1974

The independence of the perceptual and memory traces a test of Adams' closed loop model.

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THE INDEPENDENCE OF THE PERCEPTUAL AND MEMORY TRACES:
A TEST OF ADAMS' CLOSED LOOP MODEL

A Thesis
Submitted to the Faculty of Graduate Studies
through the Faculty of Physical and Health Education

by

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B.P.H.E., University of Windsor, 1973

Windsor, Ontario, Canada
1974

ABSTRACT

The functional independence of the memory and perceptual traces in Adams' (1971) model was investigated, employing a slow self-paced graded response. The task, containing the two main elements of a slow self-paced response, namely direction and extent, involved the recall of a movement in a 120 degree direction and the recognition of a movement six inches in length. Three levels of sensory fb (distorted, normal, and heightened) were studied as sources of response-produced feedback on 100 acquisition trials with no KR, early KR withdrawal and late KR withdrawal. 72 university student volunteers, 36 men and 36 women, were systematically rotated into one of the nine independent cells, so that upon completion of testing there were eight subjects per cell. The results were analyzed by single factor, two factor and three factor ANOVA with repeated measures on the blocks factor and discussed in terms of predictions from Adams' (1971) closed loop model and signal detection theory. The error detection, amplification and correction process was indexed by $\overline{CE}$, the error detection criterion level, and VE, the sensitivity of the error detection mechanism to the adopted criterion level. The accuracy of the memory and perceptual traces, using the established criterion level, was described by $\overline{AE}$, while their strength was measured by AV.

While the present data was able to support several predictions from Adams (1971) closed loop model, it was unable to substantiate the functional independence of the memory and perceptual traces. Since the present findings indicated that

the memory trace, like the perceptual trace, is self-regulating on the basis of sensory fb, the functional independence of the two traces in memory has become infinitely more difficult to establish, both memory processes being able to improve by means of subjective reinforcement. In view of this information, Adams' original (1971) model was reconceptualized as a closed loop model operating on two distinct levels. The first level, the error detection, amplification and correction processes is partially closed loop with the criterion level operating without sensory fb, but the mechanism's sensitivity being continually modified by incoming sensory fb. The second level, the controlling agents of direction and extent performance, namely the memory and perceptual traces respectively, are both closed loop in nature. Hence, control of skilled performance via a closed loop system via sensory fb has received considerable support as the superior explanation of movement control.

ACKNOWLEDGEMENTS

I wish to express my sincerest thanks to Dr. J.L. Leavitt whose tremendous encouragement and guidance in every facet of this research made its completion possible. An expression of appreciation is also extended to Dr. M. Salter, Dr. V. Cervin and Dr. G. Namikas for their interest and advice.

I also want to thank Mr. T. Čada for his technical assistance and Mr. D.A. Henessey of the Wahl Clipper Company who generously loaned the two electric massage vibrators which were essential in the distortion of sensory fb.

Most of all, I give my love and gratitude to my parents who both spent many hours assisting me in data computation and whose continual support and interest in my university career made completion of this thesis possible. A special thank you is given to my mother who spent many long hours typing this thesis.

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CHAPTER ONE

INTRODUCTION

Control of skilled performance has been a topic of considerable interest in the twentieth century. Sporadic investigations were made at the beginning of the century, which have led to greatly heightened research efforts in recent years. However, in spite of the volume of studies which have been conducted to shed light on the question "How is movement controlled?" as of yet, there is no definite answer. Due to the number and complexity of the processes and mechanisms that act simultaneously to produce the exacting control and organization, the sheer grace and beauty, that typify the performance of the skilled athlete, research has been able only to provide answers to many specific instances of movement control. Currently, a general theory of movement control is lacking, but there are two mainstreams into which proponents of a theory of movement control fall, open or central control via a motor program versus closed loop control via sensory feedback (fb).

In the past, theories of learning (i.e. associative, stimulus-response, cognitive and field) have been primarily open loop, a system that has no fb or mechanism for error regulation. An open loop system, regulated by a motor program may be viewed as

> "a set of muscle commands that are structured before a movement sequence begins, and allows the entire sequence to be carried out, uninfluenced by peripheral

fb" (Keele, 1968, p.392)

The motor commands are formulated on the basis of pertinent input and executed to fulfill a desired goal. Once the program has been initiated, it continues until completion, since peripheral error information is not used to modify the ongoing program. A new motor program may be sent out to correct an error in the previous program, but the original program itself may not be corrected. Motor program formulation is thought to be under the control of the central nervous system.

Over the years, a substantial amount of data has supported movement control via a motor program. It has been found that motor performance is still possible after complete or partial removal of sensory fb. (Lashley, 1917; Lashley and McCarthy, 1926; Lashley and Ball, 1929; Wilson, 1961; Wilson and Gettrup, 1963; Wilson, 1964; Wilson, 1968; Chase et. al., 1961; Laszlo, 1967a; Laszlo, 1967b). Furthermore, it has been demonstrated that motor skill acquisition can occur in the absence of sensory fb. (Laszlo, 1966; Laszlo and Manning, 1970a; Taub and Berman, 1968). The fact that both motor learning and motor performance are still achievable, after sensory fb has been eliminated, provides strong support for an open loop view of movement control.

In contrast to an open loop system, a closed loop system requires the detection and correction of errors, while the movement is being executed. The four essential elements of all closed loop systems include (1) a reference mechanism that specifies the desired response; (2) sensory fb from the response output, which may be used both during and after the movement; (3) comparison of the sensory fb to the reference mechanism, yielding error information; (4) the correction of the error, once it has been established. A closed loop system is self regulating, by detecting and correcting any departures from the reference.

Attempts to utilize the closed loop model to explain skilled performance have come from various scientific fields. Following World War II, engineering psychologists used the closed loop system to account for tracking behaviour. In 1954, Fairbanks developed a closed loop model of speech control and in 1965, Chase, a medical-biologist produced an information flow model, which was the first of its kind to centre around the processes of error detection and error correction. A simultaneous interest in closed loop theory was also occurring, at this time in the U.S.S.R. Prominent Soviet psychologists Bernstein (1967) and Anokhin (1969) developed very explicit closed loop models in explanation of skilled performance..

It is from this background that Adams (1971) developed his closed loop theory of motor learning. (Figure 1). Unlike Chase and the Soviet behaviourists, whose models have no specific frame of reference and are advanced in explanation of skilled performance in general, Adams has proposed a model only in explanation of the simple, self-paced graded response. Adams' reasons for restricting his model, at the present, to the self-paced graded response are threefold. Firstly, Bartlett (1948) maintained that the beginnings of skill are found in the simple, graded response. According to Bartlett, graded

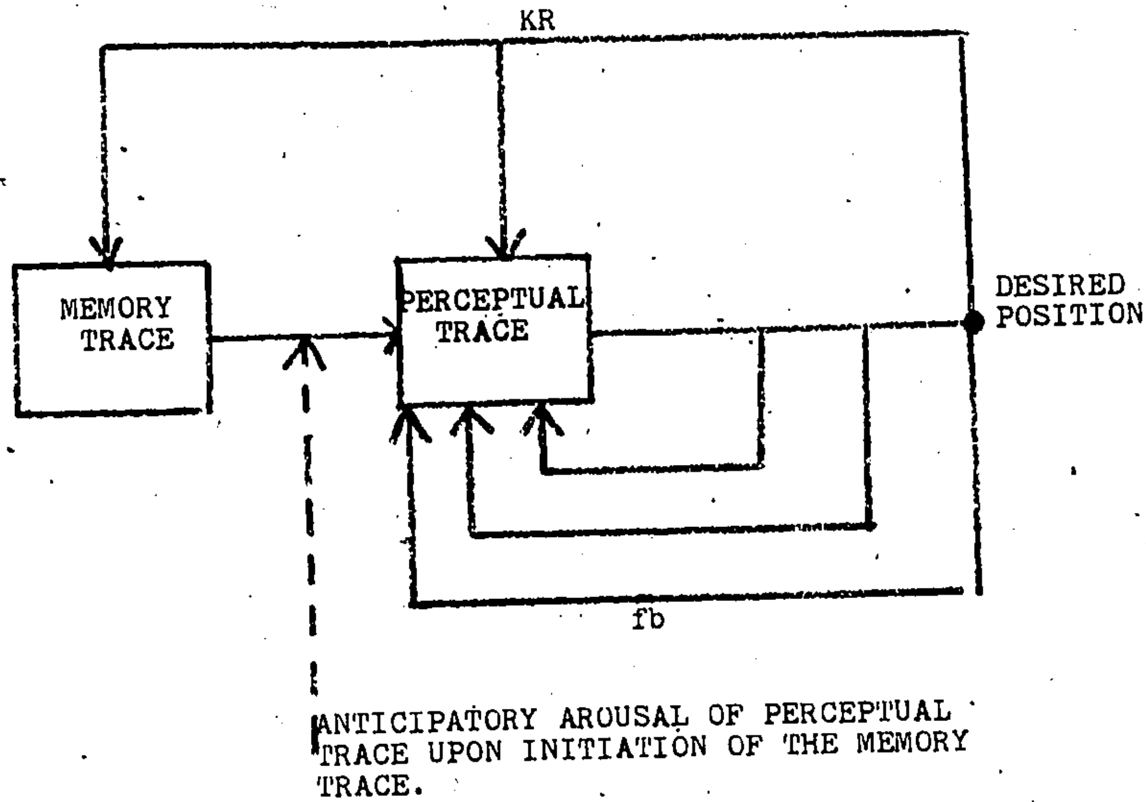

Figure 1 Adams', (1971) Closed Loop Model of Motor Learning

movements are a part of virtually all skills and the sensory fb that control it. Secondly, in order to generalize to more complex skilled behaviour, it is necessary to initiate research with simple motor movements. Once an understanding of the very simple movement is complete, the basis for comprehending more complex forms of skilled performance will be laid down. Therefore, in order to keep the movement simple, Adams restricted it to a self-paced response, hence eliminating timing, which adds considerably to the complexity of a response. And lastly, a substantial body of literature already existed on the simple graded response, providing Adams with a great deal of data with which to work. Elaborating on the graded response since it is the frame of reference for Adams' model, it is a series of steps, which in succession produce the appearance of a slow, continuous movement under the control of sensory fb. These steps are affected by various conditions, such as the rate of application of the stimulus, duration of the stimulus and state of adaptation of the peripheral organs. (Bartlett, 1948). Operationally defined, in terms of the present thesis, the simple graded response is the learning of a six inch horizontal line and an angle of 120 degrees.

A Description of the Model

Adams' model of motor performance and learning postulates movement control through closed loop circuits. Crucial to the development, maintenance and improvement of skilled behaviour are knowledge of results (KR) and sensory fb. KR is information about proficiency in a problem solving situation, provided by an experimenter, instructor or coach. It is a function of error and can be of any precision. In the present thesis, quantitative KR was used, providing error information in terms of degrees for movement direction and 1/20 inch units for movement extent.

Sensory fb, on the other hand, is the stimulus consequences of a movement after it has begun. Sources of sensory fb include proprioception, tactual and pressure, as well as vision and audition. However, the most important source, in terms of Adams' model, is proprioception.

As stated earlier, Adams' model is proposed in explanation of the simple, self-paced, graded response. Since choice of direction and extent of movement are the two main properties of a simple self-paced response (Adams, 1971), Adams has postulated two independent functional traces in memory, which are responsible for each of these properties and ultimately for motor learning and performance.

The first is termed the memory trace, which is defined as a modest motor program that selects and initiates the response and its direction, preceding the use of the perceptual trace. (Adams 1971 and 1973). The memory trace must be cued to action, at which time it arouses the perceptual trace, associated with the desired position. It is essentially open loop in nature, operating without sensory fb, its strength growing as a function of KR and the amount of practice.

The second is termed the perceptual trace and it is the representations of the sensory consequences of past responses. It is the construct which is responsible for the extent of the movement and it is what the subject uses as a reference to adjust his next movement, on the basis of KR. Movement initiation by the memory trace, causes an anticipatory arousal of the perceptual trace and sensory fb from the ongoing response is compared to it. Rather than being one single state, the perceptual trace is a complex distribution of traces. On each trial, a new trace is laid down and the accumulation of old and new traces is the distribution.

In order for learning to occur, KR, as well as the perceptual trace for a particular response and sensory fb are essential. The subject must use KR to make his next response different from the previous one. Without KR, the subject is forced to repeat incorrect responses, since the perceptual trace laid down on the previous response was incorrect.

Early in learning, or what Adams calls the Verbal-Motor Stage when the error reported in KR is large, the distribution of perceptual traces is vague. In this stage, corrections are based on KR and verbal transforms of it. (Adams, 1971). The large errors observed early in learning undoubtedly result from comparing sensory fb to an uncertain variable reference. Performance in the Verbal-Motor Stage is on the conscious level. However, late in learning, when the error reported in KR has been consistently small for some time, the distribution of perceptual traces develops a sharply defined modal value. During this late phase of learning, which Adams calls the Motor Stage, the perceptual trace for the specified response is strong, since the correct response or a very close approximation of it, has been repeated a number of times. In the Motor Stage of motor learning, the subject moves until incoming sensory fb from the present movement has zero error when compared to the perceptual trace. KR, provided by the experimenter is now unnecessary, supplying redundant information to the subject, who can now learn on the basis of internally produced error information. This self-generated error information is derived from a comparison of sensory fb to the strong, well developed perceptual trace, a process which Adams calls subjective reinforcement. Performance has now become automated. In contrast to the memory trace, the perceptual trace is closed loop in nature, its strength growing as a function of KR, the quality and quantity of sensory fb and the amount of practice.

In summary, all adjustments of a self-paced motor response are based on a comparison of current sensory fb with the perceptual trace for the determination of error. When an error is detected through a mismatch between the two, the subject will attempt to bring the sensory fb in alignment with the perceptual trace until the error is zero.

It is extremely important to physical educators to know how motor skills are acquired, improved upon and maintained and to have an understanding of the mechanisms controlling skilled performance. If motor skills are under the control of a closed loop mechanism, such as the one advanced by Adams, which by nature is a function of sensory fb, then this knowledge offers guidelines in the teaching of motor skills. Under such circumstances in the early stages of learning, specific information should be given to the performer, simultaneous to or immediately following performance in order to aid the performer in the meaningful interpretation of his sensory fb. As learning progresses and performance becomes automated, these cues supplied by the teacher should become redundant, the performer now learning by means of self-generated error information. In contrast, if motor skills are controlled by an open loop mechanism, which by nature is carried out uninfluenced by sensory fb, simultaneous information about performance would be useless since the motor program must continue until completion. KR under these circumstances, would be of a different nature, since it would not aid in the meaningful interpretation of sensory fb. Hence, the present thesis which investigates Adams' closed loop model, which has been proposed as the superior explanation of movement control, hopes to shed light on the mechanisms controlling human performance.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

A review of the literature concerning the control of skilled performance indicates that sensory fb is important, hence favouring some type of closed loop monitoring. As mentioned previously, numerous studies have been conducted in the hopes of providing empirical evidence in support of either open loop control via a motor program or closed loop control via sensory fb. A review of the data concerning movement control through an open loop motor program, has revealed a decided lack of evidence that the motor program can assume <u>sole</u> control of skilled performance. (Lashley and McCarthy, 1926; Lashley and Ball, 1929; Wilson, 1961; Wilson and Gettrup, 1963; Wilson, 1964; Wilson, 1968; Chase <u>et</u> <u>al</u>., 1961; Laszlo, 1967a; Laszlo, 1967b). Although in all of these studies, motor performance was still possible after complete or partial removal of sensory fb, the fact that it was impaired indicates that sensory fb does indeed play a role in the control of skilled performance. Consequently, as Adams (1971) has proposed, closed loop theory is alternatively, the superior explanation of movement control. It is this closed loop model of motor learning, developed by Adams (1971) that is the topic of investigation of the present thesis. Empirical verification of this model and all of its ramifications is essential in the substantiation of a closed loop theory of movement control.

