditions, all at the 0.05 level.

The output main effect was significant for the constant error score analysis at the 0.01 level (using Greenhouse and Geisser's (1959) conservative degrees of freedom). The observe black and white conditions (which do not differ from each other) are significantly smaller than all other output conditions in the range test (Appendix B, Table 24) at the 0.01 level with the exception of the passive black light condition which was significantly larger at 0.05 level. The passive black

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[1] The levels referred to in this chapter are alpha levels.

light condition was significantly smaller than the active black light and no light conditions at the 0.01 level, and the white light active and passive conditions at the 0.05 level. The active no light condition was significantly larger at the 0.01 level and the passive white light condition at the 0.05 level.

The output standard deviation main effect was not significant. However in the range test (Appendix B, Table 26) the passive no light mean standard deviation was significantly smaller than the observe black and white mean standard deviations at the 0.01 level.

Range (Hypothesis Three). The range main effect was significant for the accuracy and constant error score at the 0.01 level (using Greenhouse and Geisser's (1959) conservative degrees of freedom). The range main effect was also significant at the 0.01 level (normal degrees of freedom) for the standard deviation analysis. The short distances had more accurate, shorter constant errors and smaller standard deviations than the longer distances.

The main results of the primary analyses were the following: there were no significant input main effects, there was an output main effect for constant error but not for accuracy or standard deviations and the range effect was significant for both accuracy and constant error.

Secondary Analysis

Two secondary analyses of variance were calculated to aid the discussion of the effect of motor involvement and included only the white and black light conditions for active, passive and observe motor conditions (labelled white-black conditions). The other two secondary analyses of variance were calculated to facilitate the discussion of the effect of sensory modality and included only the active and passive motor conditions for the white, black and no light sensory conditions (labelled active-passive conditions). Excerpts of the main effects and significant interactions of these analyses are reported in the following tables: white-black conditions, accuracy scores in Table 5; active-passive conditions, accuracy scores in Table 6; white-black conditions, constant error scores in Table 7; and active-passive conditions, constant error scores in Table 8. The means and the Duncan's New Multiple Range Tests applied to main effects and simple main effects of significant interactions are reported in Appendix C. The graphs of the significant interactions are also illustrated in Appendix C. The S main effects were significant for all four secondary analyses at the 0.01 level. The graphs for the main effects are illustrated in Figures 9, 10 and 11.

Motor Input (Hypothesis Four). In the four analyses the motor input main effects were not significant.

Motor Output (Hypothesis Five). The motor output main effect was significant at the 0.01 level for both the active-passive and white-black conditions of the constant error analyses. For the white-black analysis, the motor output main effect, the observe condition was significantly smaller than the active and passive conditions at the 0.01 level. The passive condition was smaller than the active condition at the 0.05 level for the white-black analysis and at the 0.01 level for the active-passive analysis.

TABLE 5

EXCERPTS OF MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
FROM A FIVE WAY ANALYSIS OF VARIANCE
WHITE-BLACK CONDITIONS
ACCURACY SCORES

Source	df	Mean Squares	F
Range (R)	1	8741.87	220.08**
Light Output (LO)	1	0.71	0.02
Motor Output (MO)	2	33.10	0.83
R x MO	2	126.84	3.19*
Light Input (LI)	1	72.00	1.81
Motor Input (MI)	2	74.22	1.87
Subjects	19	231.42	5.83**
Error	1349	39.72	

TABLE 6

EXCERPTS OF MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
FROM A FIVE WAY ANALYSIS OF VARIANCE
ACTIVE-PASSIVE CONDITIONS
ACCURACY SCORES

Source	df	Mean Squares	F
Range (R)	1	800.89	17.81**
Light Output (LO)	2	51.89	1.15
Motor Output (MO)	1	23.00	0.51
Light Input (LI)	2	11.19	0.25
R x LI	2	181.58	4.04*
Motor Input (MI)	1	4.67	0.10
Subjects	19	148.53	3.30**
Error	1349	44.97	

** significant at the 0.01 level
* significant at the 0.05 level

TABLE 7

EXCERPTS OF MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
FROM A FIVE WAY ANALYSIS OF VARIANCE
WHITE-BLACK CONDITIONS
CONSTANT ERROR SCORES

Source	df	Mean Squares	F
Range (R)	1	2619.00	28.32**
Light Output (LO)	1	58.40	0.63
Motor Output (MO)	2	1735.78	18.77**
R x MO	2	415.97	4.50
Light Input (LI)	1	34.84	0.38
Motor Input (MI)	2	73.49	0.79
R x MO x MI	4	244.47	2.64*
Subjects	19	437.09	4.73**
Error	1349	92.49	

TABLE 8

EXCERPTS OF MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
FROM A FIVE WAY ANALYSIS OF VARIANCE
ACTIVE-PASSIVE CONDITIONS
CONSTANT ERROR SCORES

Source	df	Mean Squares	F
Range (R)	1	413.88	3.92*
Light Output (LO)	2	232.40	2.20
Motor Output (MO)	1	1071.22	10.15**
R x MO	1	321.11	3.04*
Light Input (LI)	2	432.72	4.10*
Motor Input (MI)	1	31.80	0.30
Subjects	19	436.65	4.14**
Error	1349	105.56	

** significant at the 0.01 level
 * significant at the 0.05 level

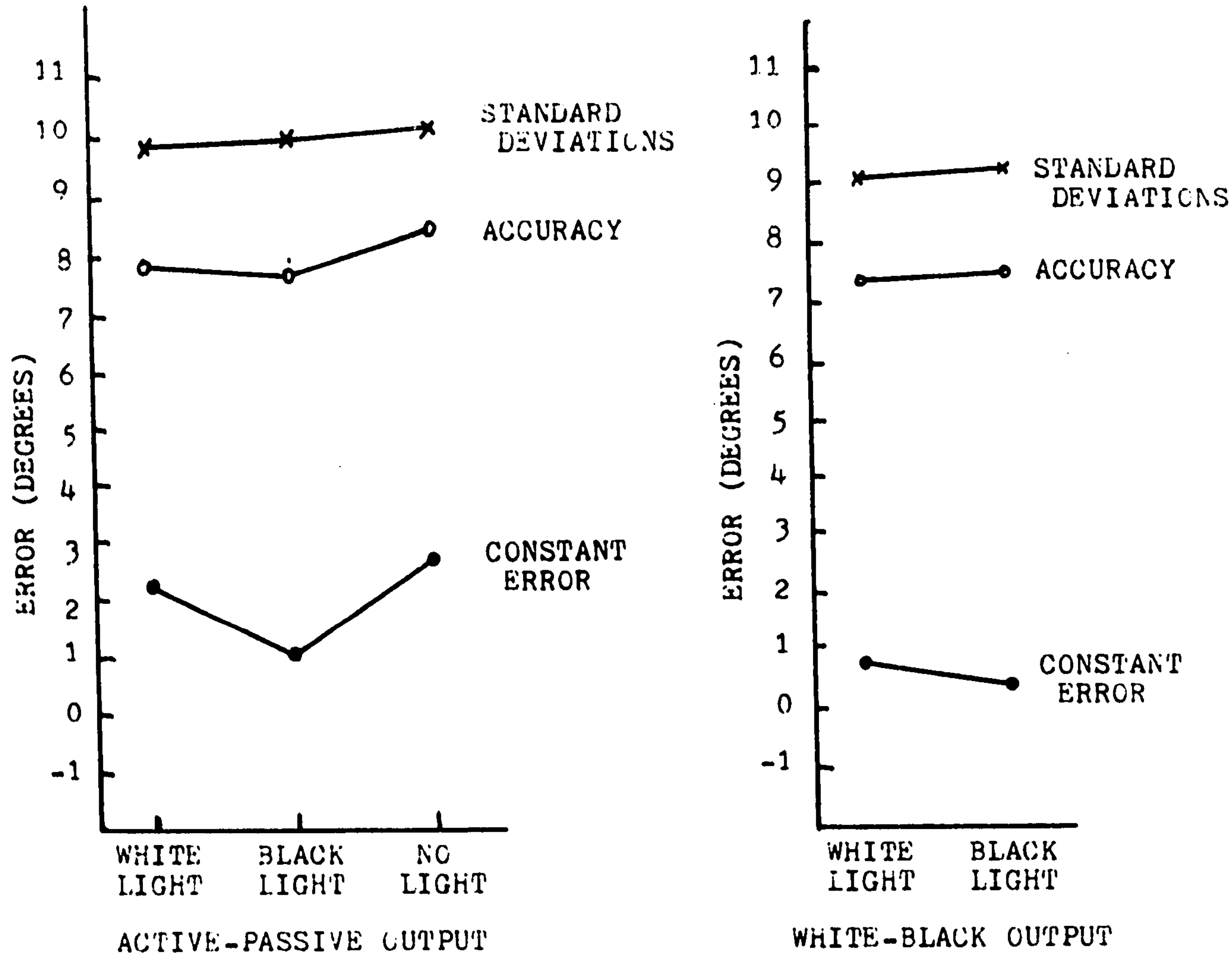

FIGURE 9

MEANS FOR THE MAIN EFFECTS OF LIGHT OUTPUT OF THE ACTIVE-PASSIVE AND WHITE-BLACK SECONDARY ANALYSIS FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

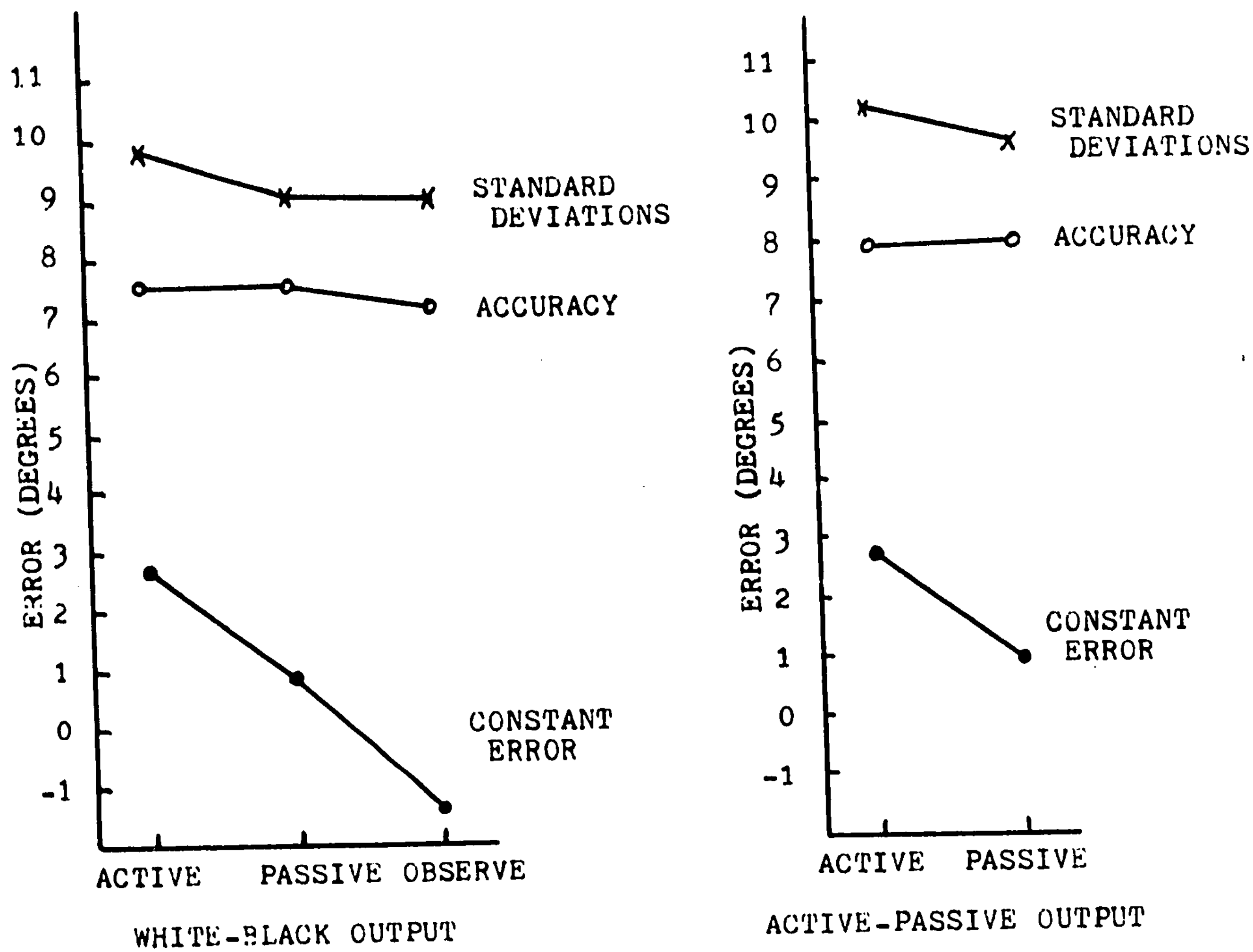

FIGURE 10

MEANS FOR THE MAIN EFFECTS OF MOTOR OUTPUT OF THE ACTIVE-PASSIVE AND WHITE-BLACK SECONDARY ANALYSIS FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