Considerable research has been done on two of the four components of Adams model, KR and fb, the elements giving the model its closed loop designation. The importance of these two variables in the control of skilled performance will briefly be discussed. Since research in the verbal domain has usually preceded its motor counterpart, a closed loop model of verbal learning and its implications for the motor realm will be considered, followed by an extensive review of the research already conducted on Adams' closed loop model.

The Importance of Sensory Fb

Recent empirical data make the importance of sensory fb in the control of skilled performance difficult to deny. Chase (1965, Part I) maintains that the most precise information which might be utilized to inform the nervous system about movement is expected to result from specialized proprioceptors in skeletal muscle or its attachment. Similarly, Pew (1973), when developing a hierarchy of different types of information in relation to a desired goal, placed KR at the base, with the exteroceptors, primarily vision and audition coming next, followed by the proprioceptors, followed at the highest level by efferent signals.

In support of the tremendous importance of sensory fb to movement control, are studies in which sensory fb has been either delayed, distorted, reduced or eliminated. Chase *et al*. (1961) distorted or delayed all sources of sensory fb, including proprioceptive, tactile, visual and auditory fb channels, both singly and in combination, during the performance of a tapping task. It was found that delayed sensory fb produced distorted performance in tapping. Moreover, it was observed that elimination of all four fb channels together produced no greater a performance decrement than distortion of proprioceptive fb alone. Consequently, Chase suggested that proprioception might be the most important source of fb for movement control in fast and rhythmical tapping.

Similarly, Laszlo (1967a) found that the reduction of proprioception alone caused a greater performance decrement than the reduction of exteroception in fast and rhythmical tapping and tracking skills. However, she noted that each task was affected to a different degree by the proprioceptive sense loss. Further evidence that loss of proprioceptive fb caused marked performance decrements was produced by Laszlo (1966 and 1968). While Laszlo (1967a) showed that loss of proprioception greatly impaired the ability to perform a familiar task, Laszlo (1968) demomstrated that loss of proprioception also impaired the performance of a novel task from the very beginning of training. Furthermore, she also refuted the previously held hypothesis that in the initial stages of learning a skill, exteroceptive cues are utilized predominantly, while during the later stages of skilled performance, proprioceptive cues assume paramount importance. Quite to the contrary subjects deprived of proprioceptive fb early in learning, showed markedly more impairment than subjects deprived of vision. (Laszlo, 1968). In addition, Laszlo and Bairstow (1971a) demonstrated that in the absence of sensory fb, error detection and error correction in a novel and accurate movement did not occur and consequently no improvement was possible. Moreover, not only did the loss of sensory fb result in decided performance decrements but it also produced a wide range of individual differences (Laszlo, 1967a; 1967b; 1968; Laszlo and Manning, 1970a).

Such strong empirical support of the importance of sensory fb in both the acquisition and maintenance of skilled performance lend considerable credence to movement control via a closed loop system.

The Importance of KR

Also of paramount importance in the control of skilled behaviour, along with sensory fb, is KR. The importance of KR in the acquisition and maintenance of skilled performance had its beginnings in Thorndike's Law of Effect. The Law of Effect states that what comes after a stimulus-response connection acts upon it to alter its strength. (Thorndike, 1927). To test his theory, Thorndike employed a line drawing task of 3, 4, 5, or 6 inches and qualitative KR of "Right" or "Wrong" was given, following each response. It was found that the satisfying stimulus-response connections i.e. the responses that were rewarded by the experimenter saying "Right" were strengthened and the percent of correct responses rose rapidly. In contrast, when no KR was given at all, no improvement was evidenced. This experiment provided crucial empirical evidence that the consequences of a stimulus-response connection work back upon it to influence its strength.

Since the early work of Thorndike, a considerable amount of data supporting the importance of KR in the acquisition and maintenance of skilled behaviour has accumulated. In an extensive review of this data Bilodeau (1969) made the comprehensive statement that learning depended upon the presence of KR and its absolute frequency. She further, elaborated that experiments manipulating KR, as an independent variable, repeatedly demonstrated the three following empirical effects: (1) performance failed to improve unless KR was introduced; (2) performance improved with KR; and (3) performance either deteriorated if KR was withdrawn or showed no further improvement.

Since it had been repeatedly demonstrated that performance did not improve unless KR was present (Thorndike, 1927; Trowbridge and Cason, 1932, Dyal, 1966) and the more precise the KR, the more rapid the improvement (Trowbridge and Cason, 1932) and the more superior the performance (Nuttin and Greenwald, 1968), KR came to be viewed as a stimulus for error correction. In support of this notion, Elwell and Grindley (1938) conducting research on KR in conjunction with different motor tasks, observed that man, unlike animals, did not repeat rewarded responses. Instead, he attempted to correct his errors on the basis of KR. Similarly, Nuttin and Greenwald (1968) concluded that KR, given after every attempt to draw a 7½ inch line was playing an error correcting role.

Furthermore, it was stated that as the amount of practice with KR was increased the amount of error progressively decreased, until an asymptotic minimal error score was achieved. (Bilodeau, 1969). In addition, sustained performance or what

Bilodeau (1969) called residual benefits were greater when KR was withdrawn, after greater amounts of practice with KR had been permitted.

However, the importance of KR in the acquisition and maintenance of skilled performance is even more apparent, when it is considered along with sensory fb. Both sensory fb and KR are essential for learning to occur. Neither a learning curve nor evidence of latent learning have been demonstrated when sensory fb was present, without KR (Bilodeau, 1969). In fact, Bilodeau (1969) suggested that learning could be viewed as the building of a scale relationship between sensory fb and KR. Experience with KR improved the subject's ability to use sensory fb by providing the information necessary to make the appropriate transformations, in the processing of sensory fb.

In another attempt to explain how KR was functional in the learning and performance of skilled behaviour, Dyal (1966) utilizing a line drawing task and manipulating immediate, delayed and no KR, in an acquisition and withdrawal paradigm, concluded like predecessors and contemporaries that performance did not improve unless KR was administered. However, he went on to state that the effect of KR on learning occurred via modification of the subject's reference mechanism toward the correct response, defined by KR. When KR was withdrawn, the subject was forced to rely upon his own reference mechanism. This reference mechanism, which had developed over trials, relied on KR in the early stages of learning. This information, which was essential to the task, could not be removed without a loss of efficiency. In a similar line of reasoning, earlier research on KR by Annett and Kay (1957) led them to suggest that if the training process was so arranged that KR, which had helped the subject initially, later became redundant, then KR could be removed without any serious loss of efficiency.

In summary, the importance of KR in the acquisition and maintenance of skilled performance lies in its capacity to define the correct response so that it can be rehearsed. Consequently over trials, KR assumes an error correcting role. Since error correction is one of the essential components of a closed loop system, the importance of KR to a closed loop system of movement control is undeniable.

A Closed Loop Model of Verbal Learning

Since Adams' (1971) closed loop model of motor learning was born of a verbal mother, a description of the essentials of this closed loop model of verbal learning seems appropriate. Employing a paired associate learning situation, Adams and Bray (1970) made the crucial conclusion that recall and recognition of verbal materials were based on two functional traces in memory, rather than one. It was observed that it was one thing to recall a response and quite another to recognize it. Since responses could often be recognized but not recalled, recognition was considered to be the more sensitive of the two measures. The memory trace was thought to be responsible for recall, while the perceptual trace was thought to be responsible for recognition. The memory and perceptual traces in motor memory are analogous to the traces allowing recall and recognition, respectively in verbal memory.

It was also found that subjects were able to distinguish correct from incorrect responses. Adams and Bray suggested that external stimuli laid down a perceptual trace and the sensory fb from the verbal response, proprioceptive, tactual and auditory in nature, were compared to this perceptual trace. If a feeling of familiarity was evoked, the subject reported that he recognized the response. Verification of response recognition in this manner was thought to be determined by sensory fb factors, including intensity, the number of fb loops and the similarity of the response to the correct one. As the continual matching process between current sensory fb and the perceptual trace produced progressively smaller discrepancies, a feeling of familiarity developed and not surprisingly, the subject's confidence in the correctness of his response also increased considerably. As this correct response was rehearsed, it was assumed that its perceptual trace strengthened and began to operate as an internal reference about the correctness of the response. At this point, KR could be withdrawn and continued learning via subjective reinforcement evidenced.

Adams (1971) by his own admission, has transposed some of the essentials of a closed loop theory of verbal learning (Adams and Bray, 1970) to the motor domain. Of paramount interest to the present thesis is whether the independent functional traces, allowing recall and recognition in verbal memory remain functionally independent in motor memory.

Empirical Verification of Adams' Closed Loop Model

The most important aspect of Adams' model is the postulation that the memory and perceptual traces are independent functional traces. Any additional hypotheses derived from the model rest necessarily on this crucial assumption. Amazingly enough, this critical assumption has never been empirically substantiated with reference to the slow, self-paced graded response. Failing to first verify the very basis of the model, researchers have proceeded blithely onwards, providing avenues of empirical support for other predictions of Adams' model.

Adams, Goetz and Marshall (1972), using a 10 inch linear displacement task, found that the amount of practice and the amount of fb influenced motor performance. Manipulating visual, auditory and proprioceptive fb in high or low amounts, they found that in acquisition the more fb permitted, the more accurate the performance. Moreover, during KR withdrawal trials, when the fb in acquisition and the fb during KR withdrawal were the same, it was noticed that performance was more accurate with augmented than with minimal fb. Both these observations support the prediction from Adams' model that the strength of the perceptual trace is a function of the amount of sensory fb. Furthermore, it was found that performance during acquisition and during KR withdrawal trials, when fb was unchanged, was positively related to the amount of practice during acquisition, substantiating the prediction that the perceptual trace strengthens as experience with sensory fb increases. Performance was worse, during KR withdrawal trials when the conditions of fb were changed due to an incompatibility between current sensory fb and the already existing perceptual trace. Performance was also worse during KR withdrawal trials, when only small amounts of sensory fb were available, since the perceptual trace that had formed was weak.

Similarly, Marteniuk and Roy (1973), using a timed 32 inch linear displacement task, found that there were significant increases in constant and variable error,[1] when fb was changed. The increase in both constant and variable error indicated that changes in sensory fb caused subjects to become less accurate in achieving the desired position and more inconsistent or less precise in their efforts to do so.

Adams, Marshall and Goetz (1972) went on to investigate the effects of fb elimination on forgetting. It was observed that attenuation of the visual, auditory and proprioceptive fb channels caused a significant loss of retention. Minimal fb produced a weak trace which was not resistant to decay over a retention interval.

Similarly, Burwitz (1972), employing an 8 inch linear lever positioning task, observed that impoverished fb produced a weak perceptual trace compared to the one produced when the visual and auditory channels were intact and proprioceptive fb was heightened. Since the subject's ability to

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1. In the present thesis, consistent with signal detection theory, constant error will be used as an indicator of the accuracy of the established criterion level for error detection and variable error will be used as an indicator of the sensitivity of the error detection mechanism at the established criterion level. In contrast, absolute error will be used as an indicator of the accuracy of the memory and perceptual trace, using the adopted criterion level while average deviation will be used as an indicator of the precision and hence the strength of the memory and perceptual traces. Hence CE and VE will be measures of the signal detection, amplification and error correction processes, while AE and AV will be meausres of the state of the memory and perceptual traces.

accurately estimate his own performance was significantly impaired in the impoverished fb condition, the strength of the perceptual trace was assumed to be weak. The weak trace was difficult to rehearse and consequently was susceptible to forgetting.

Despite the fact that the previous studies were all able to provide some measure of empirical support for Adams closed loop model, Adams (1972) himself was only very weakly able to verify his own model. In a 2 x 2 factorial design, in which augmented and minimal sensory fb and 2 or 10 practice trials were the independent variables manipulated, it was found that subjects required to learn 8 criterion movements, ranging from 3.9 to 10.9 inches and to repeat these movements in a test phase, were accurately able to detect their errors. However, both the practice and fb variables failed to reach significance, forcing Adams to conclude that neither fb nor practice played a role in error detection. In a sequel experiment, Adams (1972) discovered that subjects were definitely able to correct errors. While the fb variable was again insignificant, indicating that fb did not play a role in error correction, the practice variable was significant, suggesting that practice did play a role in error correction. Nevertheless, the data still failed to support Adams' primary assumption that the strength of the perceptual trace is a function of the amount of fb and the amount of practice.

Commenting on Adams (1971) closed loop model, Schmidt (1972) hypothesized that empirical validation of the model was difficult because the roles of the memory and perceptual trace were confounded in the self-paced response. Since the memory trace's sole function was the selection and initiation of a response with control then shifting to the perceptual trace, the independent functioning of the two traces seemed impossible. Moreover, Schmidt also maintained that error detection was infeasible. He reasoned that if the subject was using his perceptual-trace as the basis for positioning, according to the model, he would then move to that position for which he received a match between the trace and sensory fb. Upon being questioned about the magnitude of his error, theoretically the subject should say that he has not made an error, since he moved to that position that the perceptual trace and sensory fb deemed correct. Therefore, error detection did not seem possible.

As a solution, Schmidt proposed that the slow self-paced graded response be replaced by a ballistic response. In such a response, the memory trace would produce the response and the perceptual trace would evaluate its correctness after the response was over. Since the two traces would have two unique functions, Adams' processes of error detection and correction could now be realized. Within-subject correlations between objective (actual) and subjective (judged) errors, indicated that when the slow self-paced graded response was used, the mean correlation was approximately .2, suggesting that the subject did not have a very clear idea of his own error state. Conversely, when a ballistic response was employed the mean within-subject correlation soared as high as .9. This high correlation indicated to Schmidt that, in a ballistic response, subjects had a better idea of their own error state.

Consequently, several investigators have taken Adams' model out of its original frame of reference and have tested it, using the ballistic response. Crucial to closed loop theory and the ballistic response was Schmidt and White's (1972) study, in which it was concluded that all of the predictions from Adams' model and ballistic responses were supported. Given 170 trials, 10 subjects were required to move a slider 9.5 inches in exactly 150 msec. KR was withdrawn during trials 11 - 20 and 141 - 170 in experiment one and after trial 2 in experiment two. It was reported that in early practice, i.e. after only 2 trials, KR withdrawal produced a marked performance decrement. When KR was withdrawn late in practice, performance was maintained and a slight trend for learning was evidenced. Moreover, as practice continued, not only did the discrepancy between the subject's actual errors and his estimation of those errors decrease, but also his confidence in the correctness of his estimations increased, indicating the development of a strong perceptual trace.

In an extension of Schmidt and White's (1972) research Schmidt and Wrisberg (1972) attempted to substantiate the crucial assumption that the memory and perceptual traces were indeed two independent functional traces. A secondary purpose was to provide further evidence that the error detection mechanism depended upon the quality of sensory fb in acquisition. Utilizing essentially the same ballistic task as Schmidt and White (1972), 52 subjects were required to move a slide leftward through a distance of 26 inches in 200 msec. In an attempt to verify that each trace was functionally independent the effects of KR withdrawal, both early and late in practice, on the behavioural indice of each trace were observed. The measure of the strength of the memory trace, whose role in a ballistic movement is response production, was absolute error i.e. the absolute value of the difference between the objective time and 200 msec. The measure of the strength of the perceptual trace, whose role is response evaluation, was the within-subject correlation between the objective and subjective times. Support for the functional independence of the memory and perceptual trace was obtained, when it was shown that KR withdrawal produced marked decrements in the absolute accuracy of responding, while it had no reliable effects on the objective-subjective correlation. However, only partial support of the prediction that the error detection mechanism developed as a function of the quality of sensory fb was procured. The subjective-objective correlations for subjects denied vision and audition were not significantly different from those correlations of subjects who could both see and hear. Nevertheless, it was reported that when KR was withdrawn, subjects with the standard fb maintained performance significantly better than subjects with the limited fb. Schmidt and Wrisberg (1972) concluded that greater amounts of sensory fb, in the absence of KR, contributed to the development of a more sharply defined perceptual trace.

Development of the Problem

Despite the fact that Schmidt and Wrisberg (1972) have demonstrated that the memory and perceptual traces are independent memory functions, their conclusion was made with reference to the ballistic response. Since Adams proposed his model in explanation of the simple self-paced graded response, the memory and perceptual traces must be empirically verified as independent functional traces within this frame of reference before the model can be proposed in explanation of more complex motor tasks. Moreover, Adams (1971) emphatically defined the memory trace as a modest motor program that only chooses and initiates the response and its direction, rather than controlling a longer sequence. Consequently, Schmidt and White (1972) and Schmidt and Wrisberg (1972) as well as all other investigators employing a ballistic response, in which the memory trace executes or controls the movement sequence, have provided little in the way of additional information about the validity of Adams' closed loop model, as originally presented.

Furthermore, while several closed loop theorists, especially of Soviet origin, suggest that movement control may be actualized through the operation of only one neural mechanism, Adams (1971) cites three reasons, why another independent mechanism, namely a memory trace, is essential for movement control. First and foremost,

> "if the agent that fires the response also is the reference against which the response is tested for correctness, the response must necessarily be judged correct because it is compared against itself. Response activation and evaluation require independent mechanisms" (Adams, 1971, p.126).

Secondly, since control of the response is permitted through a comparison of fb to a reference mechanism, some other mechanism is required to fire the response in the first place. And lastly, evidence from a verbal study, (Adams and Bray, 1970) has demonstrated that recall and recognition of verbal responses are based on two independent traces rather than one, recall being associated with response production and recognition being associated with stimulus and response identification.

> "The starting of the movement is motor recall and it is based on the memory trace. Knowing whether the movement is proceeding correctly or not is a matter of response recognition and the perceptual trace along with ongoing fb govern it." (Adams, 1971, p.126)

The Problem

A further investigation into the functional independence of Adams' memory and perceptual traces is essential. Therefore, the purpose of the present thesis was to determine whether the memory and perceptual traces are indeed independent memory functions. The frame of reference was the slow self-paced graded response, the same frame of reference for which the model had originally been proposed. Since the postulation that the two traces are functionally independent is the most important aspect of Adams' model and any additional predictions derived from the model rest necessarily on this crucial assumption, this investigation is of immediate importance. Rather than being the next logical step in a succession of research, this study should have been the first step.

Hypotheses

Separate hypotheses were formulated concerning accuracy, precision, direction and extent, direction and extent being the behavioural responses of the memory and perceptual traces respectively. Although signal detection concepts were used to interpret two of the four dependent error scores used, the hypotheses were stated in terms of absolute error, which was the measure of the accuracy of the memory and perceptual trace and average deviation, which was the measure of the precision and thus the strength of the memory and perceptual trace.

In summary AE and AV described the actual state of the memory and perceptual traces. Since KR was the independent variable expected to cause different effects upon the behavioural indice of each trace, the hypotheses were presented in terms of the appropriate KR paradigm, first for the memory trace and then for the perceptual trace.

All hypotheses concerning practice without KR (hypotheses one to six for the memory trace and nineteen to twenty-four for the perceptual trace) were formulated from several studies, investigating reinforcement and learning. (Thorndike 1927; Trowbridge and Cason, 1932; Dyal, 1966; Bilodeau, 1969). These studies concluded that performance failed to improve unless KR was introduced. Furthermore, Adams (1971) stated that in order for learning to occur, the subject must use KR to make his next response different from his previous one. In three conditions of the present experiment, since KR is not available, the subject lacks the necessary information to form either a correct memory trace or a correct perceptual trace for the required movement. Hence neither the accuracy (AE) nor the precision (AV) of the memory or perceptual trace can improve.

All hypotheses involving early KR withdrawal and the memory trace (hypotheses seven to twelve) originated mainly from Adams' (1971) closed loop model but indirect derivations from research conducted on Adams' model were also present. According to Adams, the direction of a response is the responsibility of the memory trace and the memory trace unlike the perceptual trace is not a function of sensory fb. Therefore, withdrawal of KR should cause decrements in both the accuracy and the precision of direction performance since the only source of error information for error correction to the trace has been removed. Moreover, Adams (1971) maintained that the withdrawal of KR produces deterioration of performance when the level of training is low or moderate. Similarly, Schmidt and White (1972) and Schmidt and Wrisberg (1972) showed that early KR withdrawal produced a severe deterioration in ballistic performance.

The hypotheses concerning late KR withdrawal and the memory trace (hypotheses thirteen to eighteen) were derived directly from Adams' model. Adams (1971) stated that after a relatively large amount of training, learning can continue when KR is withdrawn, by means of subjective reinforcement. However, according to Adams (1971 and 1973) the memory trace is not a function of sensory fb. As a result, continued learning, when KR is withdrawn cannot be expected. Therefore, the accuracy and precision of direction performance is expected to stabilize during late KR withdrawal, being maintained by a strong memory trace, which has developed as a function of practice with precise KR.

The hypotheses involving early KR withdrawal and the perceptual trace (hypotheses twenty-five to thirty-one) originated directly from Adams' model, as well as from research conducted on Adams' model. Adams (1971) maintained that KR withdrawal produces deterioration of performance when the level of training is low or moderate. This belief was also corroborated by Schmidt and White (1972) and Schmidt and Wrisberg (1972). Schmidt and Wrisberg (1972) also found that, during early KR withdrawal, subjects with limited sensory fb demonstrated an immediate and pronounced decrement, while subjects with standard fb produced a decrement that emerged over trials, but never became as large as that shown by subjects with limited fb. The extensive review of the research on KR by Bilodeau (1969) also aided in the formulation of the hypotheses concerning extent performance. In her summary, she cited evidence that both sensory fb and KR were essential for learning to occur. Since, subjects had had a very limited time with which to practice with KR before it was withdrawn early in learning, they lacked the necessary experience with KR by which to improve their ability to use sensory fb. Consequently, decrements in both the accuracy and precision of extent performance were expected.

The hypotheses concerning late KR withdrawal and the perceptual trace (hypotheses thirty-two to thirty-eight) were also derived from both Adams' model itself and research conducted on the model. Adams (1971) stated that learning could continue, when KR was withdrawn, through subjective reinforcement. However, in order for this process to occur, the perceptual trace must be a strong approximation of the correct response. Both Schmidt and White (1972) and Schmidt and Wrisberg (1972) empirically verified that subjects developed a strong perceptual trace over trials. In both these studies, sensory fb was available in the interresponse interval. However, in several other studies in which sensory fb was attenuated, it was found that impoverished sensory fb produced a weak perceptual trace, which was difficult to rehearse. (Adams, Marshall and Goetz, 1972; Burwitz, 1972). This weak perceptual trace led to performance deterioration on KR withdrawal trials. (Adams, Goetz and Marshall, 1972). Consequently, in the present thesis, it was expected that the group lacking sensory fb should deteriorate in both the accuracy and precision of their line drawing performance. However, Schmidt and White (1972) demonstrated that during late KR withdrawal, when sensory fb was present, continued learning occurred. Since the perceptual trace was said to be a function of sensory fb (Adams, 1971), then it was expected that augmented sensory fb would enhance the development of a stronger perceptual trace, enabling the subjective reinforcement process to be more accurate. Hence, greater improvements in both the accuracy and precision of line drawing performance was expected from subjects, with heightened sensory fb, in comparison to subjects with normal sensory fb.

State of the Memory Trace for the Recall of the Direction of a Movement

No Knowledge of Results

Distorted Feedback

Hypothesis One:

Practice without KR will cause no change in accuracy for direction performance, when sensory fb is distorted.

Hypothesis Two:

Practice without KR will cause no change in precision for direction performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Three:

Practice without KR will cause no change in accuracy for direction performance, when sensory fb is normal.

Hypothesis Four:

Practice without KR will cause no change in precision for direction performance, when sensory fb is normal.

Heightened Feedback

Hypothesis Five:

Practice without KR will cause no change in accuracy for direction performance, when sensory fb is heightened.

Hypothesis Six:

Practice without KR will cause no change in precision for direction performance, when sensory fb is heightened.

Early Knowledge of Results Withdrawal

Distorted Feedback

Hypothesis Seven:

Early KR withdrawal will cause a decrement in accuracy for direction performance, when sensory fb is distorted.

Hypothesis Eight:

Early KR withdrawal will cause a decrement in precision for direction performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Nine:

Early KR withdrawal will cause a decrement in accuracy for direction performance, when sensory fb is normal.

Hypothesis Ten:

Early KR withdrawal will cause a decrement in precision for direction performance, when sensory fb is normal.

Heightened Feedback

Hypothesis Eleven:

Early KR withdrawal will cause a decrement in accuracy for direction performance, when sensory fb is heightened.

Hypothesis Twelve:

Early KR withdrawal will cause a decrement in precision for direction performance, when sensory fb is heightened.

Late Knowledge of Results Withdrawal

Distorted Feedback

Hypothesis Thirteen:

Late KR withdrawal will result in a stabilization in accuracy for direction performance, when sensory fb is distorted.

Hypothesis Fourteen:

Late KR withdrawal will result in a stabilization in precision for direction performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Fifteen:

Late KR withdrawal will result in a stabilization in accuracy for direction performance, when sensory fb is normal.

Hypothesis Sixteen:

Late KR withdrawal will result in a stabilization in precision for direction performance, when sensory fb is normal.

Heightened Feedback

Hypothesis Seventeen:

Late KR withdrawal will result in a stabilization in accuracy for direction performance, when sensory fb is heightened.

Hypothesis Eighteen:

Late KR withdrawal will result in a stabilization in precision for direction performance, when sensory fb is heightened.

State of the Perceptual Trace for the Recognition of the Extent of a Movement

No Knowledge of Results

Distorted Feedback

Hypothesis Nineteen:

Practice without KR will cause no change in accuracy for extent performance, when sensory fb is distorted.

Hypothesis Twenty:

Practice without KR will cause no change in precision for extent performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Twenty-One:

Practice without KR will cause no change in accuracy for extent performance, when sensory fb is normal.

Hypothesis Twenty-Two:

Practice without KR will cause no change in precision for extent performance, when sensory fb is normal.

Heightened Feedback

Hypothesis Twenty-Three:

Practice without KR will cause no change in accuracy for extent performance, when sensory fb is heightened.

Hypothesis Twenty-Four:

Practice without KR will cause no change in precision for extent performance, when sensory fb is heightened.

Early Knowledge of Results Withdrawal

Distorted Feedback

Hypothesis Twenty-Five:

Early KR withdrawal will cause a decrement in accuracy for extent performance, when sensory fb is distorted.

Hypothesis Twenty-Six:

Early KR withdrawal will cause a decrement in precision for extent performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Twenty-Seven:

Early KR withdrawal will cause a decrement in accuracy for extent performance, when sensory fb is normal.

Hypothesis Twenty-Eight:

Early KR withdrawal will cause a decrement in precision for extent performance when sensory fb is normal.

Heightened Feedback

Hypothesis Twenty-Nine:

Early KR withdrawal will cause a decrement in accuracy for extent performance, when sensory fb is heightened.

Hypothesis Thirty:

Early KR withdrawal will cause a decrement in precision for extent performance, when sensory fb is heightened.

Hypothesis Thirty-One:

The group with distorted sensory fb will exhibit the largest decrements in both accuracy and precision for extent performance, with the group receiving normal sensory fb exhibiting a smaller decrement and the group receiving heightened sensory fb exhibiting the smallest decrement.

Late Knowledge of Results Withdrawal

Distorted Feedback

Hypothesis Thirty-Two:

Late KR withdrawal will cause a decrement in accuracy for extent performance, when sensory fb is distorted.

Hypothesis Thirty-Three:

Late KR withdrawal will cause a decrement in precision for extent performance, when sensory fb is distorted.

Normal Feedback

Hypothesis Thirty-Four:

Late KR withdrawal will cause an improvement in accuracy for extent performance, when sensory fb is normal.

Hypothesis Thirty-Five:

Late KR withdrawal will cause an improvement in precision for extent performance, when sensory fb is normal.

Heightened Feedback

Hypothesis Thirty-Six:

Late KR withdrawal will cause an improvement in accuracy for extent performance, when sensory fb is heightened.

Hypothesis Thirty-Seven:

Late KR withdrawal will cause an improvement in precision for extent performance, when sensory fb is heightened.

Hypothesis Thirty-Eight:

The group receiving heightened sensory fb will exhibit a larger improvement in both accuracy and precision for extent performance than the group receiving normal sensory fb.

CHAPTER THREE

METHODOLOGY

Sample

Seventy-two student volunteers from the University of Windsor were used, with the restrictions that all subjects were right-handed and that there were an equal number of male and female subjects per experimental cell. The average age was 22 years, 3 months with a standard deviation of 1 year, 8 months.

Independent Variables

Three factors were chosen as independent variables, KR, sensory fb and practice.

Three levels of KR were used, no KR, early KR withdrawal and late KR withdrawal. In the no KR condition, subjects were given no information whatsoever during the 100 trials, regarding their performance on the required task. In the early KR withdrawal condition, KR was given during trials 1-20, withdrawn during trials 21-45 and given again during trials 46-100. In the late KR withdrawal condition, KR was given during trials 1-75 and withdrawn during trials 76-100.

Three levels of sensory fb were manipulated. Since the other sources of sensory fb, namely vision and audition, were eliminated throughout the experiment, proprioceptive fb was the only source of sensory fb that was manipulated. The three levels consisted of distorted proprioceptive fb, normal proprioceptive fb and heightened proprioceptive fb. The third factor was practice and it consisted of 100 trials which were divided into twenty blocks of five trials each.

Experimental Design

The three levels of each of the first two independent variables were combined to produce nine experimental conditions. These nine experimental conditions were observed over the third factor, blocks, of which there were twenty. Each subject was tested under only one condition. Therefore, the experimental design was a three factor fixed constants model, with repeated measures, which was Winer's case II model. More specifically, the experimental design was a 3 x 3 x 20 factorial design with repeated measures on the last factor.

All subjects completed 100 trials, which were divided into the twenty blocks, described above, for statistical analyses.

Intervening Variables

Four intervening variables were used, connecting the actual error scores ($\overline{AE}$, and AV, $\overline{CE}$ and VE) to the two traces and their respective error detection mechanisms; (1) accuracy of the established criterion level of the error detection mechanism (a) for direction (b) for extent and; (2) sensitivity of the error detection mechanism to the established criterion level (a) for direction (b) for extent and (3) accuracy of the memory processes (a) accuracy of the memory trace for recall of the direction of movement, using the adopted criterion level (b) accuracy of the perceptual trace for recognition of the extent of movement, using the adopted criterion level; and (4) precision and hence strength of the memory processes (a) precision (strength) of the memory trace (b) precision (strength) of the perceptual trace.

Dependent Variables

Memory Trace:

Criterion Level and Sensitivity of the Error Detection Mechanism for the Direction of a Movement

(1a) Accuracy of the established criterion level of the error detection mechanism, which was determined by the subject's constant error (CE), was the signed difference in degrees between the angle drawn by the subject and the required 120 degree angle.

(2a) Sensitivity of the error detection mechanism at the established criterion level, which was determined by the subject's variable error (VE), was the variability of his error scores around his mean CE.

Both CE and VE scores were calculated for blocks of five trials. Therefore, one CE score and one VE score were mean error scores for five trials. $\overline{CE}$ and VE scores were calculated for twenty such blocks of trials.