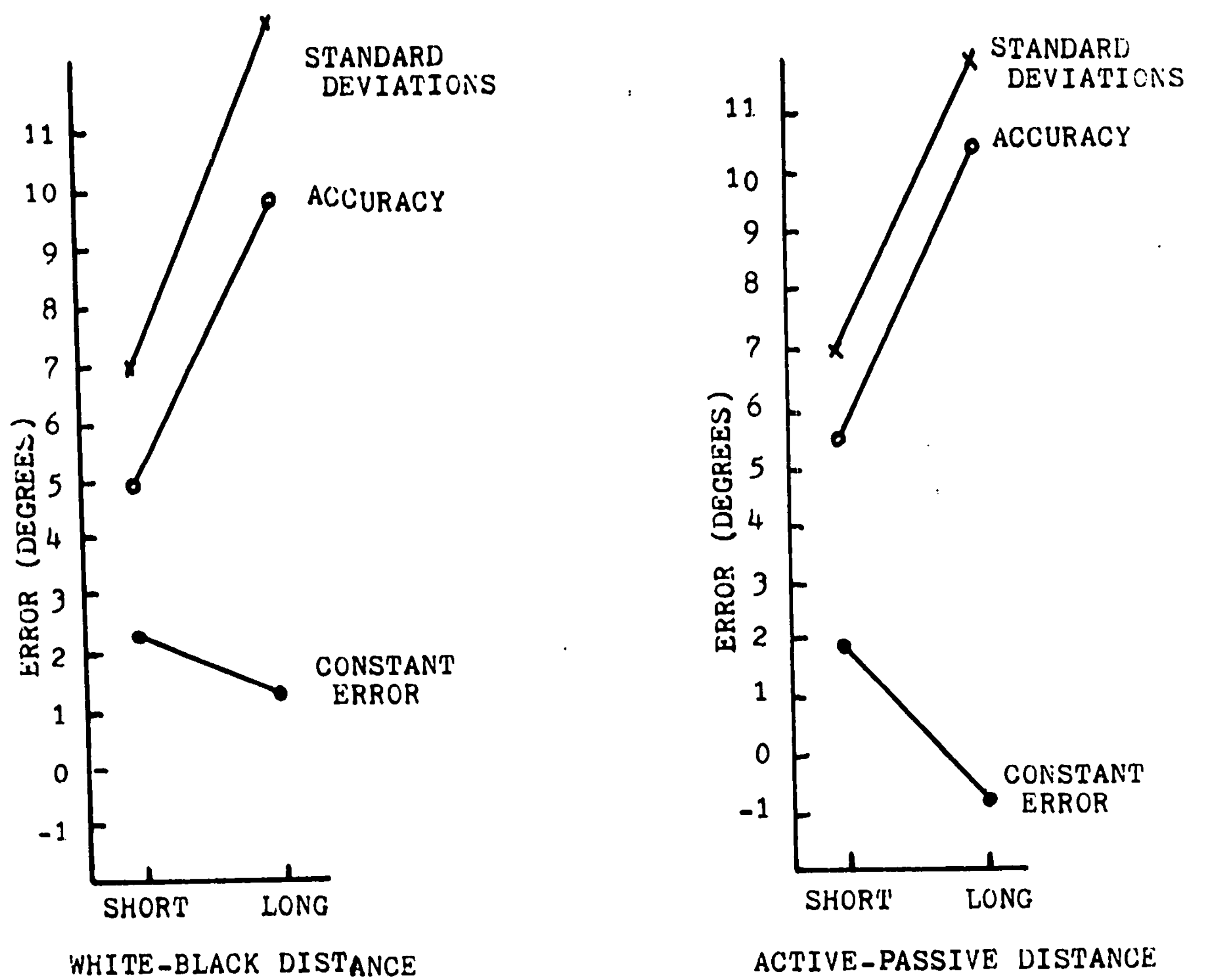

FIGURE 11

MEANS FOR THE MAIN EFFECT OF RANGE OF THE ACTIVE-PASSIVE AND WHITE-BLACK SECONDARY ANALYSIS FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

The range by motor output interaction was significant at the 0.05 level for all of the secondary analyses except for the active-passive conditions of the accuracy score analysis. For the range by motor output interaction, the observe motor output was significantly less than the active motor output at the 0.05 level for the shorter range constant error scores in the white-black analysis. However, for the longer range constant error score, the observe motor output was significantly less than the active motor output for longer ranges at the 0.05 level for the white-black analysis and at the 0.01 level for the active-passive analysis (Appendix C, Table 33).

For the motor output by range accuracy score interaction, the active motor output was less accurate than the observe motor output for the white-black conditions short range accuracy scores at the 0.05 level (Appendix C, Table 31).

The range by motor output by motor output interaction for the white-black conditions constant error scores was significant at the 0.05 level. Range tests were applied to the simple main effects of this interaction (Appendix C, Table 33). There was no solution that allowed at least two of the three comparisons of a point with other points on its simple main effects to be equal. One possible reason for this was that the passive input, passive output, long range condition was the cause of the interactions significance.

Light Input (Hypothesis Six). The light input main effect was significant at the 0.01 level for the active-passive conditions of the constant error scores. The no light condition was significantly larger than the black light condition at the 0.01 level (Appendix C, Table 34).

The range by light input interactions for the active-passive conditions accuracy scores was significant at the 0.05 level. The range tests on the simple main effects failed to find any differences on the simple main effects (Appendix C, Table 30). The interaction is also illustrated in Appendix C, Table 30.

Light Output (Hypothesis Seven). The light output main effect was not significant for any of the secondary analyses. However, for the light output main effect of the active-passive analysis, the no light condition was significantly larger than the black light at the 0.05 level for constant error scores (Appendix C, Table 30).

Range (Hypothesis Eight). The range main effects were significant at the 0.01 level for all secondary analyses with the exception of the active-passive constant error scores which were significant at the 0.05 level. The shorter distances were more accurate than the longer distances for both the active-passive and white-black accuracy score analyses at the 0.01 level. The shorter reproduced distances were significantly larger than the long distances at the 0.01 level for the white-black conditions and at the 0.05 level for the active-passive conditions.

Input-Output Paradigm

The input by output interaction for the three primary analyses (Tables 2, 3 and 4) failed to be significant at the 0.05 level. The only appropriate secondary analyses were the active-passive conditions accuracy scores and constant error scores. The F values for the light input by light output interactions for these analyses were not significant (the F ratios failed to be greater than one). The intra-modality and the inter-modality means were calculated for three combinations of light: the white-black and no light conditions, the black and no light conditions, and the white and no light conditions. These were reported in Table 9.

Identical Input-Output Analyses

Two two-way analyses of variance for accuracy scores and constant error scores were calculated and are summarized in Tables 10 and 11. Duncan's New Multiple Range Tests for the main effects are presented in Appendix D. Figure 12 represents the accuracy scores, constant error scores and standard deviations for the identical input-output main effect. The range by identical input-output interaction is illustrated in Appendix D.

The only significant effect in the analysis was the range main effect for accuracy scores. The short range was significantly more accurate than the long range at the 0.01 level.

III. DISCUSSION

Input

Gibbs and Logan (1965) found little difference in accuracy due to the source of input. They suggested that possibly the accuracy of verbal or visual associations might have been tested rather than

TABLE 9

MEANS AND DIFFERENCES BETWEEN INTRA-MODALITY AND INTER-MODALITY PERFORMANCES

Accuracy Scores			
Light sources included	Inter-modality means	Intra-modality means	Differences
White-black-none	8.06	7.66	0.40
White-none	8.18	7.69	0.49
Black-none	8.04	7.86	0.18
Constant Error Score			
Light sources included	Inter-modality means	Intra-modality means	Differences
White-black-none	1.99	1.67	0.32
White-none	1.83	1.69	0.14
Black-none	1.73	1.56	0.17

TABLE 10

TWO WAY ANALYSIS OF VARIANCE
IDENTICAL INPUT AND OUTPUT
CONSTANT ERROR SCORES

Source	df	Mean Squares	F
Range (R)	1	216.15	1.66
Input-Output (IO)	7	127.28	0.93
R x IO	7	77.90	0.60
Error	304	130.20	

TABLE 11

TWO WAY ANALYSIS OF VARIANCE
IDENTICAL INPUT AND OUTPUT
ACCURACY SCORES

Source	df	Mean Squares	F
Range (R)	1	2055.38	50.63**
Input-Output (IO)	7	23.96	0.59
R x IO	7	27.69	0.68
Error	304	40.60	

** significant at the 0.01 level

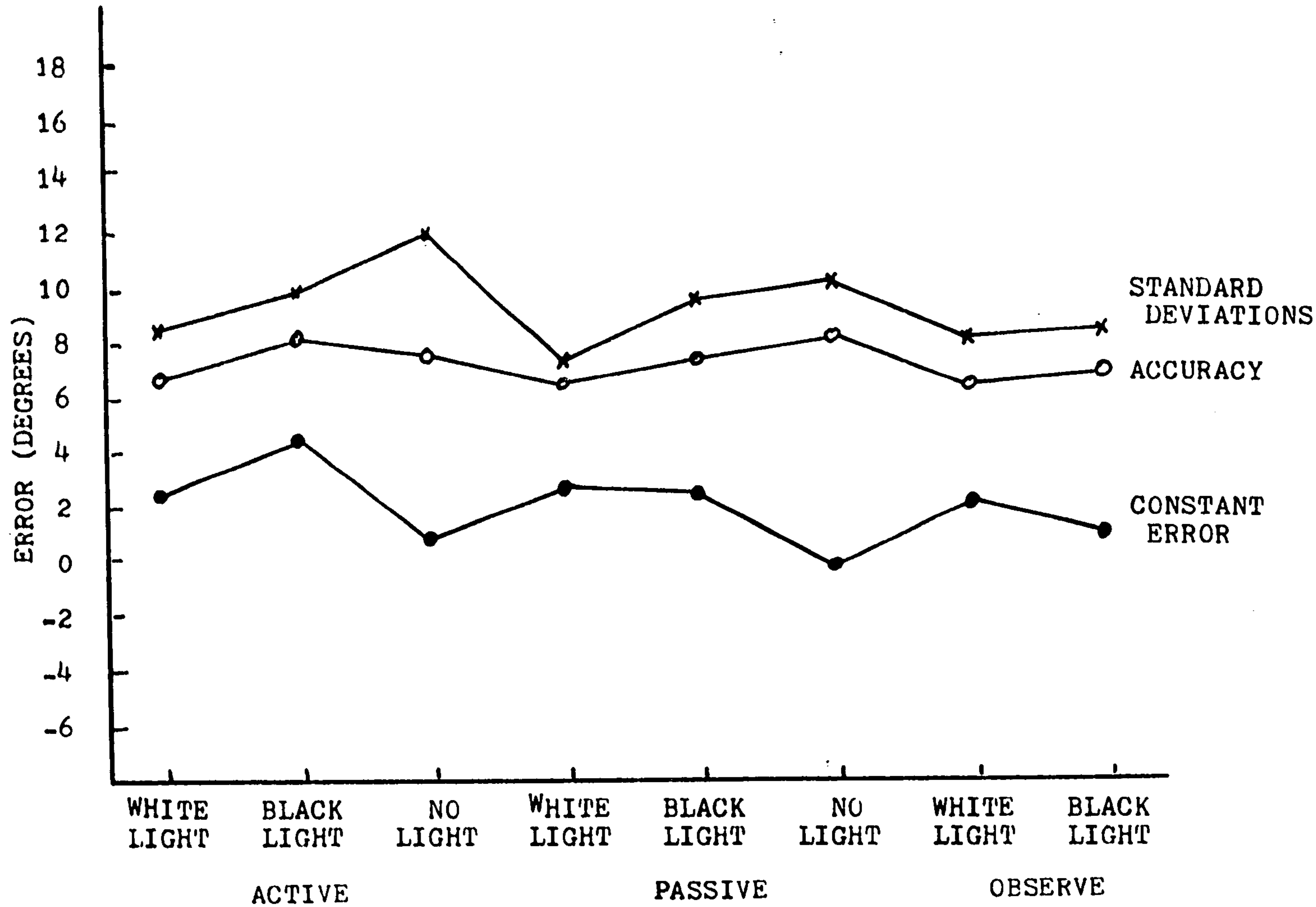

FIGURE 12

MEANS FOR THE MAIN EFFECT OF IDENTICAL INPUT-OUTPUT FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS proprioception. Posner and Konick (1966) studied visual and kinesthetic short-term memory and suggested that both modalities may have been stored using a common form of imagery. Levy (1967) commented that limited visual information did not supplement kinesthetic information and in fact, impaired performance under mixed modalities. The present study agreed with the above results in that input was not a significant main effect for any of the three primary analyses (accuracy scores, constant error scores and standard deviations). Hypothesis One (overall input) was not rejected for accuracy, constant error scores or standard deviations.

As there were no significant differences due to motor input, hypothesis Four failed to be rejected for accuracy or constant error scores.

However, the passive no light condition had a significantly shorter error than the active black light condition in the Duncan's New Multiple Range Test for input constant error scores. In the secondary analysis of the active-passive constant error input scores, the no light condition error was significantly smaller than the black light condition error. Although no conclusions can be made from these 'post hoc' analyses, this may be an important finding. It would tend to agree with Levy's (1967) findings that limited visual environment may impair performance rather than enhance it. If visual and kinesthetic imagery is in the same form then one or both of the modalities must be transformed to that common form. If the form was visual, then the visual black light condition should have been at least as accurate as the kinesthetic condition because the kinesthetic information should have lost information when it was transformed to the visual form. As it was not, then the storage must have been in a kinesthetic or a common mode of imagery. If this was true, the fact that the white light condition was not significantly different from either, the black light condition or the no light condition had to be considered. This might have been because the white light condition had environmental cues which could have aided the fidelity of the transform. This agreed with Souder (1969) who found that without complete visual field reference in the environment, movement accuracy deteriorated. There was therefore, evidence that information of a motor nature may be stored in a kinesthetic or common image but not in a visual image. The fact that this was only an effect of the constant error score can be interpreted to mean that it affected only the bias of the error and not the magnitude or variance of the error. Hypothesis Six (light input) failed to be rejected for accuracy scores but was rejected for constant error scores because the no light (kinesthetic) condition was smaller than the black light condition.