State of the Memory Trace for the Recall of the Direction of a Movement

(3a) Accuracy of the memory trace, using the adopted criterion level, which was determined by the subject's absolute error (AE), was the absolute difference in degrees between the angle drawn by the subject and the required 120 degree angle.

(4a) Precision or strength of the memory trace at the adopted criterion level, which was determined by the subject's average deviation (AV), was the variability of his error scores around his mean AE.

Both AE and AV were calculated as mean error scores over the same twenty blocks of trials as described for CE and VE.

Perceptual Trace:

Criterion Level and Sensitivity of the Error Detection Mechanism for the Extent of a Movement

(1b) Accuracy of the established criterion level of the error detection mechanism, which was determined by the subject's CE, was the signed difference in 1/20 inch units between the line drawn by the subject and the required six inch line.

(2b) Sensitivity of the error detection mechanism at the established criterion level, which was determined by the subject's VE, was the variability of his error scores around his mean CE.

Both CE and VE scores were again calculated as mean error scores over the same twenty blocks of trials as described for the memory trace.

State of the Perceptual Trace for the Recognition of the Extent of a Movement

(3b) Accuracy of the perceptual trace, using the established criterion level, which was determined by the subject's AE, was the absolute difference in 1/20 inch units between the line drawn by the subject and the required six inch line.

(4b) Precision or strength of the perceptual trace at the adopted criterion level, which was determined by the subject's AV, was the variability of his error scores around his mean AE.

Both AE and AV scores were again calculated over the same twenty blocks as described above.

Apparatus

The apparatus consisted of a glass surface supported by a wooden frame. (Appendix A) Under the glass surface was a 40 watt electric light, which illuminated a twelve inch line marked off in 1/20 inch units on 20 x 20 square graph paper. An 'L' shaped strip of plastic ¼ inch thick and fifteen inches long was fastened to the frame at each end and served the dual purpose of providing the subject with a permanently fixed straight edge along which to draw the required six inch horizontal line and a corner which designated the starting point. A roll of 3½ inch wide paper was attached to a roller on the left side of the frame and was inserted under the plastic boundary but over the marked graph paper and fed across the glass surface to another roller on the right side of the frame. This roller was equipped with a handle to facilitate easy movement of the paper once a trial had been completed and the error scores had been recorded. A 1/1000 second chronoscope was attached to the 'L' shaped plastic strip such that when the subject's pen left the starting point, it was activated and recorded the length of time the subject took to draw his estimation of the six inch line. As soon as the subject's pen left the straight edge, to move in a sideward direction of 120 degrees, the chronoscope was deactivated.

<u>Task</u>

Subjects were required to draw a six inch horizontal line along the fixed straight edge, immediately followed by an angle of 120 degrees in a sideward direction. (Figure 2) The entire movement was performed in one continuous motion. The subjects could perform the movement at their own speed, being advised that accuracy rather than speed was of the utmost importance.

<u>Testing Procedure</u>

Subjects were systematically rotated into one of the

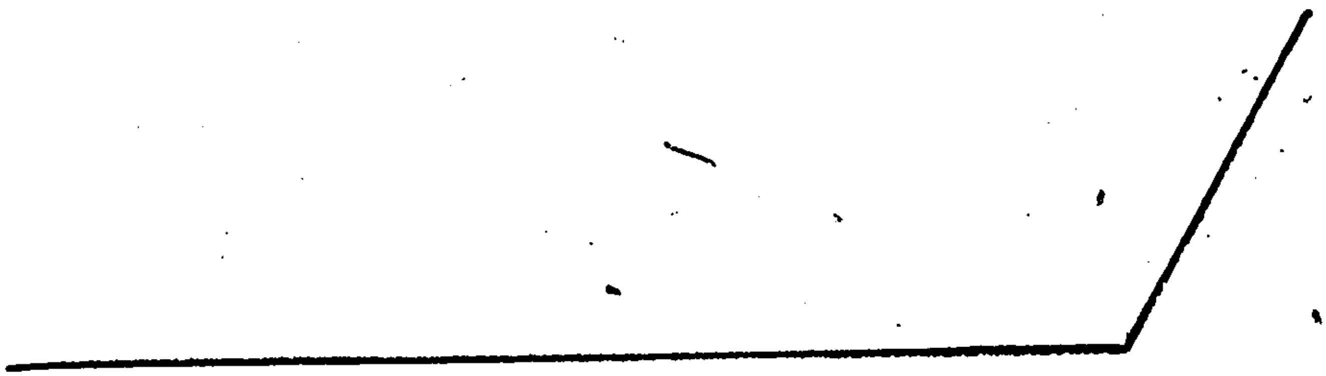


Figure 2 The Required Response

nine experimental conditions by means of a Greco-Latin square in order to counterbalance for order effects in the testing on the part of the experimenter, with the restriction that there were equal numbers of male and female subjects per cell. The same Greco-Latin square was used separately for both male and female subjects to ensure that there were an equal number of each per cell.

The apparatus was on a table with the subject seated in front of the table and the experimenter standing to the right of the subject. Appropriate instructions were read to each subject according to his experimental condition and vibrators were then strapped to the underside of the forearm just below and to the lateral side of the elbow and to the front of the shoulder over the axilla. These two Wahl electric massage vibrators, set at 60 cycles per second distorted incoming sensory fb. When heightened sensory fb was required, the subject used a pen fastened to a pulley system, with metal weights attached at the bottom. These weights provided a resistance of 1.1 pounds. Vision and hearing were also eliminated at this time by means of a blindfold and noise respectively. The noise for blocking auditory fb was set at the 80 decibel level at 750 cycles per second with a masking frequency of 50 cycles per second. It was delivered to the subject's headset from a Beltone audiometer.

The cue for the start of a trial was the onset of noise. The noise served as the signal for the subject to place his pen at the starting point and begin his response. Following completion of the movement, the experimenter switched off the noise and the vibrators. KR in degrees and 1/20 inch units were then provided by the experimenter, according to the experimental condition and error scores for direction and extent were recorded as well as the time score. The vibrators were switched back on, for those subjects in the three experimental conditions in which sensory fb was being distorted. Five seconds later, the noise was again resumed, signalling the subject to begin the next trial. 100 trials were completed in this manner.

Treatment of the Results

1. Although direct support of the experimental hypotheses would not be achieved by a three factor analysis of variance with repeated measures on the last factor, 3 x 3 x 20 analyses of variance were computed in order to determine the effects of KR and sensory fb on the criterion level and sensitivity of the error detection mechanism and the state of the memory and perceptual trace over the entire twenty blocks of trials.

2. Single factor analyses of variance with repeated measures

were computed separately over blocks 1-20 for each of the three sensory fb groups, practicing without KR, to determine if learning had occurred.

3. Two factor analyses of variance with repeated measures on blocks were computed over blocks 5-9 for the three sensory fb groups, who had had KR withdrawn early in learning, to determine the effects of early KR withdrawal.

4. Two factor analyses of variance with repeated measures on blocks were computed over blocks 16-20, for the three sensory fb groups, who had had KR withdrawn late in learning, to determine the effects of late KR withdrawal.

5. Tukey (a) tests were calculated for all significant main effects.

6. Graphs were drawn for all significant main effects.

7. Correlations between actual performance (AP) for extent and the mean movement time for each block of trials were computed over the twenty blocks to determine whether subjects were timing their response or moving to a match between incoming sensory fb and the developing perceptual trace.

8. (a) The $\alpha = .001$ level of confidence was accepted for all experimental hypotheses, expecting no significant differences.

(b) The $\alpha = .05$ level of confidence was accepted for all other experimental hypotheses, as well as for all the results pertaining to the criterion level and sensitivity of the error detection mechanism.

CHAPTER FOUR

RESULTS

Adams'model has been proposed in explanation of the simple self-paced graded response. Briefly recapitulating, since choice of direction and extent of movement are the two main properties of a simple self-paced response, Adams has postulated two independent functional traces in memory, which are responsible for each of these properties. In his closed loop model, Adams stated that the memory trace selects and initiates the motor response and its direction, while the perceptual trace is responsible for the extent of the movement. The perceptual trace is a function of both KR and sensory fb, while the memory trace is only a function of KR.

In the present thesis, the required task, the drawing of a six inch horizontal line followed immediately by moving at a 120 degree angle in a sideward direction, contained both properties of a simple self-paced response. According to Adams' model, the memory trace is responsible for the movement in a 120 degree direction and the perceptual trace controls the extent of the six inch line. Hence, the effects of KR withdrawal, both early and late in practice, on the two behavioural indices of each trace ($\overline{AE}$ and AV) and on the two behavioural indices of each error detection mechanism ($\overline{CE}$ and VE) were observed in an attempt to substantiate the functional independence of the two traces. However, before this could be done, the effects of practice without KR on the four behavioural indices were observed in order to provide support, using the present data, for the previously established phenomenon that performance failed to improve unless KR was introduced. In the present thesis, the fact that learning could not occur in the absence of KR was a necessary antecedent to the expected effects of early and late KR withdrawal on the memory and perceptual trace.

Since Adams' model is by nature closed loop, the accuracy and strength of the perceptual trace may be considered to be the result of some internal servo mechanism. A servo mechanism, after the desired response has been specified, by definition, consists of three basic functional components: an error detector, an amplifier and an error corrector. Consequently, it was considered that the most meaningful interpretation of the data would be obtained through the use of signal detection concepts.

Two different distributions of error scores described the data. The CE, VE distribution were indicators of the signal detection, amplification and error correction processes. More specifically, $\overline{CE}$ was a measure of the accuracy of the established criterion level for error detection, in both the 120 degree angle and the six inch line. VE was a measure of the sensitivity of the error detection and correction mechanisms, at the adopted criterion level.

In contrast, the AE, AV distribution described the actual state of both the memory and perceptual traces. In this distribution, $\overline{AE}$ represented the accuracy of both the memory and perceptual traces, using the adopted criterion level. AV, on the other hand, indicated the precision and hence the strength of both the memory and perceptual traces, using the adopted criterion level.

Due to the dual nature of the interpretation chosen, the results were presented separately in terms of the criterion level of the error detection mechanism and its sensitivity and the actual error state of the two respective traces.

Memory Trace

Criterion Level and Sensitivity of the Error Detection Mechanism for Direction of Movement

All analyses, computed on data for the error detection mechanism, were used to remain consistent with the analyses of the data under the same experimental conditions for the state of the memory and perceptual traces.

No Knowledge of Results

All analyses, in this section, were separate single factor analyses of variance with repeated measures over the twenty blocks of five trials, on $\overline{CE}$ and VE.

Distorted Feedback

A significant change in the criterion level for detecting errors in the required movement in a 120 degree direction was observed. (Table 1) Inspection of Figure 3 indicated that initially the 120 degree angle was overshot, with the criterion level for error detection then passing through a perfect level of detection and then changing to undershooting after block 5. It was this shift in the adopted criterion level, from positive to negative, that caused the significant blocks effect, rather than an improvement in the error detection processes. Analysis of

TABLE 1

F RATIOS OF THE STATE OF THE ERROR DETECTION MECHANISM FOR DIRECTION OVER TWENTY BLOCKS FOR GROUPS RECEIVING NO KNOWLEDGE OF RESULTS

Location of ANOVA Tables		Distorted Fb	Normal Fb	Heightened Fb
Appendix C Tables 19, 23, 27	$\overline{CE}$	3.29*	1.24	21.33*
Appendix C Tables 20, 24, 28	VE	1.05	0.62	0.93

* significant at the .05 level

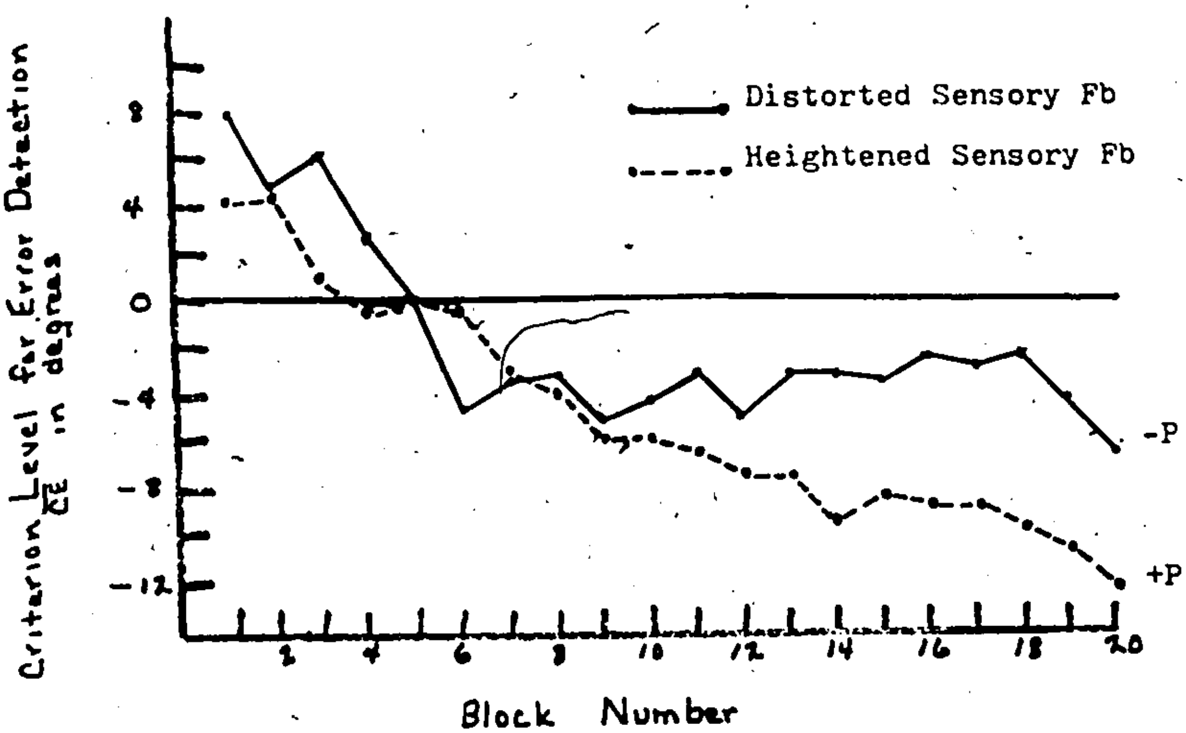


Figure 3 Criterion Level for Error Detection for the Direction of Movement for the Distorted and Heightened Fb Groups Receiving No Knowledge of Results

variance on VE revealed no change in the sensitivity of the error detection mechanism at the adopted criterion level, over the twenty blocks of trials. (Table 1)

Normal Feedback

Analyses of variance on $\overline{CE}$ and VE indicated that neither the accuracy of the subjects' established criterion level for error detection nor the mechanism's sensitivity to error signals at that criterion level changed significantly over the twenty blocks of trials. (Table 1)

Heightened Feedback

Analysis of variance on $\overline{CE}$ revealed a significant change in the subjects' criterion level for detecting errors. (Table 1) Inspection of Figure 3 revealed the same trend observed under conditions of distorted fb. The shift in the adopted criterion level for error detection caused the significant blocks effect, rather than an improvement in the accuracy of the criterion level. Analysis of variance on VE failed to reach significance, demonstrating that the sensitivity of the error detection mechanism at the adopted criterion level did not change over the twenty blocks of trials.

Early Knowledge of Results Withdrawal

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{CE}$ and VE in the early KR withdrawal condition.

KR was given during blocks 1-4 (trials 1-20) and then withdrawn during blocks 5-9 (trials 21-45). The insignificant main effect for blocks, for both $\overline{CE}$ and VE, indicated that neither the accuracy of the criterion level for detecting errors in a movement in a direction of 120 degrees, nor the error detection mechanism's sensitivity at the adopted criterion level deteriorated when KR was withdrawn early in learning. (Table 2)

The insignificant main effect for sensory fb for $\overline{CE}$ demonstrated that there were no differences in the accuracy of the established criterion level for error detection between groups differing in sensory fb. (Table 2) The main effect for sensory fb was also insignificant for VE, showing that the sensitivity of the error detection mechanism at the adopted criterion level was not influenced by sensory fb. (Table 2) However, a significant fb x blocks interaction for VE indicated that the effects of sensory fb on the sensitivity of the error detection mechanism changed over the five blocks of trials, during which KR was withdrawn. (Table 2)

TABLE 2

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE ERROR DETECTION MECHANISM FOR DIRECTION OVER FIVE BLOCKS FOR GROUPS DURING EARLY KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 31	$\overline{CE}$	0.73	1.65	1.08
Appendix C Table 32	VE	3.09+	0.67	2.22*

* significant at the .05 level
\+ significant at the .07 level

Late Knowledge of Results Withdrawal

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were also calculated for $\overline{CE}$ and VE in the late KR withdrawal condition.

KR was given during blocks 1-15 (trials 1-75) and withdrawn during blocks 16-20 (trials 76-100). Insignificant main effects for blocks for both $\overline{CE}$ and VE demonstrated that neither the accuracy of the established criterion level for detecting errors in a movement in a 120 degree direction nor the sensitivity of the error detection mechanism to the adopted criterion level changed when KR was withdrawn late in learning. (Table 3)

An insignificant fb effect for $\overline{CE}$ indicated that, similar to groups during early KR withdrawal, there were no differences in the accuracy of the established criterion level for error detection, between groups differing in sensory fb. The fb x blocks interaction for $\overline{CE}$, too, was insignificant, revealing no change in the fb effect over the five blocks of trials. (Table 3) However, despite no differences in the accuracy of the error detection mechanism as a function of sensory fb, a significant main effect for sensory fb for VE showed that the sensitivity of the error detection mechanism to the established criterion level was indeed a function of sensory fb. Secondary analyses by means of a Tukey (a) Test indicated that the sensitivity of the error detection mechanism of both the distorted and heightened sensory fb groups differed from that of the group receiving normal fb. (Table 3) The sensitivity of the error detection

TABLE 3

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE ERROR DETECTION MECHANISM FOR DIRECTION OVER FIVE BLOCKS FOR GROUPS DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 35	$\overline{CE}$	0.43	0.68	0.56
Appendix C Table 36	VE	3.46*	0.75	0.83

* significant at the .05 level

DIFFERENCES BETWEEN THE THREE LEVELS OF SENSORY FEEDBACK FOR VARIABLE ERROR DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL "TUKEY (a) PROCEDURE"

TOTALS	a_2 (P)	a_1 (-P)	a_3 (+P)
(degrees)	115.52	173.47	175.68
115.52		57.95*	60.16*
173.47			2.21

mechanism at the adopted criterion level was significantly better for subjects receiving normal sensory fb. Nevertheless, the effects of fb on the sensitivity of the error detection mechanism remained constant over blocks, as indicated by the insignificant fb x blocks interaction for VE. (Table 3)

<u>Overall Analysis of Data Including All Levels of Knowledge of Results and All Levels of Sensory Feedback Over Twenty Blocks of Trials</u>

A 3 x 3 x 20 analysis of variance (KR x fb x blocks) with repeated measures on the last factor was computed for $\overline{CE}$ and VE in order to provide some additional insights into the criterion level and sensitivity of the error detection mechanism.

Significant main effects for blocks for $\overline{CE}$ and VE indicated that an improvement in both the accuracy of the established criterion level for detecting errors in a movement in a direction of 120 degrees and the sensitivity of the error detection mechanism to the adopted criterion level had occurred over the twenty blocks of trials. (Table 4)

Surprisingly, both main effects for KR for $\overline{CE}$ and VE were insignificant, indicating that neither the accuracy of the criterion level for error detection nor the sensitivity of the error detection mechanism at the adopted criterion level were influenced by different KR paradigms. (Table 4) However, the effects of KR on both the accuracy of the criterion level for error detection and the sensitivity of the error detection mechanism at the adopted criterion level did not remain constant over the twenty blocks of trials, as indicated by a significant KR x blocks interaction for $\overline{CE}$

and VE. (Table 4)

TABLE 4

F RATIOS OF MAIN EFFECTS AND INTERACTIONS OF THE STATE OF THE ERROR DETECTION MECHANISM FOR DIRECTION OVER TWENTY BLOCKS

Location of ANOVA Tables		KR (A)	Fb (B)	KRxFb (AB)	Blocks (C)	(AC)	(BC)	(ABC)
Appendix C Table 39	$\overline{CE}$	0.05	2.03	0.89	3.56*	4.28*	1.75*	1.57*
Appendix C Table 40	VE	0.79	6.58*	0.88	9.84*	1.52*	1.24	0.84

* significant at the .05 level

The insignificant main effect for sensory fb for $\overline{CE}$ indicated that sensory fb did not play a significant rôle in the established criterion level for error detection. However, the effects of sensory fb on the criterion level changed over the twenty blocks of trials, as indicated by a significant fb x blocks interaction for $\overline{CE}$. (Table 4) In contrast, a significant sensory fb effect for VE demonstrated that the sensitivity of the error detection mechanism at the adopted criterion level was indeed influenced by sensory fb. Nevertheless, this fb effect remained constant over the twenty blocks of trials, as indicated by an insignificant fb x blocks interaction for VE. (Table 4)

Neither two way interaction between KR and fb for $\overline{CE}$ and VE reached significance, but the KR x fb x blocks interaction for $\overline{CE}$ was significant. Hence, the effects of the relationship between KR and fb on the accuracy of the criterion level for error detection did not remain constant over the twenty blocks of trials.

State of the Memory Trace for the Recall of the Direction of a Movement

No Knowledge of Results

All analyses in this section were separate single factor analysis of variance with repeated measures over the twenty blocks of five trials for $\overline{AE}$ and AV. A single factor analysis of variance was used for two reasons. Firstly, KR was the independent variable of concern over the twenty blocks of trials. It was the effects of practice without KR over the twenty blocks that was important to the present thesis. Secondly, since learning has not been evidenced when sensory fb was present, without KR, no differences were expected between groups differing in sensory fb and as a consequence comparisons between fb groups were not necessary.

Distorted Feedback

In accordance with expectations, (hypotheses (h.) 1 and 2) an analysis of variance on $\overline{AE}$ and AV indicated that there was no change in the state of the memory trace during practice without KR. (Table 5) Neither the accuracy of the memory trace, using the adopted criterion level, nor the precision of the memory trace improved without KR.

Normal Feedback

Analysis of variance conducted on $\overline{AE}$ and AV, for subjects receiving normal sensory fb, produced the same results observed under conditions of distorted fb. Insignificant blocks effects demonstrated that neither the

TABLE 5

F RATIOS OF THE STATE OF THE MEMORY TRACE OVER TWENTY BLOCKS FOR GROUPS RECEIVING NO KNOWLEDGE OF RESULTS

Location of ANOVA Tables		Distorted Fb	Normal Fb	Heightened Fb
Appendix C Tables 21, 25, 29	$\overline{AE}$	1.30	1.13	0.97
Appendix C Tables 22, 26, 30	AV	1.40	0.67	1.19

* significant at the .001 level[2]

accuracy nor the precision of the memory trace improved in the absence of KR. (Table 5)

Heightened Feedback

Analysis of variance, computed on $\overline{AE}$ and AV, for subjects receiving heightened sensory fb, produced the same results observed under conditions of both distorted and normal fb. Insignificant blocks effects indicated that the memory trace neither became more accurate nor more precise without KR.

Early Knowledge of Results Withdrawal

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{AE}$ and AV in the early KR withdrawal condition in order to observe the effects of both sensory fb and practice on the state of the memory

2 The .001 level of significance was chosen for all experimental hypotheses stated in the null in order to minimize the chances of cimmitting a Type 1 or alpha error.

trace, when KR was withdrawn early in learning.

The expected decrements in direction performance (h.7-12), when KR was withdrawn were not evidenced in either $\overline{AE}$ or AV scores. The insignificant main effects for blocks indicated that neither the accuracy of the memory trace for the recall of a movement in the direction of 120 degrees, using the adopted criterion level nor its strength deteriorated when KR was withdrawn early in learning. (Table 6) However, inspection of Figure 4 indicated that the trend was in the expected direction, although it was not statistically significant.

According to predictions (h.7-12), insignificant main effects for sensory fb for $\overline{AE}$ and AV indicated that neither the accuracy nor the precision of the memory trace was affected by sensory fb. The fb x blocks interactions for $\overline{AE}$ and AV, too, were insignificant revealing no change in the fb effect on the state of the memory trace over the five blocks of trials, during which KR was withdrawn. (Table 6)

Late Knowledge of Results Withdrawal

Once again, consistent with the early KR withdrawal condition, two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{AE}$ and AV in order to observe the effects of both sensory fb and practice on the state of the memory trace, when KR was withdrawn late in learning.

The insignificant blocks effect for $\overline{AE}$ and AV indicated that the expected stabilization in both accuracy and precision for direction performance had indeed occurred (h.13-18). (Table 7)

TABLE 6

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE MEMORY TRACE OVER FIVE BLOCKS FOR GROUPS DURING EARLY KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 33	$\overline{AE}$	0.55	1.77	0.82
Appendix C Table 34	AV	0.93	1.14	1.56

* significant at the .05 level

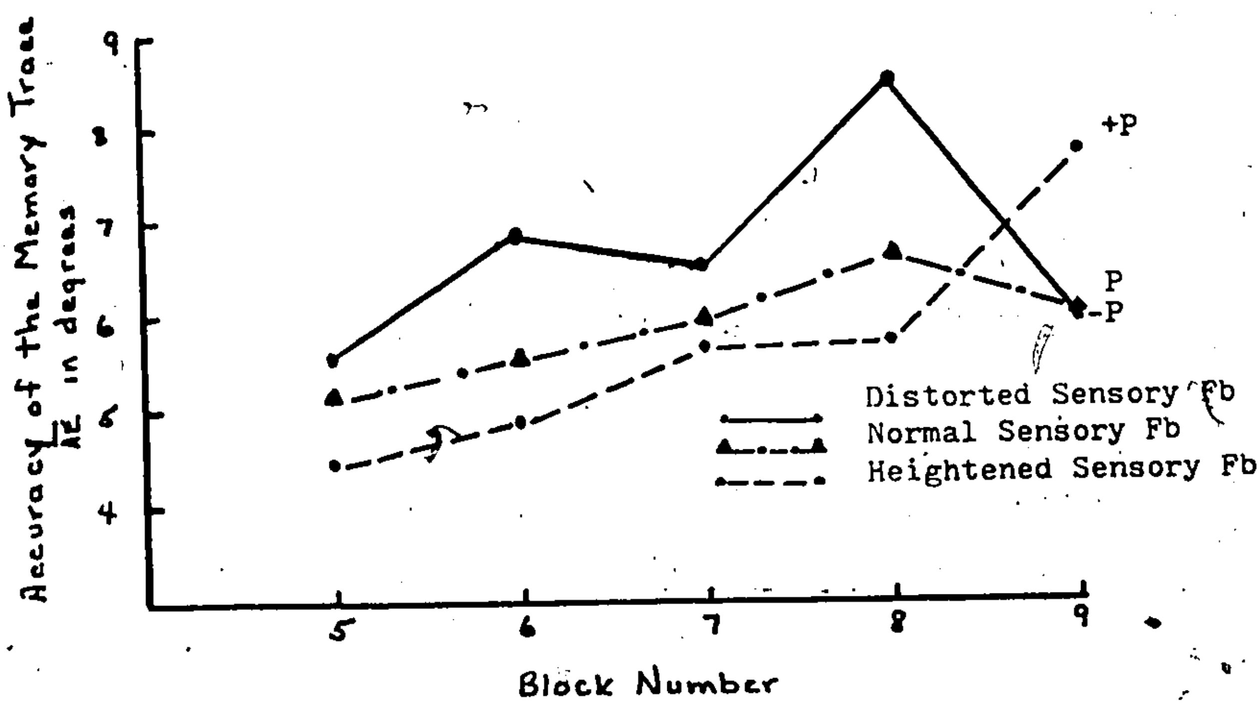


Figure 4 Accuracy of the Memory Trace for the Direction of Movement for Fb Groups During Early Knowledge of Results Withdrawal

Although the .001 level of significance was required in order to avoid committing a Type 1 error, it was observed that the blocks effect was significant at the .02 level. However, because the comparison between blocks was extremely important to Adams' theory and the experimenter did not wish to mistakenly miss a real difference, if one did exist, a post hoc Tukey (a) Test was computed on the five blocks of trials. (Table 7) It was observed that the only significant difference occurred between block 16 and block 20. There were no other significant differences between the blocks, thus lending statistical support to the expected stabilization in accuracy for the memory trace.

Consistent with the results observed during early KR withdrawal and with predictions (h.13-18), insignificant main effects for sensory fb for $\overline{AE}$ and AV indicated that neither the accuracy nor the precision of the memory trace was affected by sensory fb. (Table 7) The fb x blocks interactions for $\overline{AE}$ and AV, too, were insignificant revealing no change in the fb effect on the state of the memory trace, when KR was withdrawn late in practice. (Table 7)

Overall Analysis of Data Including All Levels of Knowledge of Results and All Levels of Sensory Feedback Over Twenty Blocks of Trials

A 3 x 3 x 20 analysis of variance (KR x fb x blocks) with repeated measures on the last factor was computed for $\overline{AE}$ and AV in order to provide additional insights into the state of the memory trace. Since the previous two factor analyses of variance were calculated over only the five blocks of trials during which KR was withdrawn, it was

TABLE 7

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE MEMORY TRACE OVER FIVE BLOCKS FOR GROUPS DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 37	AE	0.98	3.07+	1.10
Appendix C Table 38	AV	2.22	0.46	2.32+

* significant at the .001 level
+ significant at the .02 level.

DIFFERENCES BETWEEN THE FIVE BLOCKS OF TRIALS FOR ABSOLUTE ERROR DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL "TUKEY (a) PROCEDURE"

TOTALS	b_{16}	b_{17}	b_{19}	b_{18}	b_{20}
(degrees)	102.60	125.40	125.80	132.40	152.90
102.60		22.80	23.20	29.80	50.30*
125.40			0.40	7.00	27.50
125.80				6.60	27.10
132.40					20.50

thought advantageous to observe the effects of both KR and sensory fb on the state of the memory trace over the entire twenty blocks of five trials.

Significant main effects for blocks for $\overline{AE}$ and AV indicated that an improvement in both the accuracy and strength of the memory trace for a movement in a 120 degree direction, using the established criterion level had occurred over the twenty blocks of trials. (Table 8) As expected, the main effects for KR for $\overline{AE}$ and AV were both significant, demonstrating that the state of the memory trace had improved as a function of KR. Moreover, the effects of KR on the accuracy of the memory trace did not remain constant over blocks, as indicated by a significant KR x blocks interaction for $\overline{AE}$. The KR x blocks interaction for AV just failed to reach significance. (Table 8)

Contrary to predictions, significant main effects for sensory fb for both $\overline{AE}$ and AV implied that the state of the memory trace was also a function of sensory fb. A significant fb x blocks interaction for $\overline{AE}$ indicated that the effects of sensory fb on the accuracy of the memory trace changed over the twenty blocks of trials. The fb x blocks interaction for AV just failed to reach significance. (Table 8)

Neither two way interaction between KR and fb reached significance. Similarly, neither three way interaction for $\overline{AE}$ or AV were significant, meaning that the interaction between KR and fb was not a function of practice. (Table 8)

TABLE 8

F RATIOS OF MAIN EFFECTS AND INTERACTIONS OF THE STATE OF THE MEMORY TRACE OVER TWENTY BLOCKS

Location of ANOVA Tables		KR (A)	Fb (B)	KRxFb (AB)	Blocks (C)	(AC)	(BC)	(ABC)
Appendix C Table 41	$\overline{AE}$	25.15*	4.20*	0.72	5.41*	1.64*	1.68*	1.21
Appendix C Table 42	AV	4.37*	9.03*	1.43	7.54*	1.36+	1.34+	1.05

* significant at the .05 level
\+ significant between the .07 and .08 levels

Perceptual Trace

Criterion Level and Sensitivity of the Error Detection Mechanism for Extent of Movement

All analyses computed on data for the error detection mechanism were used to remain consistent with analyses of the data under the same experimental conditions for the state of the memory and perceptual traces.