For the significant range by light input interaction, there were no significant differences on the primary main effects. However from a cursory analysis, the interaction appeared to be a produce of a differential effect of long and short distance errors under kinesthetic conditions. The magnitude of the kinesthetic error for shorter distances appeared to be somewhat smaller than that of the visual and for longer distances slightly larger than the visual.

Although there was no significant effect, there was a directional one for the input standard deviations. The kinesthetic (no light) conditions were more variable than the visual conditions (white and black light). The accuracy scores input (Table 2, Figure 6) did not demonstrate any pattern at all.

Output

Mountcastle and Powell (1959), Ludvigh (1962), Merton (1961) and Cohen (1958, 1961) have provided convincing neurological and behavioural evidence that the joint receptors and not the muscle receptors are the primary sensory nerve endings for movement and position information commonly called kinesthesis. Assuming this to be true then there would have been no reason to expect active types of movement to produce afferent information that would have made it superior to passive types of movement.

Whether or not there was a difference between the active and passive performance is not clear. Brown _et al_ (1954) and Provins (1958) conducted almost identical studies, Provins on the toe and Brown _et al_ on the finger, and obtained opposite results for movement thresholds. Lloyd and Caldwell (1965) and Lloyd (1968) found active positioning of the leg superior to the passive positioning. However, Levy (1967) failed to obtain a significant difference in an arm positioning task.

One explanation of the superiority of active performance over passive performance is given by the efference theory. Some researchers such as Brindley and Merton (1960) and Festinger and Canon (1965) used the eye muscles, which have little or no proprioception to test their hypothesis of efferent or motor out-flow information as a useable source of information. Held and Freedman (1963) and Held (1965) used active and passive movement in visual displacement and found a lack of compensatory shifts were due to the efferent output of the active condition. Merton (1964) used nerve blocking and found that active movement accuracy was not affected, however the passive movement accuracy was affected by the block. Legge (1965) concluded from a review of the literature that awareness of position sense may not be due to proprioceptive afference but rather to the monitoring of efferent copy. Higgins and Angel (1969) data lent support to the efferent theory when it was found that error correction time was too fast for afferent information.

Of the three manipulations of the dependent variable, only the constant error scores were significant on the output factors. According to Duncan's New Multiple Range Tests (Table 17), the observe conditions had significantly shorter responses than either the active or passive conditions. There were some differences and some overlap in the primary analysis between the active and passive conditions. Hypothesis Two (overall output) failed to be rejected for accuracy or standard deviation scores but was rejected for constant error scores. The constant error output range test had several significant differences but the overall effect was not clear.

In the pooled secondary analysis, the passive condition was significantly smaller than the active condition. Both the active and passive conditions were significantly larger than the observe condition. Further examination of these differences showed that the observe conditions were significantly less than zero[1] or unbiased error. For the passive

[1] Differences from zero were considered significant if the difference from zero was greater than the range of two means.

condition, there was a very slight positive bias that was not significantly different from zero. For the active condition, there was a positive bias that was significantly different from zero. In other words, the passive condition hardly had any bias while the active condition had overshoot and the observe condition had undershoot. There was no effect for the accuracy score analysis. Hypothesis Five (motor output) for accuracy scores failed to be rejected except for constant error scores, it was rejected because the observe condition was significantly less than the passive condition and both were significantly smaller than the active condition.

These results do not agree with any of the reported studies. However there were basic methodological differences. Brown et al (1954) and Provins (1958) used threshold discrimination tasks while Lloyd and Caldwell (1965) and Lloyd (1968) used a positioning task to a required angle. Levy (1967) used a similar task and failed to detect any difference.

The significant range by motor output interaction of the constant error score secondary analysis (Tables 7 and 8) was examined to try to clarify the output main effect. The long range motor output conditions accounted for most of the main effect. The observe short distance output effect was significantly less than the active short distance output. However, all the short output conditions were positive which would agree with Pepper and Herman's (1970) range effect. The motor output long distances were the same as the motor output main effect above. For the long distance motor output, the active was significantly greater than zero at the 0.01 level; the observe was significantly less than zero while the passive was very close to zero. It appeared that the range effect only applied to longer distances for the observe condition and not the active and passive conditions.

Short distances tended to be overshot for motor output, however not quite as much if the performer just observed the output as when he actively performed the output. For long distances, the range effect applied only to the observe condition. For the passive condition, the S had the least bias. However for the active condition the performer had less overshoot for the long distance than the short. The range effect would have predicted undershoot for the active and passive conditions as well as the observe condition. Somehow in this study the efferent and afferent information for long distances must cause the distance reproduction to be longer than was expected. The observe output distances tended to be shorter than the active output distance for both the long and short range.

For accuracy scores, there was a significant main effect for output at the 0.05 level (normal degrees of freedom, Table 2). The Duncan's New Multiple Range Test partially isolated the kinesthetic (no light) conditions from the visual (white and black light) conditions. The division was not clear and was not evident in the secondary analysis (Tables 6 and 7). However, the direction remained the same, that is, kinesthetic performance being worse than visual performance. The direction of the error is in agreement with the majority of the studies reported (Gibbs and Logan (1965), Robb (1966), Posner and Konick (1966), Posner (1967), Wilberg (1969), Moyst (1969), Hughes (1969), and McClements (1969)). However, hypothesis Seven (light output) failed to be rejected for either accuracy or constant error scores.

The variability analysis in this study was handicapped because of the one entry per S per cell and thus there was between S variability. Directionally for the output, the kinesthetic (no light) conditions were worse than the visual (white and black light) conditions. It is this writer's opinion that intra-individual variability measures should be analysed in future studies.

Summary of the Input and Output

In this study the motor variables (active, passive, observe) were only effective on the bias of the output side of the model. This writer tentatively concluded that the effect of the type of motor involvement was not a perceptual or sensory variable but rather was involved in movement control and as such was only effective at the response side of the black box. There is some inconclusive evidence that the modality factors (white, black and no light) had a limited effect on the accuracy of the output or response side of the black box. However there is some evidence that modality factors had some effect on the bias at the input end or possibly inside the black box itself. The directionality of the inter-individuality variability led this writer to suggest that intra-individuality variability be analysed in future studies.

Range

Long and short distances have produced two types of results depending on the nature of the dependent variable.

Accuracy was directly related to the size of the distance moved. Weiss (1955), Smalheiser (1965), Christina (1967), Lloyd (1968), Stelmach (1968), Posner and Konick (1966) and McClements (1969) all found a linear relationship between the amount of error (accuracy) and the log (base two) of the distance moved. Other studies have failed to obtain the difference: Ellis et al (1968), Stelmach (1969) and Stelmach and Wilson (1970). In this study, shorter distances had significantly more accurate scores than longer distances (Tables 2, 5, and 6, and Figures 8 and 11). The standard deviation or variability scores followed a similar pattern to the accuracy scores. It was concluded that shorter distance reproduction was more accurate and less variable than long distance reproduction. This agrees with Hypothesis Three (a) as well as Hypothesis Eight (a), that short distance reproduction is more accurate than long distance reproduction. However Hypothesis Three (c) and Eight (c) were rejected because the short distance reproduction was less variable than the long distance reproduction.

Constant error scores produced a range effect for distance. Brown et al (1948) reported that Ss overshot at shorter distances and undershot at longer distances. Pepper and Herman (1970) reviewed the data of Keele (1968), Posner (1967), and Posner and Konick (1966) and suggested that when the constant error scores were analysed the range effect was confirmed. Their own data produced only overshooting while Adams and Dijkstra (1966) reported undershooting. Pepper and Herman (1970) explained that the two studies were on extreme ends of the range effect.

In this study, although the range main effect was significant for all of the analyses (Tables 3, 7 and 8, and Figures 8 and 11) the effect was more complex when examined as an interaction with motor output (Tables 7 and 8) as was discussed above. The range effect only occurred for the observe condition although there was less overshoot for active and passive long distances than short distances. It was concluded that the range effect holds only for the observe conditions. Although the results lend support to Hypotheses Three (b) and Eight (b) that short distance reproduction task constant error scores should be smaller than long distance reproduction error scores the concept of range effect must be questioned.

Input-Output Paradigm

Three studies have used the input-output paradigm to investigate the intra-modality verses inter-modality performance of visual and kinesthetic tasks. They all reported that the intra-modality performance was superior to inter-modality performance. Legge (1965) concluded that the integration of visual and proprioceptive information provided an additional process. Levy (1967) gave the possible explanation that intersensory conflict may have caused the discrepancy between intra-modality performance and inter-modality performance. Connolly and Jones (1970) suggested that the transformation from one modality to the other may have caused greater error in cross modality matching than in intra-modality matching.

The failure of the light input by light output interaction of the secondary active-passive analyses was further examined to find out if the results followed the same direction as the above studies. The data presented in Table 32 had the intra-modality performance less than the inter-modality performance for both the accuracy and constant error scores. Although this study failed to verify Legge (1965), Levy (1967) and Connolly and Jones (1970), it did produce results that were at least in the same direction. Inter-modality matching may lose some information due to conflict, integration or transforms from one modality to the other.

Identical Input-Output

All the behavioural studies in Chapter II with the exception of the input-output paradigm studies mentioned above have used identical input-output. Investigators such as Posner and Konick (1966), Posner (1967), Wilberg (1969), Moyst (1969), Hughes (1969), and McClements (1969) generally agreed that the visual performance was superior to kinesthetic performance. However Levy (1967) reported that limited visual information did not supplement kinesthetic information. A similar lack of influence due to modality input was reported by Gibbs and Logan (1965). Souder (1969) found that without complete visual field reference in the environment, movement accuracy deteriorated.

There were no significant differences between the identical input-output conditions for accuracy or constant error scores (Tables 10 and 11 and Figure 12). This agrees with Levy (1967) and Gibbs and Logan (1965). However these analyses were based on a small number of entries per cell. The kinesthetic (no light) performance were less accurate and more variable than the visual (white light) performances but had less bias than the visual. The black light conditions' performances, were less accurate, more variable and had more bias than the white light condition performances, which if they had been significant, would have supported Souder's (1969) results.

There was no difference between the active and passive conditions which agreed with Provins (1958) and Levy (1967) but disagreed with Brown _et al_ (1954), Lloyd and Caldwell (1965) and Lloyd (1968). The role of active and passive muscular involvement was discussed in the output section found above.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

The purpose of this study was to examine the input and output ends of the black box as the location for the kinesthetic-visual performance discrepancy. The design was a treatment by subjects, factorial, complete block, mixed model with repeated measures. The Ss were twenty firemen and physical education graduate students between the ages of twenty and thirty.

The apparatus was basically a smoothly rotating handle modified to facilitate data collection. Two parallel light systems, one white and one black, controlled the amount of visual information. The task was the reproduction of an angular distance.

There were three factors of experimental interest: range effect with two levels (short from ten to thirty degrees and long from sixty to eighty degrees), input, and output with eight identical levels (active-white light, active-black light, active-no light, passive-white light, passive-black light, passive-no light, observe-white light and observe-black light).

The specific problems examined in the study were:

1. The effect of visual cues with and without environmental cues and kinesthesis on input and output performance.[1]

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[1] For this chapter, 'performance' is defined as the accuracy, variability (standard deviation) and bias (constant error).

2. The effect of active and passive motor involvement and observation on input and output performance.

3. The effect of long and short distances on input and output performance.

4. The effect of varying the amount of input and output information available to the performer on the performance.

Four hypotheses were formed on the primary analyses to help structure this study. The first primary hypothesis stated that there was no effect on performance due to the eight input conditions. The second primary hypothesis stated that there was no effect on performance due to the eight output conditions. The third primary hypothesis stated that short distance accuracy scores were smaller than long distance accuracy scores, short distance constant error scores were smaller than long distance constant error scores and short distance variability equalled long distance variability.

The purpose of the secondary analyses was to aid in the discussion of the results, not to draw conclusions. There were five hypotheses formed for the secondary analyses. The first secondary hypothesis stated that for input, active performance equalled passive performance equalled observe performance. The second secondary hypothesis stated that for output, active performance equalled passive performance equalled observe performance. The third secondary hypothesis stated that for input, white light performance equalled black light performance equalled no light performance. The fourth secondary hypothesis stated that for output, white light performance equalled black light performance equalled no light performance. The fifth secondary hypothesis was identical to the third primary hypothesis.

Three hypotheses were concerned with input. Hypothesis One (overall input) was not rejected for accuracy, constant error or standard deviation scores. Hypothesis Four (motor input) failed to be rejected for the accuracy or constant error scores. Hypothesis Six (light input) failed to be rejected for accuracy or standard deviations but rejected for constant error scores because the no light (kinesthetic) condition was smaller than the black light condition.

Hypotheses Two, Five and Seven were concerned with output. Hypothesis Two (overall output) failed to be rejected for accuracy or standard deviation scores but was rejected for constant error scores. The constant error output range test had several significant differences but the overall effect was not clear until the secondary analyses Hypotheses (Five and Seven) were examined. Hypothesis Five (motor output) for accuracy scores failed to be rejected but for constant error scores it was rejected because the observe condition was significantly less than the passive condition and both were significantly smaller than the active condition. Hypothesis Seven (light output) failed to be rejected for either accuracy or constant error scores.