No Knowledge of Results

All analyses in this section were separate single factor analysis of variance with repeated measures over twenty blocks of five trials, on $\overline{CE}$ and VE.

Distorted Feedback

Analysis of variance on $\overline{CE}$ revealed a significant change in the criterion level for detecting errors in the required six inch line. (Table 9) Inspection of Figure 5 indicated that the accuracy in detecting errors improved over the twenty blocks of trials, the majority of this improvement occurring in the first seven blocks. Analysis of variance computed on VE revealed a significant change in the sensitivity of the error detection mechanism to the adopted criterion level. (Table 9) However, inspection of Figure 6 indicated that the significant blocks effect observed was the result of tremendous variability in the error detection mechanism's sensitivity at the established criterion level, rather than the result of an improvement in its sensitivity.

Normal Feedback

Analysis of variance on $\overline{CE}$ demonstrated that there was no change in the accuracy of the established criterion level for detecting errors in the required six inch line, during practice without KR. (Table 9) Analysis of variance computed on VE showed that there was a significant change in

TABLE 9

F RATIOS OF THE STATE OF THE ERROR DETECTION MECHANISM FOR EXTENT OVER TWENTY BLOCKS FOR GROUPS RECEIVING NO KNOWLEDGE OF RESULTS

Location of ANOVA Tables		Distorted Fb	Normal Fb	Heightened Fb
Appendix C Tables 43, 47, 51	$\overline{CE}$	6.94*	0.46	2.28*
Appendix C Tables 44, 48, 52	VE	2.05*	1.72*	1.63*

* significant at the .05 level

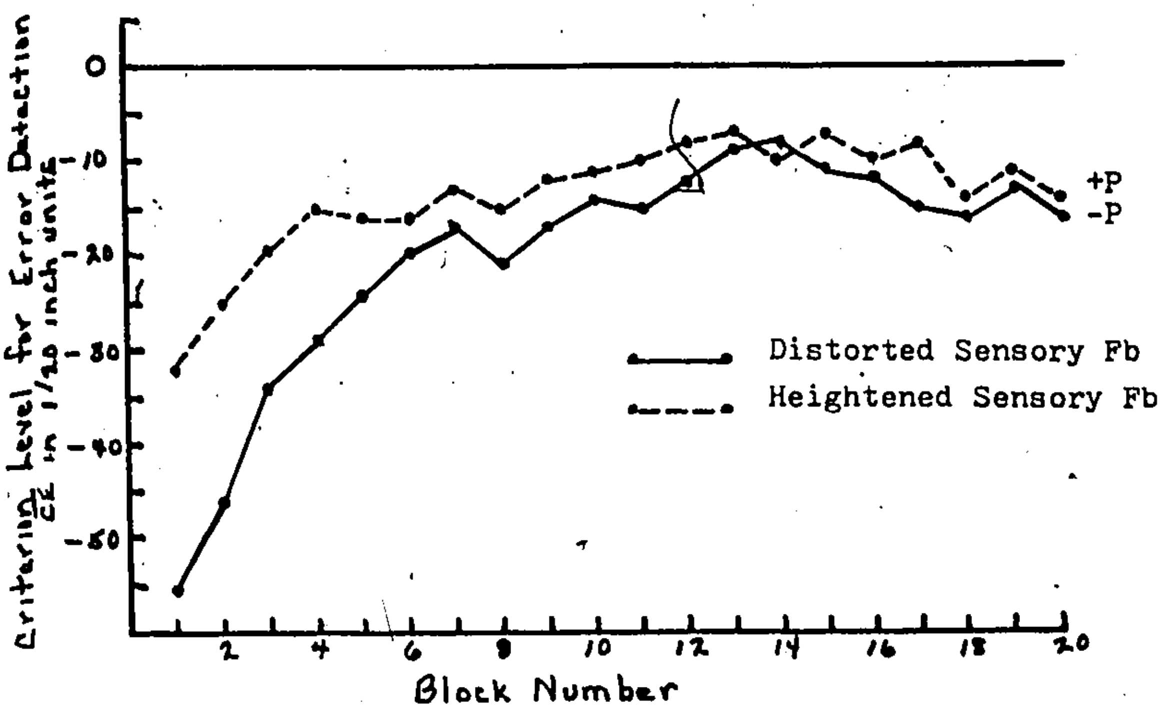


Figure 5 Criterion Level for Error Detection for the Extent of Movement for the Distorted and Heightened Fb Groups Receiving No Knowledge of Results

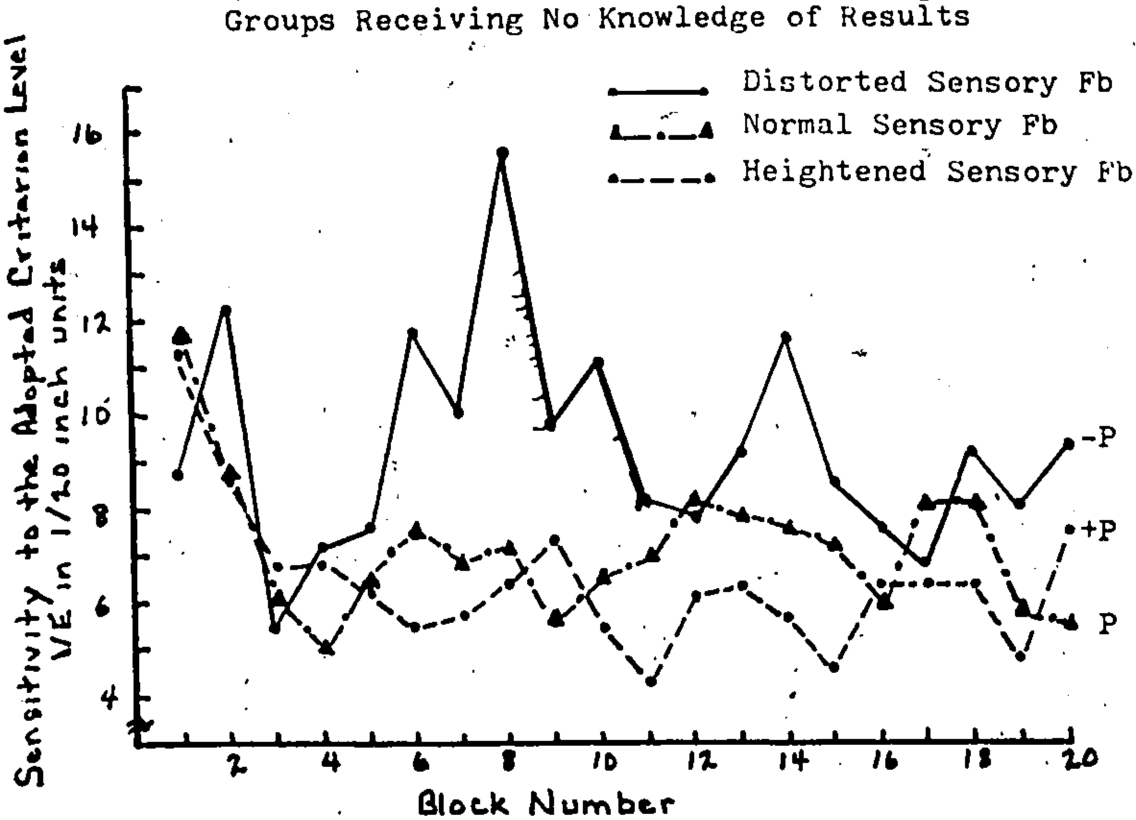


Figure 6 Sensitivity of the Error Detection Mechanism for the Extent of Movement for Fb Groups Receiving No Knowledge of Results

the sensitivity of the error detection mechanism at the adopted criterion level. (Table 9) Inspection of Figure 6 indicated that, contrary to the distorted fb condition, the significant blocks effect observed was the result of an improvement in the sensitivity of the error detection mechanism at the adopted criterion level.

Heightened Feedback

Analysis of variance on $\overline{CE}$ revealed a significant change in the criterion level for error detection. (Table 9) Inspection of Figure 5 revealed the same trend observed under conditions of distorted fb. The accuracy of the criterion level for error detection improved over the twenty blocks of trials, the majority of the improvement occurring in the first four blocks. Analysis of variance computed on VE revealed the same trend observed under conditions of normal fb. Inspection of Figure 6 indicated that once again the significant blocks effect observed was the result of an improvement in the error detection mechanism's sensitivity to the adopted criterion level.

Early Knowledge of Results Withdrawal

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{CE}$ and VE, in the early KR withdrawal condition.

Insignificant main effects for blocks for $\overline{CE}$ and VE indicated that neither the accuracy of the criterion level for detecting errors in a six inch line nor the error detection mechanism's sensitivity at the adopted criterion level deteriorated when KR was withdrawn early in learning. (Table 10)

TABLE 10

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE ERROR DETECTION MECHANISM FOR EXTENT OVER FIVE BLOCKS FOR GROUPS DURING EARLY KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 55	$\overline{CE}$	0.20	0.40	0.69
Appendix C Table 56	VE	0.50	0.83	0.91

* significant at the .05 level

The main effects for sensory fb also failed to reach significance demonstrating that there were no differences in either the accuracy of the established criterion level for error detection or the error detection mechanism's sensitivity to the adopted criterion level between groups differing in sensory fb. Both fb x blocks interactions, too, were insignificant revealing no change in the fb effect on the criterion level and sensitivity of the error detection mechanism over the five blocks of trials. (Table 10)

<u>Late Knowledge of Results Withdrawal</u>

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{CE}$ and VE in the late KR withdrawal condition.

An insignificant blocks effect for $\overline{CE}$ showed that the accuracy of the established criterion level for detecting errors in a six inch line did not change, when KR was withdrawn late in learning. (Table 11) However, the analysis of variance computed on VE yielded a significant main effect for blocks, indicating that the sensitivity of the error detection mechanism to the established criterion level deteriorated when KR was withdrawn late in learning. Secondary analyses by means of a Tukey (a) Test on the five blocks of trials demonstrated that the only significant differences between the blocks occurred between blocks 17 and 19. (Table 11) Inspection of Figure 7 revealed that the deterioration in the error detection mechanism's sensitivity was attributable mainly to the group receiving distorted sensory fb. The sensitivity of the error detection mechanism at the adopted criterion level for groups receiving normal and heightened sensory fb appeared to stabilize when KR was withdrawn late in learning.

Insignificant main effects for sensory fb for both $\overline{CE}$ and VE were observed, indicating that there were no differences in either the accuracy of the established criterion level for error detection or the error detection mechanism's sensitivity to the adopted criterion level, between groups differing in sensory fb. Both fb x blocks interactions, also, were insignificant revealing no change in the fb effect over the five blocks of trials during which KR was withdrawn late in practice. (Table 11) Hence, sensory fb did not affect the criterion level or the sensitivity of the error detection mechanism.

TABLE 11

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE ERROR DETECTION MECHANISM FOR EXTENT OVER FIVE BLOCKS FOR GROUPS DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 59	CE	0.31	0.18	0.99
Appendix C Table 60	VE	3.07+	2.69*	1.54

* significant at the .05 level
\+ significant at the .07 level

DIFFERNCES BETWEEN THE FIVE BLOCKS OF TRIALS FOR VARIABLE ERROR DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL "TUKEY (a) PROCEDURE"

TOTALS	b17	b16	b20	b18	b19
(1/20 inch units)	156.06	178.54	184.85	201.54	216.39
156.06		22.84	28.79	45.48	60.33*
178.54			6.31	23.00	37.85
184.85				16.69	31.54
201.54					14.85

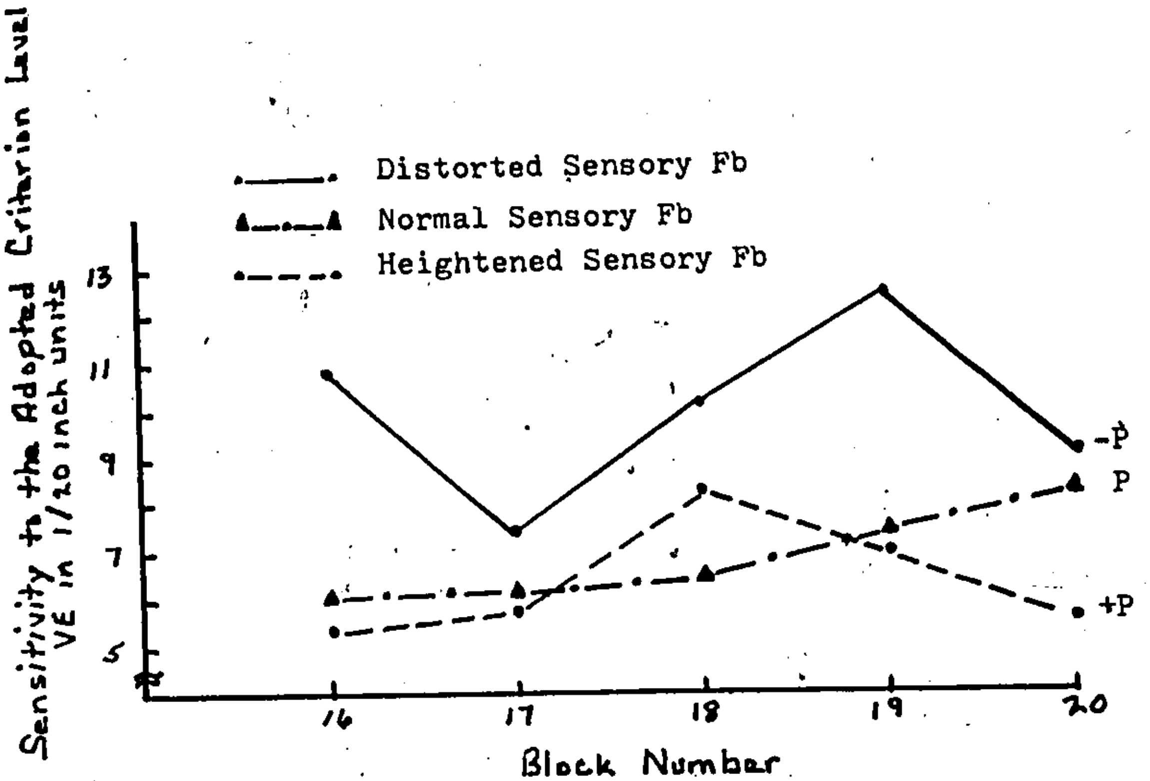


Figure 7 Sensitivity of the Error Detection Mechanism for the Extent of Movement for Fb Groups During Late Knowledge of Results Withdrawal

Overall Analysis of Data Including All Levels of Knowledge of Results and All Levels of Sensory Feedback Over Twenty Blocks of Trials

A 3 x 3 x 20 analysis of variance (KR x fb x blocks) with repeated measures on the last factor was computed on $\overline{CE}$ and VE in order to provide some additional insights into the criterion level and sensitivity of the error detection mechanism for extent.

Significant main effects for blocks for $\overline{CE}$ and VE indicated that an improvement in both the accuracy of the established criterion level for detecting errors in a six inch line and the sensitivity of the error detection mechanism to the adopted criterion level had occurred over the twenty blocks of trials. (Table 12)

TABLE 12

F RATIOS OF MAIN EFFECTS AND INTERACTIONS OF THE STATE OF THE ERROR DETECTION MECHANISM FOR EXTENT OVER TWENTY BLOCKS

Location of ANOVA Tables		KR (A)	Fb (B)	KRxFb (AB)	Blocks (C)	(AC)	(BC)	(ABC)
Appendix C Table 63	$\overline{CE}$	4.88*	0.11	0.17	20.70*	2.52*	2.12*	1.25+
Appendix C Table 64	VE	7.69*	10.78*	0.60	24.79*	3.69*	1.25	1.03

* significant at the .05 level
\+ significant at the .08 level

Both main effects for KR for $\overline{CE}$ and VE were also significant, demonstrating that the criterion level and sensitivity of the error detection mechanism improved as a function of KR. In addition, it was noted that the effects of KR on both the criterion level and sensitivity of the error detection mechanism changed over the twenty blocks of trials, as indicated by significant KR x blocks interactions for $\overline{CE}$ and VE. (Table 12)

An insignificant main effect for sensory fb for $\overline{CE}$ indicated that sensory fb did not play a role in the established criterion level for error detection. However, a significant fb x blocks interaction for $\overline{CE}$ revealed that the effects of sensory fb changed over the twenty blocks of trials. (Table 12) In contrast, a significant sensory fb effect for VE demonstrated that the sensitivity of the error detection mechanism to the adopted criterion level was indeed influenced by sensory fb. Nevertheless, this fb effect remained constant over the twenty blocks of trials, as indicated by an insignificant fb x blocks interaction for VE. (Table 12)

Neither two way interaction between KR and fb reached significance. The two third order interactions also both failed to reach significance. Consequently, it was noted that practice did not change the effects of the relationship between KR and fb on the criterion level and sensitivity of the error detection mechanism for the extent of movement.

State of the Perceptual Trace for the Recognition of the Extent of a Movement

No Knowledge of Results

All analyses in this section were separate single factor analysis of variance with repeated measures over the twenty blocks of five trials for $\overline{AE}$ and AV. A single factor analysis of variance was chosen for two reasons. Firstly, KR was the independent variable of concern over the twenty blocks of trials. It was the effects of practice without KR over the twenty blocks of trials that was important to the present thesis. Secondly, since learning has not been evidenced when sensory fb was present, without KR, no differences were expected between groups differing in sensory fb and as a consequence comparisons between fb groups were not necessary.

Distorted Feedback

In accordance with predictions (h.19 and 20), analysis of variance computed on $\overline{AE}$ and AV indicated that there were no changes in the state of the perceptual trace during practice without KR. (Table 13) Although the .001 level of significance was required, in order to avoid committing a Type 1 error, it was observed that the blocks effect was significant for AV at the .003 level. However, inspection of Figure 8 indicated that this blocks effect was the result of tremendous variability in the precision of the perceptual trace over blocks, rather than the result of an improvement over blocks.

Normal Feedback

Analyses of variance conducted on $\overline{AE}$ and AV for subjects receiving normal sensory fb produced the same results observed under conditions of distorted fb. Insignificant blocks effects for both $\overline{AE}$ and AV demonstrated that neither the accuracy nor the precision of the perceptual trace improved in the absence of KR. (Table 13) Similar to the distorted fb condition, AV, while not being significant at the required .001 level, was significant at the .03 level. Again, inspection of Figure 8 indicated that the blocks effect was the result of tremendous variability in the precision of the perceptual trace over blocks, rather than the result of learning.

Heightened Feedback

In accordance with expectations (h.23 and 24), analyses of variance on $\overline{AE}$ and AV indicated that there were no changes in the state of the perceptual trace, during practice without KR. (Table 13) Neither the accuracy of the perceptual trace, using the adopted criterion level, nor its strength improved without KR.

TABLE 13

F RATIOS OF THE STATE OF THE PERCEPTUAL TRACE OVER TWENTY BLOCKS FOR GROUPS RECEIVING NO KNOWLEDGE OF RESULTS

Location of ANOVA Tables		Distorted Fb	Normal Fb	Heightened Fb
Appendix C Tables 45, 49, 53	$\overline{AE}$	1.07	0.68	0.30
Appendix C Tables 46, 50, 54	AV	2.33+	1.76+	1.31

* significant at the .001 level
\+ significant at the .003 and .03 levels, respectively

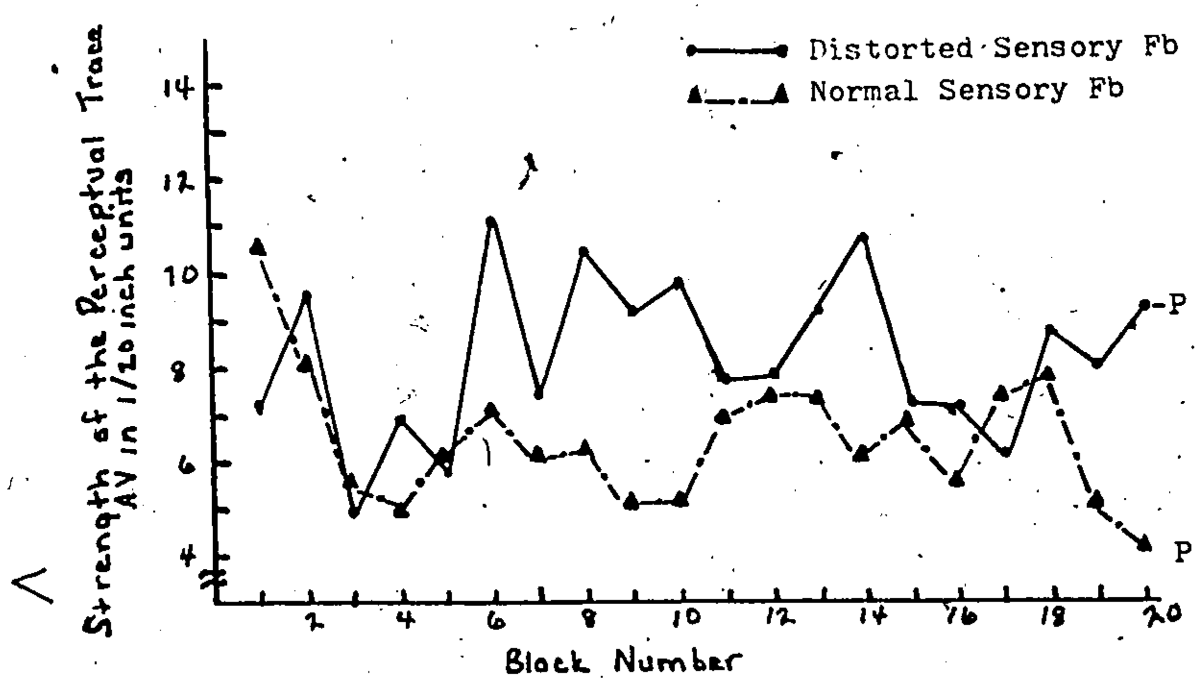


Figure 8 Strength of the Perceptual Trace for the Extent of Movement for the Distorted and Normal Feedback Groups Receiving No Knowledge of Results

Early Knowledge of Results Withdrawal

Two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{AE}$ and AV, in the early KR withdrawal condition in order to observe the effects of both sensory fb and practice on the state of the perceptual trace, when KR was withdrawn early in learning. More specifically, this statistical analysis was essential to test the experimental hypotheses, for this condition, since differences were expected between the three sensory fb groups. A significant main effect would then permit secondary analyses of the data to determine the exact location of the difference.

The expected decrement in extent performance, when KR was withdrawn (h. 25-30) was not evidenced in either $\overline{AE}$ or AV scores. The insignificant main effects for blocks indicated that neither the accuracy of the perceptual trace for recognition of a six inch line, using the adopted criterion level nor its strength deteriorated, when KR was withdrawn early in learning. (Table 14) However, inspection of Figure 9 revealed that there were decrements in performance for the distorted and heightened fb groups, although they were insignificant.

Also contrary to predictions (h. 31), insignificant main effects for sensory fb for $\overline{AE}$ and AV demonstrated that neither the accuracy nor the precision of the perceptual trace was affected by sensory fb. The fb x blocks interactions, too, were insignificant revealing no change in the fb effect on the state of the perceptual trace over the five blocks of trials when KR was withdrawn. (Table 14)

TABLE 14

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE PERCEPTUAL TRACE OVER FIVE BLOCKS FOR GROUPS DURING EARLY KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 57	$\overline{AE}$	1.61	1.54	1.30
Appendix C Table 58	AV	0.78	0.28	0.55

* significant at the .05 level

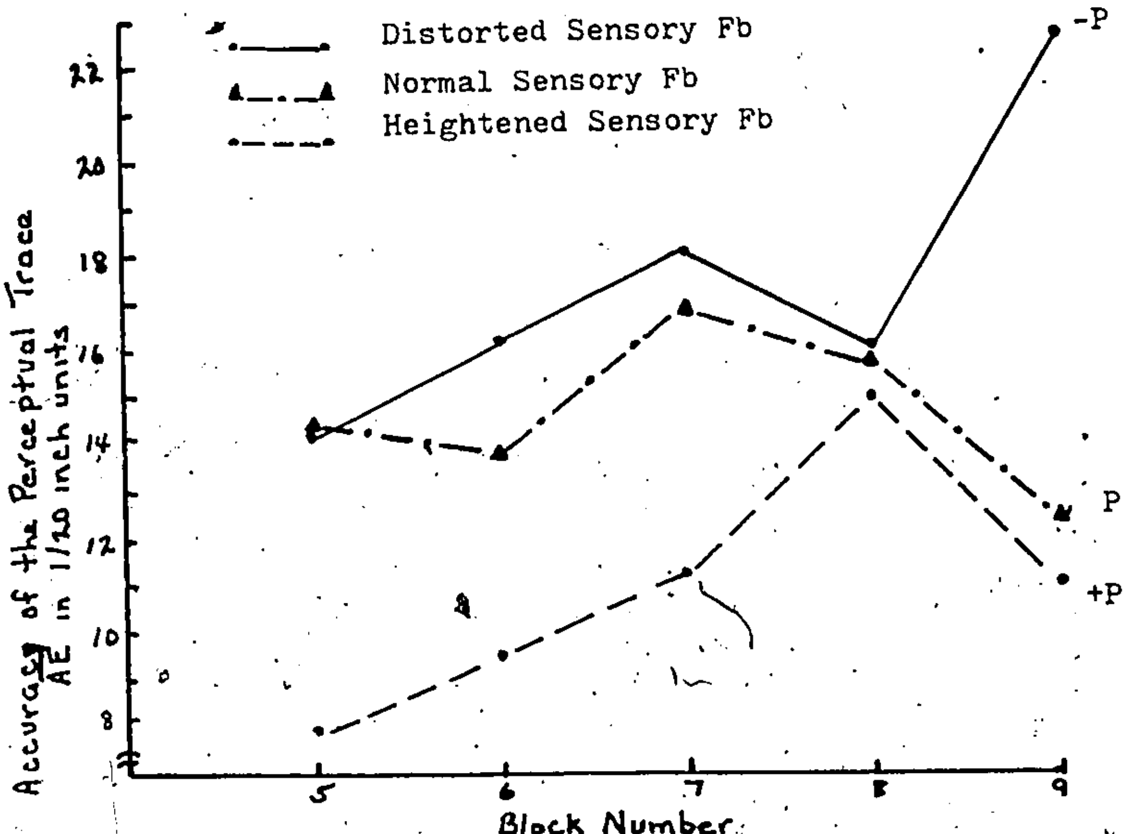


Figure 9 Accuracy of the Perceptual Trace for the Extent of Movement for Fb Groups During Early Knowledge of Results Withdrawal

Late Knowledge of Results Withdrawal

Again, two factor analyses of variance (fb x blocks) with repeated measures on blocks were computed on $\overline{AE}$ and AV in the late KR withdrawal condition, in order to observe the effects of both sensory fb and practice on the state of the perceptual trace when KR was withdrawn late in learning. More specifically, this statistical analysis was crucial in the testing of the experimental hypotheses, for this condition, since differences were expected in both learning, as measured by the blocks effect and between groups differing in sensory fb. These significant main effects, if present, would permit secondary analyses of the data to determine the exact location of these differences, their direction and magnitude. This information, that is the size of these differences, if present and their direction is crucial to the substantiation of the functional independence of the memory and perceptual traces.

Contrary to expectations (h. 34-37), analysis of variance computed on $\overline{AE}$ indicated that extent performance deteriorated when KR was withdrawn late in learning. (Table 15) However, since this comparison was crucial to Adams' theory, a Tukey (a) Test was computed on the five blocks. It was observed that blocks 19 and 20 differed significantly from blocks 16 and 17. Nevertheless, neither blocks 19 and 20 nor blocks 16 and 17 were significantly different from block 18. (Table 15) Inspection of Figure 10 revealed that the group having distorted sensory fb produced the expected (h. 32) deterioration in the accuracy of the perceptual trace until block 20. It was also observed that the group receiving heightened sensory fb had a stabilization in the accuracy of

TABLE 15

F RATIOS OF MAIN EFFECTS AND INTERACTION OF THE STATE OF THE PERCEPTUAL TRACE OVER FIVE BLOCKS FOR GROUPS DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL

Location of ANOVA Tables		Fb (A)	Blocks (B)	Fb x Blocks (AB)
Appendix C Table 61	$\overline{AE}$	1.80	5.37*	2.32*
Appendix C Table 62	AV	1.81	1.96	2.32*

* significant at the .05 level

DIFFERENCES BETWEEN THE FIVE BLOCKS OF TRIALS FOR ABSOLUTE ERROR DURING LATE KNOWLEDGE OF RESULTS WITHDRAWAL "TUKEY (a) PROCEDURE"

TOTALS	b_{16}	b_{17}	b_{18}	b_{19}	b_{20}
(1/20 inch units)	181.98	191.20	222.60	259.80	264.40
181.98		9.22	40.62	77.82*	82.42*
191.20			31.40	68.60*	73.20*
222.60				37.20	41.80
259.80					4.60

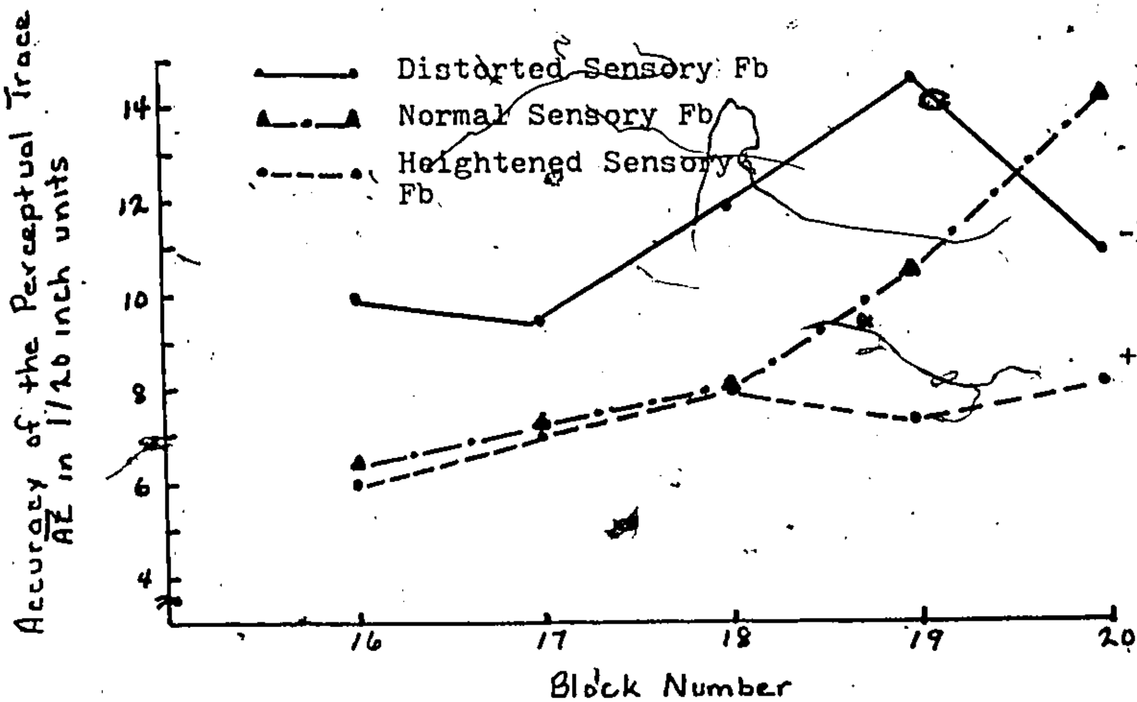


Figure 10 Accuracy of the Perceptual Trace for the Extent of Movement for Fb Groups During Late Knowledge of Results Withdrawal

their perceptual trace when KR was withdrawn late in learning. However, contrary to expectations (h.34), the accuracy of the perceptual trace for subjects receiving normal sensory fb stabilized until block 18 and then deteriorated. Also contrary to predictions (h.33, 35, 37) was the insignificant blocks effect for AV, showing that there was no change in the strength of the perceptual trace, when KR was withdrawn late in learning. (Table 15)

A further inconsistency with predictions (h.32, 33, 38) was evidenced in the insignificant fb effects for $\overline{AE}$ and AV, which indicated that neither the accuracy nor the precision of the perceptual trace was affected by sensory fb. (Table 15) There were no differences in extent performance between groups differing in sensory fb, when KR was withdrawn late in learning. However, significant fb x blocks interactions for both $\overline{AE}$ and AV demonstrated a change in the fb effect on the state of the perceptual trace with practice. (Table 15)

Overall Analysis of Data Including All Levels of Knowledge of Results and All Levels of Sensory Feedback Over Twenty Blocks of Trials

A 3 x 3 x 20 analysis of variance (KR x fb x blocks) with repeated measures on the last factor was calculated for $\overline{AE}$ and AV in order to provide some additional insights into the state of the perceptual trace. Since the previous two factor analyses of variance were calculated only over the five blocks of trials during which KR was withdrawn, it was thought advantageous to observe the effects of both KR and sensory fb and their interactions, if present, on the state of the perceptual trace over the entire twenty blocks of five trials.