For the range effect, the results supported Hypotheses Three (a) and Eight (a) that short distance reproduction was more accurate than the long distance reproduction. However Hypothesis Three (c) and Eight (c) were rejected because the short distance reproduction was less variable than the long distance reproduction. Although the results support Hypotheses Three (b) and Eight (b) that short distance reproduction constant error scores are smaller than long distance reproduction error scores, the concept of range effect was questioned.

II. CONCLUSIONS

On the basis of the results obtained and within the limitations of the design and the techniques of data collection, the following conclusions were drawn from the primary analyses.

1. There did not appear to be any effect of muscular involvement or sensory modality at the input end of the black box.

2. The type of output motor involvement had an effect on the bias of the output response but did not affect the accuracy or variability of the response. There did not appear to be any effect of sensory modality at the output end of the black box.

3. Ss were more accurate for short distance reproduction than long distance reproduction. For constant error, Ss slightly undershot on long distance reproductions and overshot on short distance reproductions.

4. The range effect appears to be more complicated than what was originally postulated by Pepper and Herman (1970).

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APPENDIX A

INSTRUCTIONS TO Ss

This experiment has been designed to study the motor memory of distances under different sensory and motor conditions.

sensory:		motor:	
	no light		watch
	black light		hold
	white light		turn

These have been paired to make eight possible conditions.

turn	hold	watch
white, black, none	white, black, none	white, black

There will also be two types of distances: short and long. For both the short and long distances, there will be small differences. It is very important that you attend to these distances.

The general idea of the study is that for the first part you will store information either by holding, turning and/or watching the handle. At the end of the first distance, a tone will sound and you will release the handle. After a short interval, you will attempt to show me the first distance by turning, holding and/or watching the handle.

Conditions

1. There are three sensory conditions: white light, black light and no light. These are E controlled and at no time do you have to worry about them.

2. There are two classifications of distances: long and short. For the first part, these are E controlled. As the Ss, you are asked to pay close attention to these distances using all the information

available to you as you will be expected to show me the same distances under the second part. Again you are reminded that there are small but important differences within the two groups.

3. There are three types of motor involvement: turn, hold and watch. These are your concern. For the turn, you will hold the handle and turn it yourself watching your hand and the handle whenever possible. For the hold, you will hold the handle and watch whenever possible. For the watch, you will rest your arm and just watch the handle. I will do the turning for both the turn and watch conditions.

Before the first part, you will be told the motor condition for both the first and second parts.

eg. first - turn second - watch

On the instruction 'ready', you will grasp the handle for the turn or hold conditions or place it at the resting location if it is a watch condition. On the instruction 'start', either you will turn the handle or the handle will turn itself (depending on the condition) until a tone sounds. On hearing the tone, you will release the handle if you were holding it and return to the resting location; or if at the resting, stay there. The resting location is the bottom of the circle directly in front of you.

In the short interval between first and second phases, the handle will move and the light condition may or may not change. Note: You will always turn the handle from right to left and keep your arm straightened and do not let go of the handle until the part is over.

On the instruction 'turn' or 'hold', you will return your hand to the handle and for 'watch', your hand will remain at the resting location.

On the instruction '<u>start</u>', either you will turn the handle or the handle will turn itself depending upon the condition. If the condition is <u>turn</u>, you will reproduce the distance. When you are satisfied, you will tell the <u>E</u>, eg., <u>finished</u> and release the handle. For the <u>hold</u> or <u>watch</u> conditions, you will give instructions to the <u>E</u> such as '<u>stop-too far</u>' or '<u>stop-not far enough</u>' or '<u>stop-finished</u>': Again, if it is a hold condition, you will release the handle.

<u>Remember</u>: The task is to repeat the first distance as well as possible. Please try to pay attention to these distances. For the first part, I determine the distance; in the second part, you try to show me how long the first part was.

APPENDIX B

TABLE 12

MEANS FOR THE SIXTY-FOUR SHORT DISTANCE EXPERIMENTAL CONDITIONS
ACCURACY SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	5.35	5.50	3.85	5.00	5.90	4.90	5.05	4.40	4.99
Active	Black light	6.20	6.00	7.45	8.85	3.65	4.20	5.00	4.95	5.79
	No light	5.80	6.75	4.20	8.60	7.50	5.50	4.50	7.95	6.35
	White light	6.35	7.00	3.75	3.95	5.00	4.65	3.95	5.50	5.02
Passive	Black light	4.90	7.15	4.00	4.70	4.80	5.90	4.40	3.20	4.88
	No light	5.65	6.40	4.85	5.55	6.40	4.35	8.85	7.30	6.17
	White light	2.75	3.00	4.20	3.90	4.70	6.15	4.65	3.45	4.10
Observe	Black light	4.10	4.90	4.50	5.20	3.35	4.25	3.80	4.50	4.32
	Mean Inputs	5.14	5.84	4.60	5.72	5.16	4.99	5.02	5.16	5.20

TABLE 13

MEANS FOR THE SIXTY-FOUR LONG DISTANCE EXPERIMENTAL CONDITIONS
ACCURACY SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
Active	White light	8.10	9.45	12.40	9.85	12.25	12.15	10.05	7.75	10.25
	Black light	9.90	10.60	10.55	8.35	9.20	9.75	10.85	10.25	9.93
	No light	8.05	12.65	11.25	10.50	8.00	11.80	12.75	12.80	10.97
Passive	White light	11.00	9.25	8.60	8.95	12.60	11.50	6.65	8.50	9.63
	Black light	9.05	9.70	10.35	8.60	10.25	10.25	9.85	9.85	9.74
	No light	13.00	7.95	10.40	11.50	10.55	12.05	12.10	13.20	11.34
Observe	White light	10.25	11.30	12.40	9.00	11.10	13.30	8.15	13.35	11.11
	Black light	11.25	7.75	12.90	9.90	12.70	11.20	7.85	9.00	10.32
	Mean Inputs	10.07	9.83	11.11	9.58	10.83	11.50	9.78	10.59	10.41

TABLE 14

MEANS FOR THE INPUT BY OUTPUT INTERACTION
ACCURACY SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	6.72	7.47	8.12	7.42	9.07	8.52	7.55	6.07	7.62
Active	Black light	8.05	8.30	9.00	8.60	6.42	6.97	7.92	7.60	7.86
	No light	6.92	9.70	7.72	9.55	7.75	8.65	8.62	10.37	8.66
	White light	8.67	8.12	6.17	6.45	8.80	8.07	5.30	7.00	7.32
Passive	Black light	6.97	8.42	7.17	6.65	7.52	8.07	7.12	6.52	7.31
	No light	9.32	7.17	7.62	8.52	8.47	8.20	10.47	10.25	8.76
	White light	6.50	7.15	8.30	6.45	7.90	9.72	6.40	8.40	7.60
Observe	Black light	7.67	6.32	8.70	7.55	8.02	7.72	5.82	6.75	7.32
	Mean Inputs	7.61	7.83	7.85	7.65	8.00	8.24	7.40	7.87	7.81

TABLE 15

MEANS FOR THE SIXTY-FOUR SHORT DISTANCE EXPERIMENTAL CONDITIONS
CONSTANT ERROR SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	2.95	2.70	0.05	1.10	3.70	0.50	3.35	2.10	2.06
Active	Black light	3.30	4.40	2.65	4.65	1.35	-0.90	2.80	2.35	2.57
	No light	2.50	4.05	0.90	6.50	6.40	2.60	3.50	7.65	4.26
	White light	4.45	3.80	0.55	2.55	4.10	1.55	0.55	2.90	2.56
Passive	Black light	2.10	2.85	1.60	-3.40	2.20	1.30	0.90	1.10	1.08
	No light	1.45	4.20	0.45	2.35	3.50	-0.25	6.15	5.20	2.88
	White light	-0.65	-0.10	0.80	0.30	1.10	-3.85	1.95	0.75	0.04
Observe	Black light	1.40	0.90	-1.00	2.30	0.65	-1.65	1.90	0.70	0.65
	Mean Inputs	2.19	2.85	0.75	2.04	2.87	-0.09	2.64	2.84	2.01

TABLE 16

MEANS FOR THE SIXTY-FOUR LONG DISTANCE EXPERIMENTAL CONDITIONS
CONSTANT ERROR SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	2.20	6.25	0.30	-1.05	1.45	6.05	3.75	-5.65	1.66
Active	Black light	4.90	2.10	2.85	1.15	2.70	-0.65	-1.15	3.65	1.94
	No light	2.75	9.35	0.85	1.30	1.40	3.20	1.65	0.10	2.57
	White light	-0.70	1.25	2.20	3.65	5.10	-1.40	-1.75	-2.70	0.71
Passive	Black light	-3.65	-2.20	-4.45	1.10	-0.35	-1.25	0.65	-1.55	-1.46
	No light	-0.30	-0.65	2.80	-1.80	-1.65	1.35	-3.30	-2.30	-0.73
	White light	0.35	-4.80	-5.30	-7.60	-2.60	-4.90	-5.15	-0.85	-3.86
Observe	Black light	-4.85	-4.65	-1.70	-5.90	-5.20	-7.30	-2.55	-2.40	-4.32
	Mean Inputs	0.09	0.83	-0.31	-1.14	0.11	-0.61	-0.98	-1.46	-0.44

TABLE 17

MEANS FOR THE INPUT BY OUTPUT INTERACTION
CONSTANT ERROR SCORES

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
Active	White light	2.57	4.47	0.17	0.02	2.57	3.27	3.55	-1.78	1.86
	Black light	4.10	3.25	2.75	2.90	2.02	-0.78	0.82	3.00	2.26
	No light	2.62	6.70	0.88	3.90	3.90	2.90	2.57	3.87	3.42
Passive	White light	1.87	2.52	1.37	3.10	4.60	0.07	-0.60	0.10	1.63
	Black light	-0.78	0.32	-1.43	-1.15	0.92	0.02	0.77	-0.23	-0.19
	No light	0.57	1.77	1.62	0.27	0.92	0.55	1.42	1.45	1.07
Observe	White light	-0.15	-2.45	-2.25	-3.65	-0.75	-4.37	-1.60	-0.05	-1.91
	Black light	-1.73	-1.87	-1.35	-1.80	-2.28	-4.48	-0.33	-0.85	-1.83
	Mean Inputs	1.14	1.84	0.22	0.45	1.49	-0.35	0.83	0.69	0.79

TABLE 18

SCORES FOR THE SIXTY-FOUR SHORT DISTANCE EXPERIMENTAL CONDITIONS
STANDARD DEVIATIONS

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	6.31	7.20	5.46	6.49	11.73	5.93	6.07	5.66	6.86
Active	Black light	7.15	6.06	11.08	12.51	5.43	5.67	5.86	6.92	7.58
	No light	6.19	8.11	5.24	7.76	6.82	7.15	4.95	6.35	6.57
	White light	7.94	8.28	5.84	4.33	5.29	5.72	5.33	6.72	6.18
Passive	Black light	6.28	7.71	4.92	5.38	5.61	9.17	4.99	4.36	6.05
	No light	7.04	6.93	6.01	6.57	7.44	5.62	10.90	7.96	7.31
	White light	3.73	3.84	5.45	5.31	6.09	6.15	6.12	4.24	5.12
Observe	Black light	5.09	6.50	5.49	6.58	4.42	5.37	5.17	6.09	5.59
	Mean Inputs	6.22	6.83	6.19	6.87	6.60	6.35	6.17	6.04	6.41

TABLE 19

SCORES FOR THE SIXTY-FOUR LONG DISTANCE EXPERIMENTAL CONDITIONS
STANDARD DEVIATIONS

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
Active	White light	10.58	10.69	17.03	12.52	14.43	14.51	13.49	7.54	12.60
	Black light	11.79	14.13	12.21	11.01	11.45	14.14	13.89	13.75	12.80
	No light	11.43	12.53	17.21	13.42	10.04	14.71	15.69	16.55	13.95
Passive	White light	13.31	11.26	10.93	10.33	13.90	13.93	10.27	11.01	11.87
	Black light	11.63	12.25	12.92	12.35	12.94	13.50	12.12	12.69	12.55
	No light	15.46	10.63	12.80	13.87	13.96	14.63	15.09	17.30	14.22
Observe	White light	14.31	13.64	14.00	8.06	15.53	16.52	9.63	17.51	13.65
	Black light	13.29	11.06	16.62	11.57	15.19	13.04	9.72	10.39	12.61
	Mean Inputs	12.72	12.02	14.21	11.64	13.43	14.37	12.49	13.34	13.03

TABLE 20

MEANS FOR THE INPUT BY OUTPUT INTERACTION
STANDARD DEVIATIONS

Output Conditions		Input Conditions								
		Active			Passive			Observe		Mean
		White light	Black light	No light	White light	Black light	No light	White light	Black light	Outputs
	White light	8.44	8.94	11.24	9.50	13.08	10.22	9.78	6.60	9.73
Active	Black light	9.47	10.09	11.64	11.76	8.44	9.90	9.87	10.33	10.19
	No light	8.81	10.32	11.22	10.59	8.43	10.93	10.32	11.45	10.26
	White light	10.62	9.77	8.38	7.33	9.59	9.82	7.80	8.86	9.02
Passive	Black light	8.95	9.98	8.92	8.86	9.27	11.33	8.55	8.52	9.30
	No light	11.25	8.78	9.40	10.22	10.70	10.12	12.99	12.63	10.76
	White light	9.02	8.74	9.72	6.68	10.81	11.33	7.87	10.87	9.38
Observe	Black light	9.19	8.78	11.05	9.07	9.80	9.20	7.44	8.24	9.10
	Mean Inputs	9.47	9.43	10.20	9.25	10.02	10.36	9.33	9.69	9.72

TABLE 21

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR INPUT CONDITIONS ACCURACY SCORES

	Observe White Light	Active White Light	Passive White Light	Active Black Light	Active No Light	Observe Black Light	Passive Black Light	Passive No Light	Shortest Significant Ranges	
Means	7.40	7.61	7.65	7.83	7.85	7.87	8.00	8.24	0.01	0.05
7.40		0.21	0.25	0.43	0.45	0.47	0.60	0.84	R_2 = 1.37	= 1.04
7.61			0.04	0.22	0.24	0.26	0.39	0.63	R_3 = 1.43	= 1.09
7.65				0.18	0.20	0.22	0.35	0.59	R_4 = 1.47	= 1.13
7.83					0.02	0.04	0.17	0.41	R_5 = 1.50	= 1.15
7.85						0.02	0.15	0.39	R_6 = 1.52	= 1.17
7.87							0.13	0.37	R_7 = 1.54	= 1.19
8.00								0.24	R_8 = 1.55	= 1.20

TABLE 22

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR OUTPUT CONDITIONS ACCURACY SCORES

	Passive Black Light	Passive White Light	Observe Black Light	Observe White Light	Active White Light	Active Black Light	Active No Light	Passive No Light	Shortest Significant Ranges
Means	7.31	7.32	7.32	7.60	7.62	7.86	8.66	8.76	0.01 0.05
7.31		0.01	0.01	0.29	0.31	0.55	1.35*	1.45*	R_2 = 1.37 = 1.04
7.32			0.00	0.28	0.30	0.54	1.34*	1.44*	R_3 = 1.43 = 1.09
7.32				0.28	0.30	0.54	1.34*	1.44*	R_4 = 1.47 = 1.13
7.60					0.02	0.26	1.06	1.16*	R_5 = 1.50 = 1.15
7.62						0.24	1.04	1.14*	R_6 = 1.52 = 1.17
7.86							0.80	0.90	R_7 = 1.54 = 1.19
8.66								0.10	R_8 = 1.55 = 1.20

* significant at the 0.05 level

TABLE 23

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR INPUT CONDITIONS CONSTANT ERROR SCORES

	Passive No Light	Active No Light	Passive White Light	Observe Black Light	Observe White Light	Active White Light	Passive Black Light	Active Black Light	Shortest Significant Ranges
Means	-0.35	0.22	0.45	0.69	0.83	1.14	1.49	1.84	0.01 0.05
-0.35		0.57	0.80	1.04	1.18	1.49	1.84	2.19*	R_2 = 2.15 = 1.62
0.22			0.23	0.47	0.61	0.92	1.27	1.62	R_3 = 2.24 = 1.71
0.45				0.24	0.38	0.69	1.04	1.39	R_4 = 2.30 = 1.76
0.66					0.14	0.45	0.80	1.15	R_5 = 2.35 = 1.82
0.83						0.31	0.66	1.01	R_6 = 2.38 = 1.84
1.14							0.35	0.70	R_7 = 2.41 = 1.86
1.49								0.35	R_8 = 2.44 = 1.89

* significant at the 0.05 level

TABLE 24

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES
BETWEEN K = 8 MEANS FOR OUTPUT CONDITIONS
CONSTANT ERROR SCORES

	Observe White Light	Observe Black Light	Passive Black Light	Passive No Light	Passive White Light	Active White Light	Active Black Light	Active No Light	Shortest Significant Ranges
Means	-1.91	-1.83	-0.19	1.07	1.63	1.86	2.26	3.42	0.01 0.05
-1.91		0.08	1.72*	2.98**	3.54**	3.77**	4.17**	5.33**	R_2 = 2.15 = 1.62
-1.83			1.64*	2.90**	3.46**	3.69**	4.09**	5.25**	R_3 = 2.24 = 1.71
-0.19				1.26	1.82*	2.05*	2.45**	3.61**	R_4 = 2.30 = 1.76
1.07					0.56	0.79	1.19	2.35**	R_5 = 2.35 = 1.82
1.63						0.23	0.63	1.79*	R_6 = 2.38 = 1.84
1.86							0.40	1.56	R_7 = 2.41 = 1.86
2.26								1.16	R_8 = 2.44 = 1.89

** significant at the 0.01 level
* significant at the 0.05 level

TABLE 25

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR INPUT CONDITIONS STANDARD DEVIATIONS

	Passive White Light	Observe White Light	Active Black Light	Active White Light	Observe Black Light	Passive Black Light	Active No Light	Passive No Light	Shortest Significant Ranges
Means	9.25	9.33	9.43	9.47	9.69	10.02	10.20	10.36	0.01 0.05
9.25		0.08	0.18	0.22	0.44	0.77	0.95	1.11	R_2 = 1.88 = 1.40
9.33			0.10	0.14	0.36	0.69	0.87	1.03	R_3 = 1.95 = 1.48
9.43				0.04	0.26	0.59	0.77	0.93	R_4 = 2.01 = 1.53
9.47					0.22	0.55	0.73	0.89	R_5 = 2.05 = 1.56
9.69						0.33	0.51	0.67	R_6 = 2.08 = 1.59
10.02							0.18	0.32	R_7 = 2.10 = 1.61
10.20								0.16	R_8 = 2.13 = 1.63

TABLE 26

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR OUTPUT CONDITIONS STANDARD DEVIATIONS

	Passive White Light	Observe Black Light	Passive Black Light	Observe White Light	Active White Light	Active Black Light	Active No Light	Passive No Light	Shortest Significant Ranges
Means	9.02	9.10	9.30	9.38	9.73	10.19	10.26	10.76	0.01 0.05
9.02		0.08	0.28	0.36	0.71	1.21	1.28	1.78*	R_2 = 1.88 = 1.40
9.10			0.20	0.28	0.63	1.09	1.16	1.66*	R_3 = 1.95 = 1.48
9.30				0.08	0.43	0.89	0.96	1.46	R_4 = 2.01 = 1.53
9.38					0.35	0.81	0.88	1.38	R_5 = 2.05 = 1.56
9.73						0.46	0.53	1.03	R_6 = 2.08 = 1.59
10.19							0.07	0.57	R_7 = 2.10 = 1.61
10.26								0.50	R_8 = 2.13 = 1.63

* significant at the 0.05 level

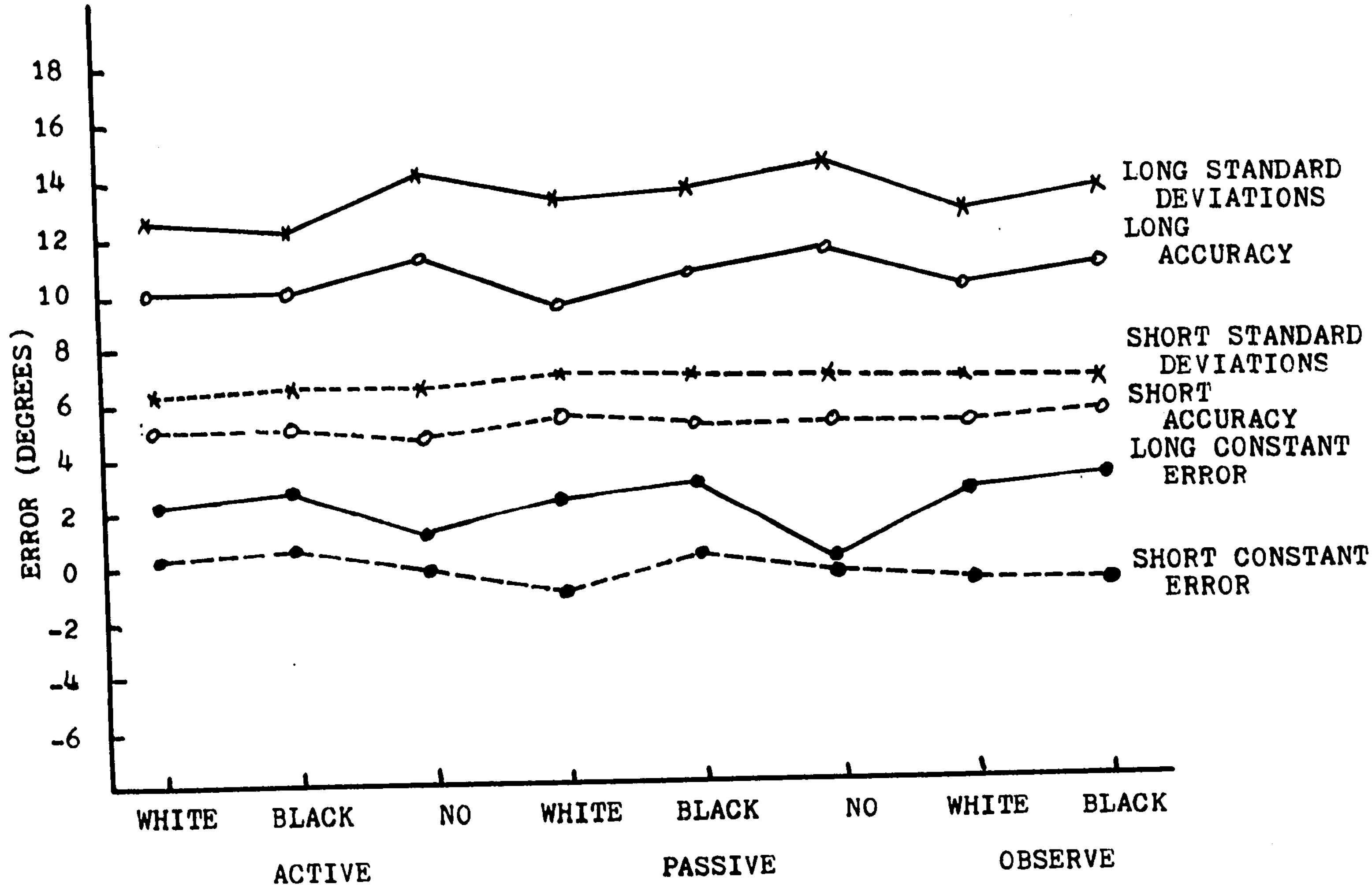

FIGURE 13

MEANS FOR THE INTERACTION BETWEEN THE INPUT AND RANGE FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

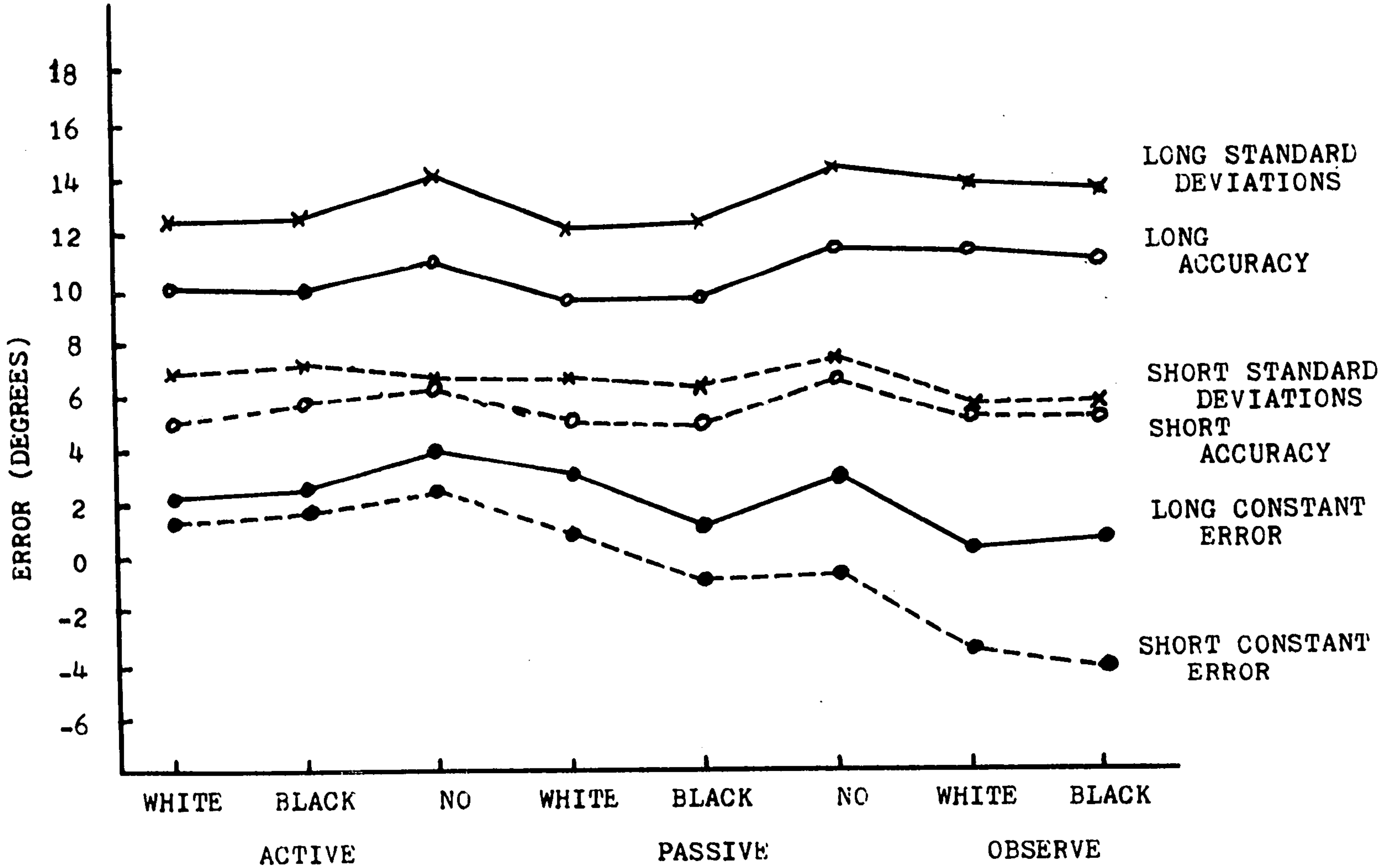

FIGURE 14

MEANS FOR THE INTERACTION BETWEEN THE OUTPUT AND RANGE FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

APPENDIX C

TABLE 27

MEANS FOR MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
WHITE-BLACK LIGHT CONDITIONS
CONSTANT ERROR SCORES

Motor output by motor input by range interaction

		Motor output			
		Active	Passive	Observe	Mean
Motor input short range	Active	3.34	3.30	0.39	
	Passive	2.70	1.36	1.09	
	Observe	2.65	1.36	1.32	
	Mean	2.90	2.01	0.93	1.95
Motor input long range	Active	3.86	-1.33	-3.49	
	Passive	1.06	2.38	-5.33	
	Observe	0.15	-1.38	-2.74	
	Mean	1.69	-0.11	-3.85	-0.75

Motor input and output main effects

	Active	Passive	Observe
Motor input	1.02	0.54	0.23
Motor output	2.29	0.95	-1.45

Light input and output main effects

	White light	Black light
Light input	0.44	0.75
Light output	0.80	0.40

TABLE 28

MEANS FOR MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
ACTIVE-PASSIVE CONDITIONS
ACCURACY SCORES

Light input by range interaction

	White light	Black light	No light	Mean
Short range	5.91	5.92	4.80	5.57
Long range	9.74	10.20	10.92	10.29

Motor input and output main effects

	Active	Passive
Motor input	7.87	7.99
Motor output	8.03	7.78

Light input by light output interaction[1]

		Input			
		White light	Black light	No light	Mean Output
	White light	7.32	8.36	7.72	7.81
	Black light	7.57	7.67	7.80	7.68
Output	No light	8.63	8.27	8.05	8.30
	Mean Input	7.83	8.11	7.86	7.93

[1]Not significant but important in the analysis.

TABLE 29

MEANS FOR MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
WHITE-BLACK LIGHT CONDITIONS
ACCURACY SCORES

Motor output by range interaction				
	Active	Passive	Observe	Mean
Short range	5.49	5.07	4.03	4.86
Long range	9.72	9.52	10.13	9.79
Motor input and output main effects				
	Active	Passive	Observe	
Motor input	7.53	7.58	6.88	
Motor output	7.61	7.30	7.08	
Light input and output main effects				
	White light	Black light		
Light input	7.10	7.55		
Light output	7.30	7.35		

TABLE 30

MEANS FOR MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
ACTIVE-PASSIVE CONDITIONS
CONSTANT ERROR SCORES

Motor output by range interaction

	Active	Passive	Mean
Short range	2.74	1.96	2.35
Long range	2.61	-0.05	1.28

Motor input and output main effects

	Active	Passive
Motor input	1.97	1.67
Motor output	2.68	0.96

Light input by light output interaction[1]

		Input: White light	Input: Black light	Input: No light	Mean Output
	White light	1.89	3.54	1.82	2.22
	Black light	1.27	1.63	0.14	1.01
Output	No light	1.84	3.32	1.49	2.65
	Mean Input	1.68	2.84	0.96	1.82

[1]Not significant but important in the analysis.

TABLE 31

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO MAIN EFFECTS AND SIGNIFICANT INTERACTIONS WHITE-BLACK LIGHT CONDITIONS ACCURACY SCORES

		Motor output for short range		
	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	4.03	5.07	5.49	R_2 = 1.51 = 1.14
4.03		1.04	1.46*	R_3 = 1.57 = 1.20
5.07			0.40	
		Motor output for long range		
	Passive	Active	Observe	Shortest significant ranges
				0.01 0.05
Means	9.52	9.72	10.13	R_2 = 1.51 = 1.14
9.52		0.20	0.61	R_3 = 1.57 = 1.20
9.72			0.41	
		Motor output main effect		
	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	7.08	7.30	7.61	R_2 = 1.06 = 0.81
7.08		0.22	0.53	R_3 = 1.11 = 0.85
7.61			0.31	
		Motor input main effect		
	Observe	Active	Passive	Shortest significant ranges
				0.01 0.05
Means	6.88	7.53	7.58	R_2 = 1.06 = 0.81
6.88		0.65	0.70	R_3 = 1.11 = 0.85
7.53			0.05	

* significant at the 0.05 level

TABLE 32

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO
MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
ACTIVE-PASSIVE CONDITIONS
ACCURACY SCORES

Light input for short range

Means	No light 4.80	White light 5.91	Black light 5.92	Shortest significant ranges 0.01 0.05
4.80		1.11	1.12	R_2 = 1.60 = 1.21
5.91			0.01	R_3 = 1.67 = 1.28

Light input for long range

Means	White light 9.74	Black light 10.20	No light 10.92	Shortest significant ranges 0.01 0.05
9.74		0.46	1.18	R_2 = 1.60 = 1.21
10.20			0.72	R_3 = 1.67 = 1.28

Light input main effect

Means	White light 7.83	No light 7.86	Black light 8.11	Shortest significant ranges 0.01 0.05
7.83		0.03	0.28	R_2 = 1.13 = 0.86
7.86			0.25	R_3 = 1.18 = 0.90

Light output main effect

Means	Black light 7.68	White light 7.81	No light 8.30	Shortest significant ranges 0.01 0.05
7.68		0.13	0.62	R_2 = 1.13 = 0.86
7.81			0.49	R_3 = 1.18 = 0.90

TABLE 33

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO MAIN EFFECTS AND SIGNIFICANT INTERACTIONS WHITE-BLACK LIGHT CONDITIONS CONSTANT ERROR SCORES

Motor output for short range

	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	0.93	2.01	2.90	
0.93		1.08	1.97*	R_2 = 2.30 = 1.74
2.01			0.89	R_3 = 2.40 = 1.83

Motor output for long range

	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	-3.85	-0.11	1.69	
-3.85		3.74**	5.54**	R_2 = 2.30 = 1.74
-0.11			1.80*	R_3 = 2.40 = 1.83

Motor output main effect

	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	-1.45	0.95	2.29	
-1.45		2.40**	3.74**	R_2 = 1.62 = 1.23
0.95			1.34**	R_3 = 1.69 = 1.29

Motor input main effect

	Observe	Passive	Active	Shortest significant ranges
				0.01 0.05
Means	0.23	0.54	1.02	
0.23		0.31	0.79	R_2 = 1.62 = 1.23
0.54			0.48	R_3 = 1.69 = 1.29

** significant at the 0.01 level
* significant at the 0.05 level

TABLE 33 (continued)

Active motor output for short range

	Observe	Active	Passive
Means	2.65	2.70	3.34
2.65		0.05	0.69
2.70			0.64

Active motor output for long range

	Observe	Passive	Active
Means	0.15	1.06	3.86
0.15		0.91	3.71**
1.06			2.80

Passive motor output for short range

	Observe	Passive	Active
Means	1.36	1.36	3.30
1.36		0.00	1.94
1.36			1.94

Passive motor output for long range

	Observe	Active	Passive
Means	-1.38	-1.33	2.38
-1.38		0.05	3.76*
-1.33			3.71*

Observe motor output for short range

	Active	Passive	Observe
Means	0.39	1.09	1.32
0.39		0.60	0.93
1.09			0.23

Observe motor output for long range

	Passive	Active	Observe
Means	-5.33	-3.49	-2.74
-5.33		1.84	2.59
-3.49			0.75

Active motor input for short range

	Observe	Passive	Active
Means	0.39	3.30	3.34
0.39		2.91	2.95
3.30			0.04

Active motor input for long range

	Observe	Passive	Active
Means	-3.49	-1.33	3.86
-3.49		2.16	7.35**
-1.33			5.19**

Passive motor input for short range

	Observe	Passive	Active
Means	1.09	1.34	2.70
1.09		0.27	1.61
1.34			1.34

Passive motor input for long range

	Observe	Active	Passive
Means	-5.33	1.06	2.38
-5.33		6.39**	7.71**
1.06			1.32

Observe motor input for short range

	Observe	Passive	Active
Means	1.32	1.36	2.65
1.32		0.04	1.33
1.36			1.29

Observe motor input for long range

	Observe	Passive	Active
Means	-2.74	-1.38	0.15
-2.74		1.36	2.89
-1.38			1.53

TABLE 33 (continued)

		INPUT		
		Active	Passive	Observe
	Active	0.52	1.64	2.50
OUTPUT	Passive	4.63**	1.02	2.74
	Observe	3.88*	6.42*	4.06*

Shortest significant ranges

	0.01	0.05
R_2 =	3.98 =	3.01
R_3 =	4.49 =	3.17

** significant at the 0.01 level
* significant at the 0.05 level

TABLE 34

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO
MAIN EFFECTS AND SIGNIFICANT INTERACTIONS
ACTIVE-PASSIVE CONDITIONS
CONSTANT ERROR SCORES

Motor output for short range

	Passive	Active	Shortest significant ranges
			0.01 0.05
Means	1.96	2.74	
1.96		0.78	R_2 = 2.00 = 1.52

Motor output for long range

	Passive	Active	Shortest significant ranges
			0.01 0.05
Means	-0.05	2.61	
-0.05		2.66**	R_2 = 2.00 = 1.52

Light input main effect

	No light	White light	Black light	Shortest significant ranges
				0.01 0.05
Means	0.96	1.68	2.84	
0.96		0.72	1.88**	R_2 = 1.74 = 1.31
1.68			1.16	R_3 = 1.81 = 1.38

Light output main effect

	Black light	White light	No light	Shortest significant ranges
				0.01 0.05
Means	1.01	2.22	2.65	
1.01		1.21	1.64**	R_2 = 1.74 = 1.31
2.22			0.43	R_3 = 1.81 = 1.38

** significant at the 0.01 level
* significant at the 0.05 level

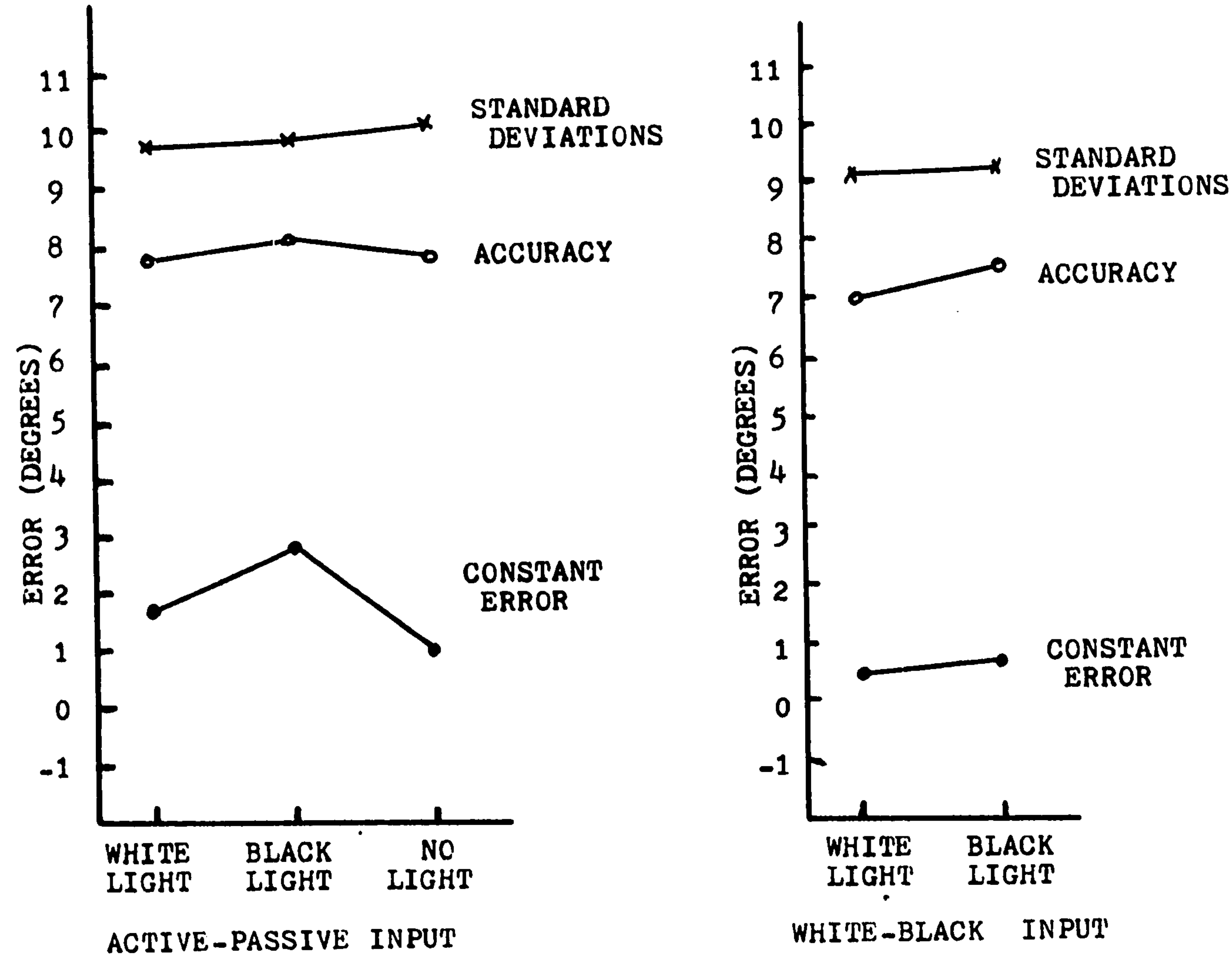

FIGURE 15

MEANS FOR THE MAIN EFFECTS OF LIGHT INPUT OF THE ACTIVE-PASSIVE AND WHITE-BLACK SECONDARY ANALYSES FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

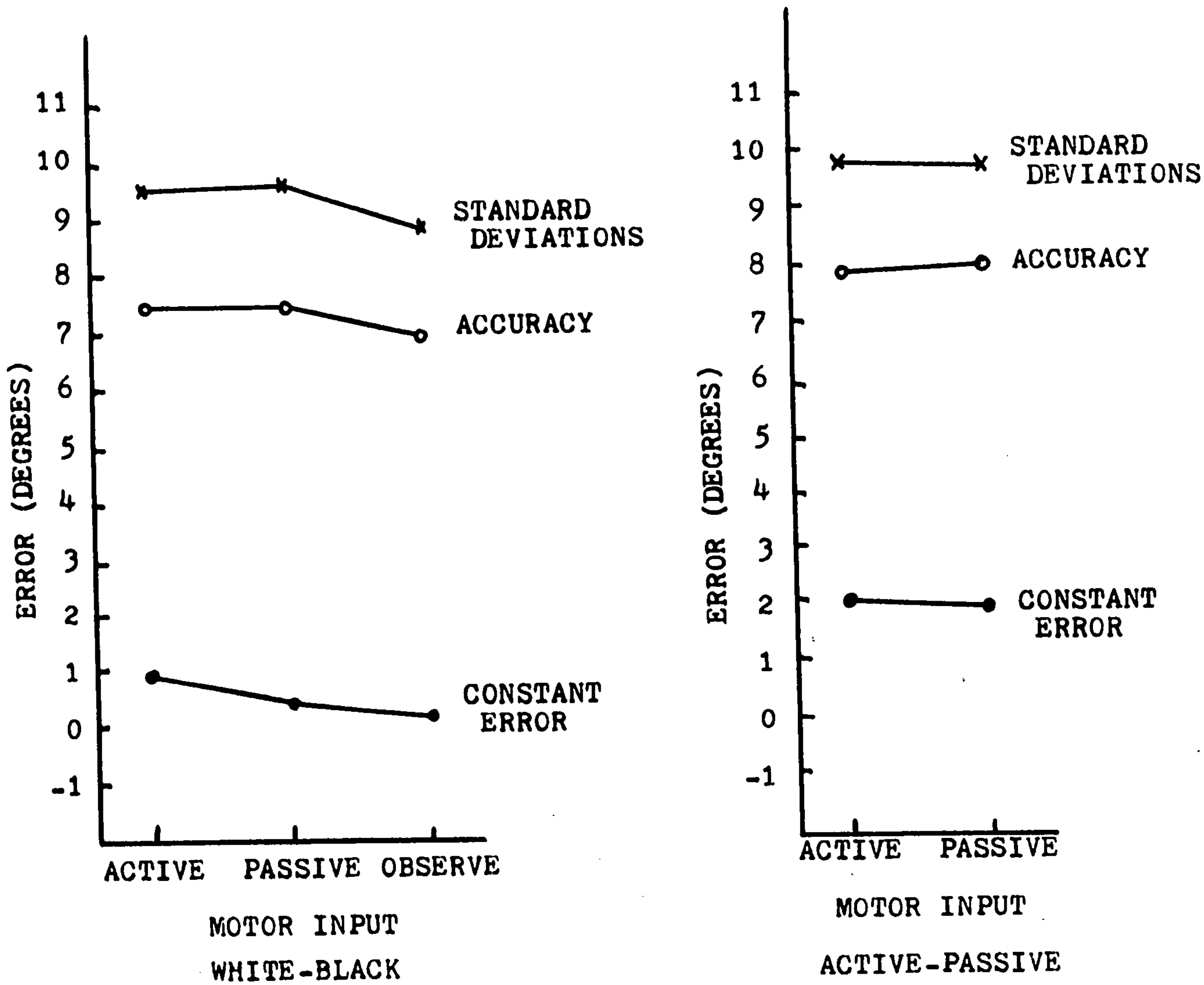

FIGURE 16

MEANS FOR THE MAIN EFFECTS OF MOTOR INPUT OF THE ACTIVE-PASSIVE AND WHITE-BLACK SECONDARY ANALYSIS FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS

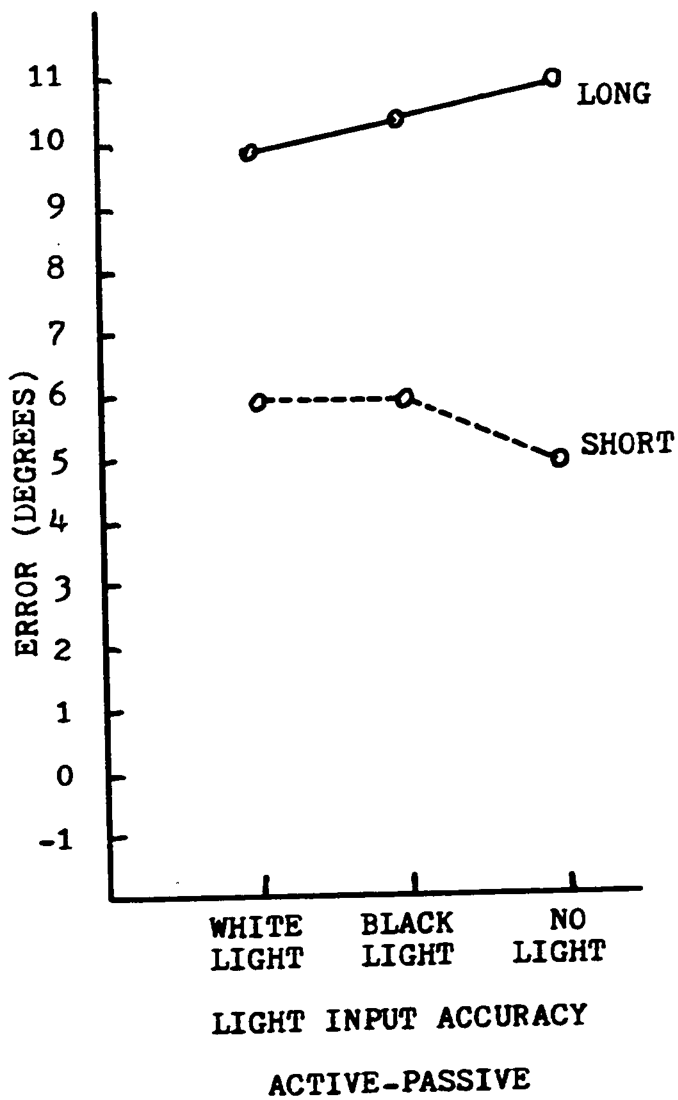

FIGURE 17

MEANS FOR THE INTERACTION BETWEEN MOTOR INPUT AND RANGE OF THE ACTIVE-PASSIVE SECONDARY ANALYSIS FOR ACCURACY SCORES

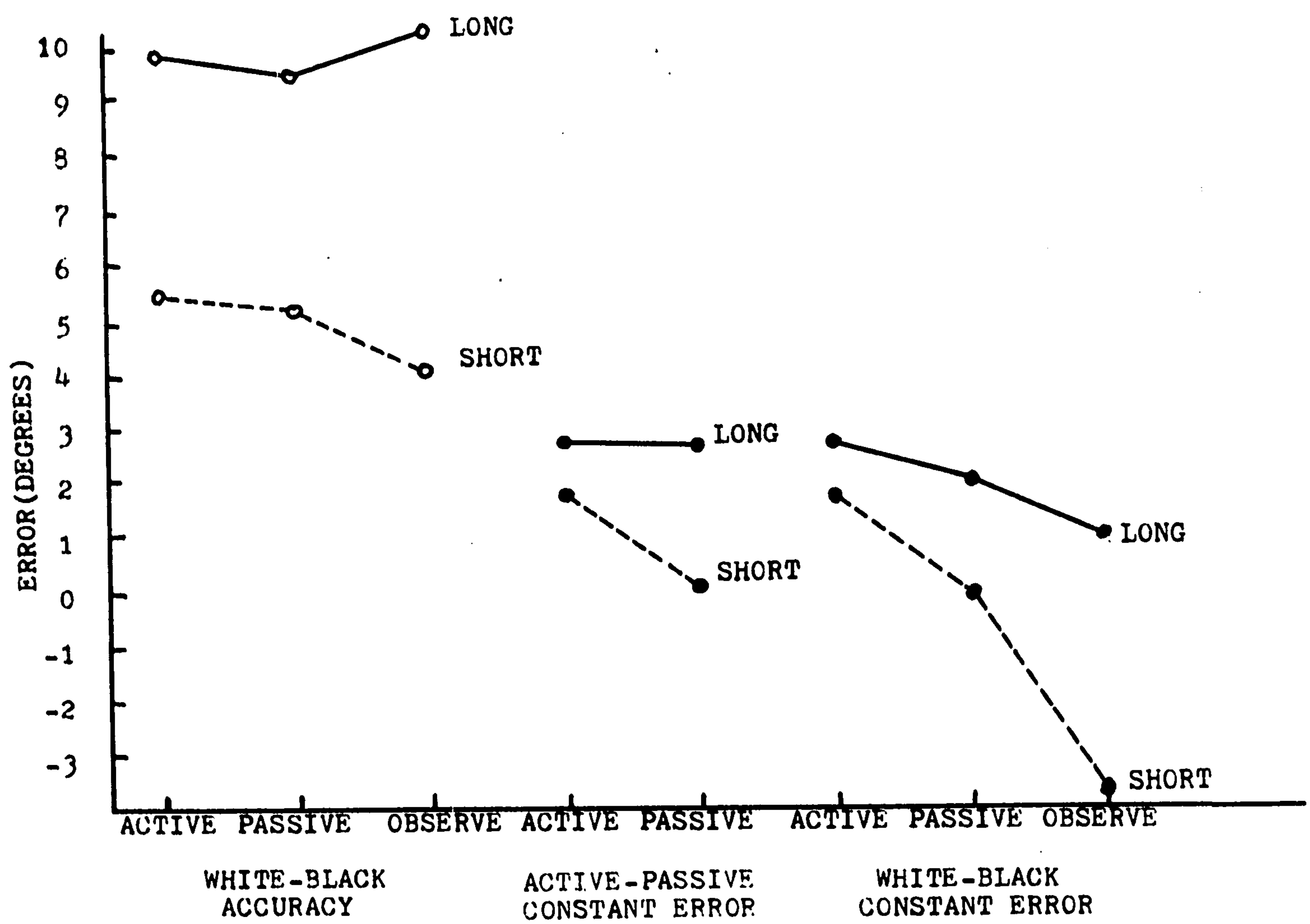

FIGURE 18

MEANS FOR THE INTERACTION BETWEEN MOTOR OUTPUT AND RANGE OF THE WHITE-BLACK SECONDARY ANALYSIS ACCURACY SCORES AND CONSTANT ERROR SCORES AND THE ACTIVE-PASSIVE SECONDARY ANALYSIS FOR CONSTANT ERROR SCORES

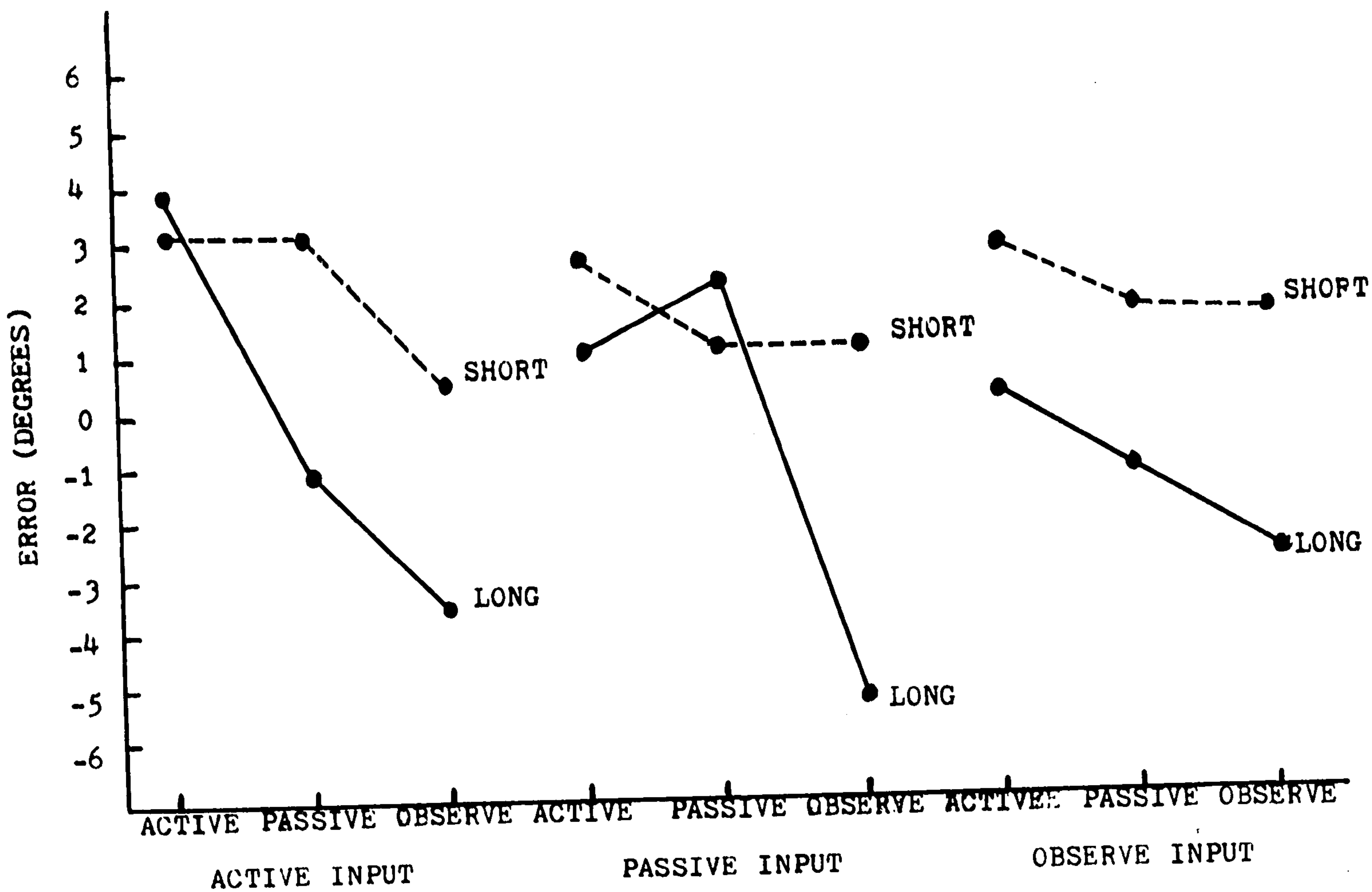

FIGURE 19

MEANS FOR THE INTERACTION BETWEEN MOTOR INPUT, MOTOR OUTPUT AND RANGE OF THE WHITE-BLACK SECONDARY ANALYSIS CONSTANT ERROR SCORES

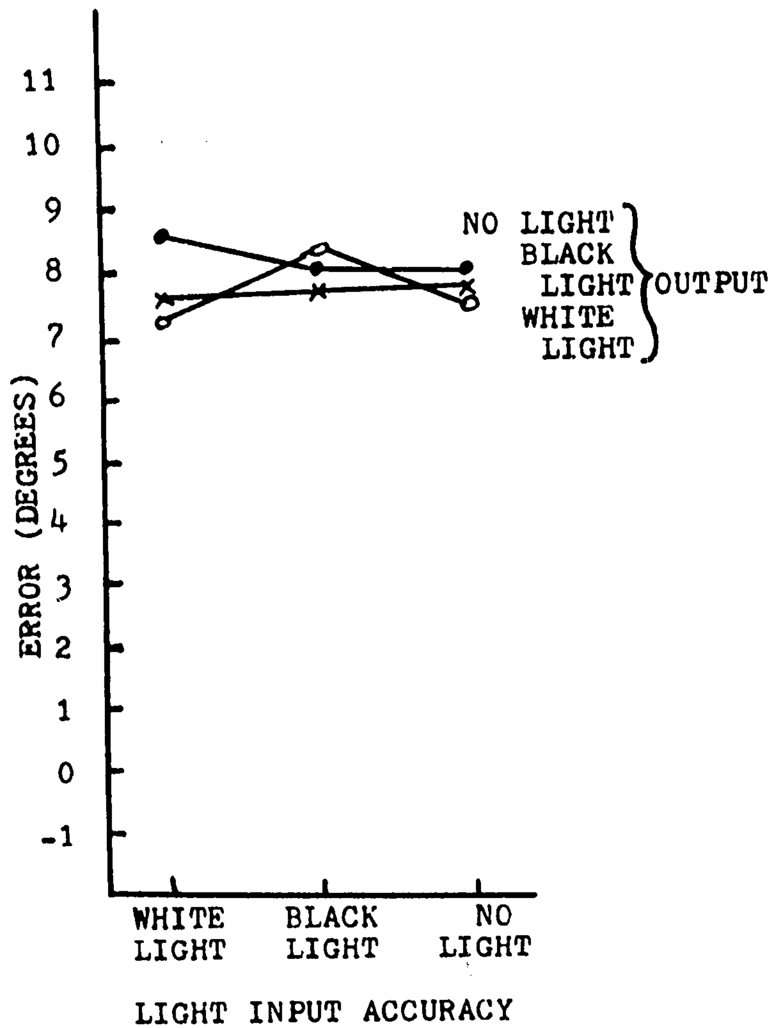

FIGURE 20

MEANS FOR THE INTERACTION BETWEEN LIGHT INPUT AND LIGHT OUTPUT OF THE ACTIVE-PASSIVE SECONDARY ANALYSIS ACCURACY SCORES

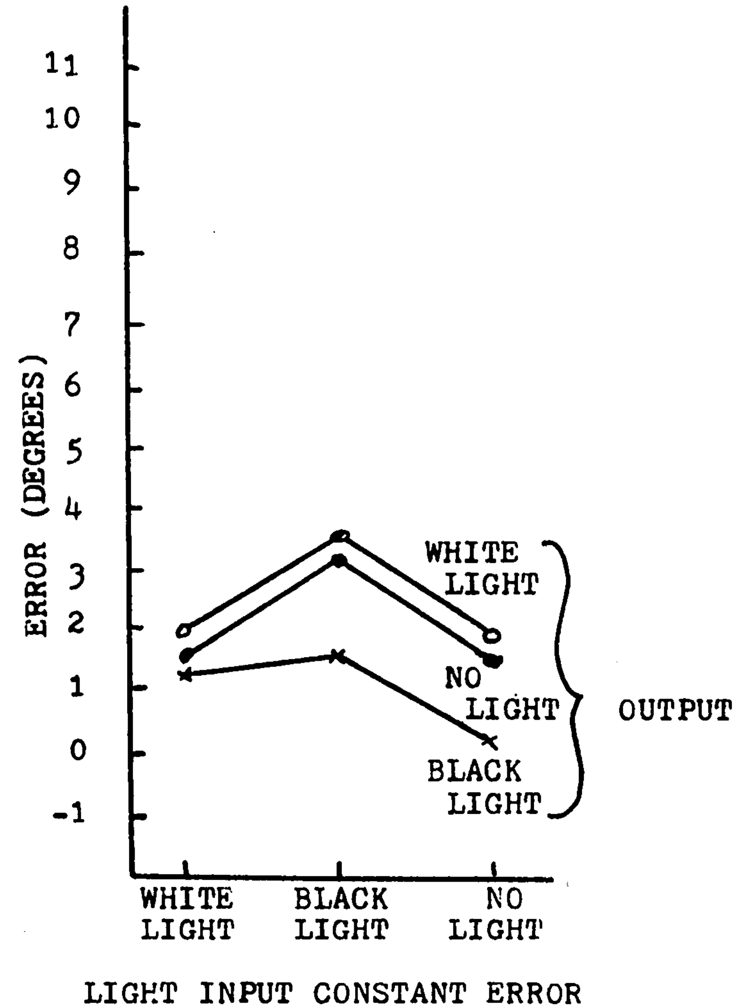

FIGURE 21

MEANS FOR THE INTERACTION BETWEEN LIGHT INPUT AND LIGHT OUTPUT OF THE ACTIVE-PASSIVE SECONDARY ANALYSIS CONSTANT ERROR SCORES

APPENDIX D

TABLE 35

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR IDENTICAL INPUT-OUTPUT ACCURACY SCORES

	Observe White Light	Passive White Light	Active White Light	Observe Black Light	Passive Black Light	Active No Light	Passive No Light	Active Black Light	Shortest Significant Ranges
Means	6.40	6.45	6.72	6.75	7.52	7.72	8.20	8.30	0.01 0.05
6.40		0.05	0.32	0.35	1.12	1.32	1.80	1.90	R_2 = 3.73 = 2.82
6.45			0.27	0.30	1.07	0.27	1.75	1.85	R_3 = 3.89 = 2.97
6.72				0.03	0.80	1.00	1.48	1.58	R_4 = 3.99 = 3.07
6.75					0.77	0.97	1.45	1.55	R_5 = 4.07 = 3.14
7.52						0.20	0.68	0.78	R_6 = 4.14 = 3.20
7.72							0.48	0.58	R_7 = 4.19 = 3.24
8.20								0.10	R_8 = 4.23 = 3.28

TABLE 36

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED TO DIFFERENCES BETWEEN K = 8 MEANS FOR IDENTICAL INPUT-OUTPUT CONSTANT ERROR SCORES

	Observe White Light	Observe Black Light	Passive No Light	Active No Light	Passive Black Light	Active White Light	Passive White Light	Active Black Light	Shortest Significant Ranges
Means	-1.60	-0.85	0.55	0.88	0.92	2.57	3.10	3.25	0.01 0.05
-1.60		-0.75	2.15	2.48	2.52	4.17	4.70	4.85	R_2 = 6.68 = 5.05
-0.85			1.40	1.73	1.77	3.42	3.95	4.10	R_3 = 6.96 = 5.31
0.55				0.33	0.37	2.02	2.55	2.70	R_4 = 7.15 = 5.49
0.88					0.04	1.69	2.22	2.37	R_5 = 7.30 = 5.62
0.92						1.65	2.18	2.33	R_6 = 7.41 = 5.72
2.57							0.53	0.68	R_7 = 7.50 = 5.80
3.10								0.15	R_8 = 7.58 = 5.87

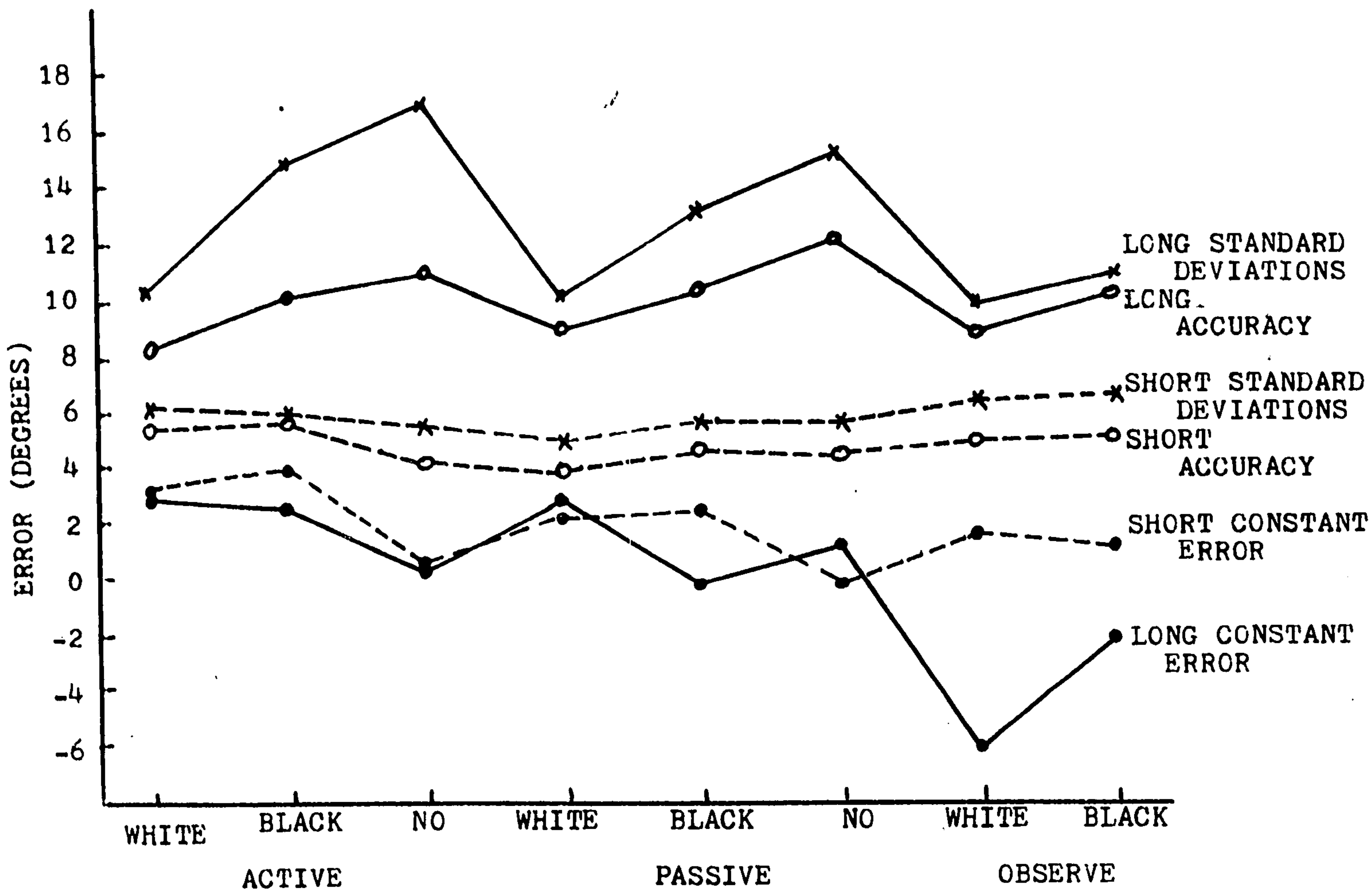

FIGURE 22

MEANS FOR THE INTERACTION BETWEEN IDENTICAL INPUT-OUTPUT AND RANGE FOR ACCURACY SCORES, CONSTANT ERROR SCORES AND STANDARD DEVIATIONS