Significant main effects for blocks for $\overline{AE}$ and AV indicated that an improvement in both the accuracy and strength of the perceptual trace for the recall of a six inch line, using the established criterion level, had occurred over the twenty blocks of trials. (Table 16) As expected, the main effect for KR for $\overline{AE}$ was significant, demonstrating that the accuracy of the perceptual trace had improved as a function of KR. In addition, a significant KR x blocks interaction for $\overline{AE}$ revealed a change over blocks in the KR effect on the accuracy of the perceptual trace. (Table 16) However, contrary to expectations, the main effects for KR for AV failed to reach significance, indicating that the precision of the perceptual trace was not affected by KR. Nevertheless,

TABLE 16

F RATIOS OF MAIN EFFECTS AND INTERACTIONS OF THE STATE OF THE PERCEPTUAL TRACE OVER TWENTY BLOCKS

Location of ANOVA Tables		KR (A)	[illegible] (B)	KRxFb (AB)	Blocks (C)	(AC)	(BC)	(ABC)
Appendix C Table 65	$\overline{AE}$	40.89*	1.55	1.84	13.11*	2.53*	1.59*	0.70
Appendix C Table 66	AV	1.24	13.21*	0.73	27.30*	4.29*	1.04	1.26+

* significant at the .05 level
\+ significant at the .08 level

a significant KR x blocks interaction for AV implied that the effects of KR on the strength of the perceptual trace changed over the twenty blocks of trials. (Table 16)

Also inconsistent with predictions was the insignificant main effect for sensory fb for $\overline{AE}$, indicating that the accuracy of the perceptual trace was not affected by fb. However, a significant fb x blocks interaction for $\overline{AE}$ demonstrated that the effects of fb on the accuracy of the perceptual trace changed over the twenty blocks of trials. (Table 16) A significant main effect for fb for AV indicated that the precision of the perceptual trace improved as a function of sensory fb. However, an insignificant fb x blocks interaction for AV showed that the effects of fb on the strength of the perceptual trace remained constant over the twenty blocks of trials. (Table 16)

The KR x fb interactions, as well as the KR x fb x blocks interaction for both AE and AV were insignificant. Consequently, learning did not change the effects of the relationship between KR and fb on the state of the perceptual trace for recognition of the extent of movement.

Independence of the Memory and Perceptual Traces

The crucial test of independence of the two traces in memory would be to directly change the state of the memory trace and observe the changes that occur, if any, in the perceptual trace, or of course, the reverse process. In short, the state of the memory trace would be an independent variable and the state of the perceptual trace would be a dependent variable. The two processes could be said to be independent if the state of the perceptual trace could not be derived from knowing the state of the memory trace and vice versa.

The correlation between the memory and perceptual traces would provide evidence on the independence of individual differences. A high positive correlation between the memory and perceptual trace would indicate that the differences between people are the same in each process, while a low positive correlation between the two traces would imply that the differences between people are different in the two processes.

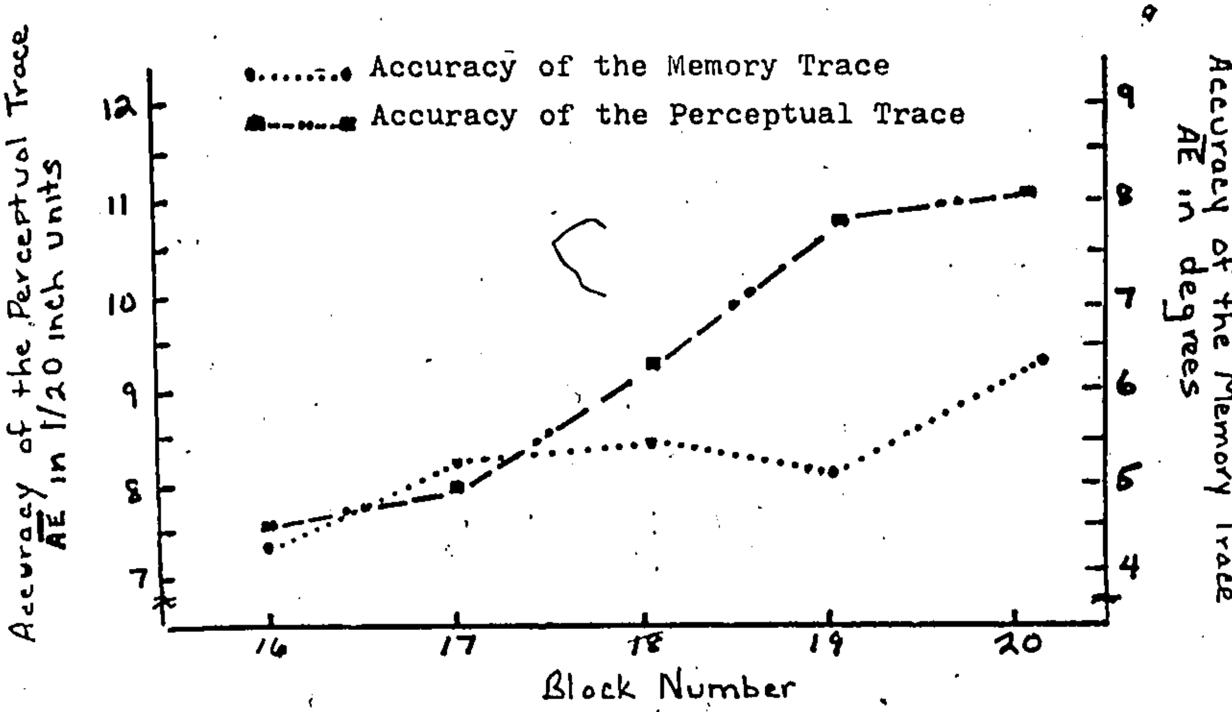
Therefore, since correlation does not provide evidence of independence and since observations on the manner in which the two traces affect each other are not possible, the next logical test of independence is functional independence. Support for functional independence of the memory and perceptual trace in the present study would be provided if a given independent variable resulted in different effects on the behavioural indices of the two traces. In the present thesis, it was anticipated that late KR withdrawal would result in different effects on $\overline{AE}$ and AV, the behavioural indices of the two traces.

As expected late KR withdrawal did produce different effects on $\overline{AE}$ for the memory and perceptual traces. However, inspection of Figure 11 revealed that while the predicted stabilization of the accuracy of the memory trace did indeed occur when KR was withdrawn late in learning, the predicted differences in the accuracy of the perceptual trace between the three fb groups did not materialize. Accuracy in the recognition of movement extent deteriorated when KR was withdrawn late in learning and continued learning via subjective reinforcement as predicted by Adams' model did not occur. Moreover, late KR withdrawal did not result in different effects on AV for the memory and perceptual traces. Inspection of Figure 12 showed that the strength of the memory trace as measured by AV stabilized during late KR withdrawal as predicted by the model but contrary to predictions from the model the strength of the perceptual trace also stabilized during late KR withdrawal.

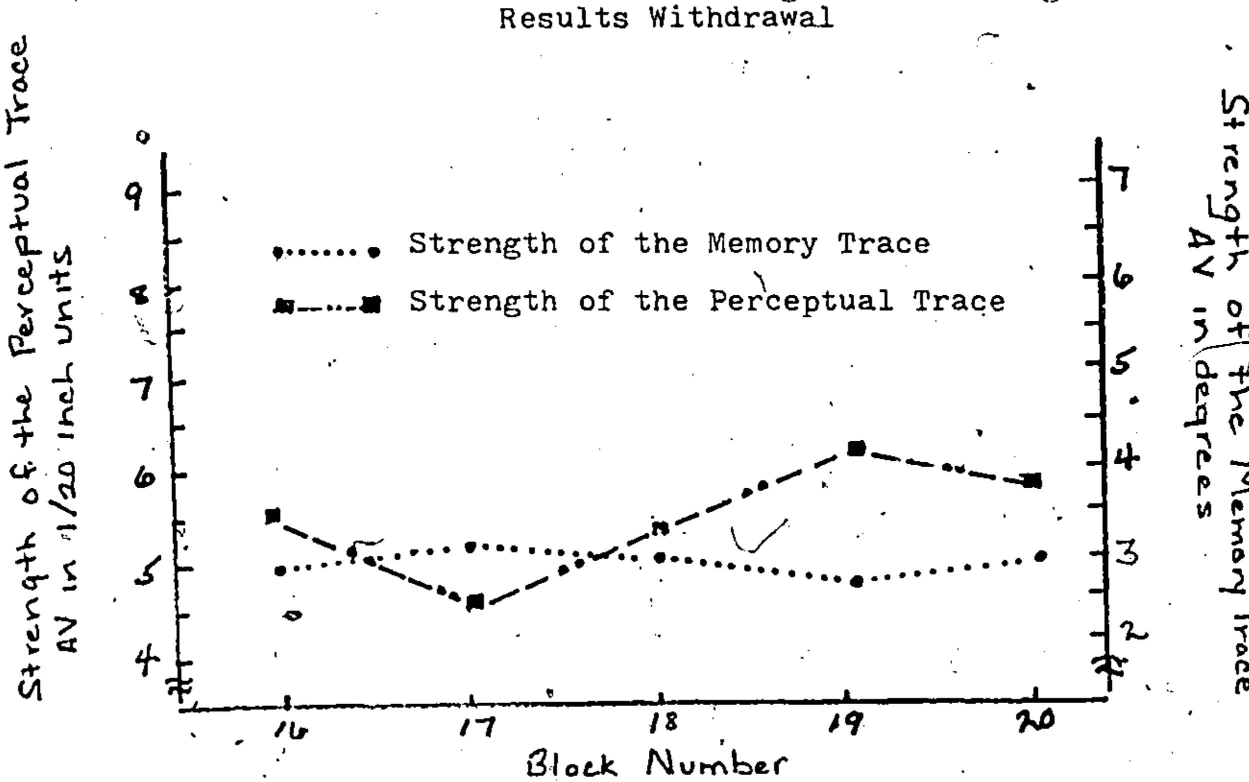
Hence, while late KR withdrawal did result in different effects on $\overline{AE}$, it failed to result in different effects on AV. Moreover, the different effects observed, were not entirely in the predicted direction. Therefore, the present data failed to provide strong enough evidence to substantiatw the functional independence of the memory and perceptual traces.

Timing Scores as Measured by Movement Time

In order to ensure that subjects were performing a slow self-paced graded response, rather than a ballistic one, the movement time of the subject's estimation of the required



<u>Figure 11</u> Accuracy of the Memory Trace for the Direction of Movement and Accuracy of the Perceptual Trace for the Extent of Movement During Late Knowledge of Results Withdrawal



<u>Figure 12</u> Strength of the Memory Trace for the Direction of Movement and Strength of the Perceptual Trace for the Extent of Movement During Late Knowledge of Results Withdrawal

six inch line was recorded. Inspection of the mean time scores in Table 17 confirmed that the subjects were not moving ballistically and the desired slow self-paced response had been made.

Correlations between AP for extent and the mean movement time for each block of trials were computed for the twenty blocks of trials to determine whether subjects were timing their response or moving to a match between incoming sensory fb and the developing perceptual trace. Separate correlations between movement time and AP for each of the twenty blocks were conducted for each of the nine experimental cells. The mean correlation of the twenty blocks for each experimental condition failed to reach significance, with the exception of the correlation for the group denied KR and receiving distorted fb, indicating that subjects were not timing their responses by an internal timing mechanism. (Table 18)

TABLE 17

MEAN TIMING SCORES IN SECONDS AS MEASURED BY MOVEMENT TIME OVER TWENTY BLOCKS OF TRIALS FOR EACH OF THE NINE EXPERIMENTAL CONDITIONS

		Knowledge of Results		
		No KR	Early KR Withdrawal	Late KR Withdrawal
	-P	3.38	7.33	6.39
Fb	P	4.21	5.51	5.25
	+P	5.26	4.34	6.36

TABLE 18

MEAN CORRELATIONS BETWEEN MEAN MOVEMENT TIME AND AP OVER TWENTY BLOCKS OF TRIALS FOR EACH OF THE NINE EXPERIMENTAL CONDITIONS

		Knowledge of Results		
		No KR	Early KR Withdrawal	Late KR Withdrawal
	-P	.76*	-.32	.37
Fb	P	.35	-.45	.36
	+P	-.15	.01	.18

Obtained correlations were converted to Fisher z scores, their mean was found and this mean was converted back to a Pearson product moment correlation.

* An r of .71 was required for significance at the .05 level of significance with 6 degrees of freedom

However, a significant mean correlation, for the group receiving distorted fb and no KR, demonstrated that there was a high positive relationship between movement time and the actual distance moved. Hence, under conditions in which subjects were deprived of all error information concerning their performance and consequently could not develop a perceptual trace, they employed an internal timing mechanism to guide their response.

CHAPTER FIVE

DISCUSSION

Control of skilled performance has been a topic of intensive investigation over recent years. Controversial evidence has been presented, producing a severe dichotomy between those favouring movement control via an open loop system or motor program and those advocating movement control via a closed loop system via sensory fb. Adams (1971) has developed a closed loop model of motor learning, which he argues is the superior explanation of movement control. Hence, empirical verification of Adams' model and all its ramifications is essential in the substantiation of a closed loop theory of movement control.

As suggested by Schmidt and Wrisberg (1972), the most important difference between Adams' closed loop theory of movement control and previously popular open loop accounts was the functional independence of the memory and perceptual traces, which were analogous to recall and recognition memory for verbal material. Support for their functional independence would be provided if it could be shown that a given independent variable produced different effects on the behavioural indices of the two traces. In the present thesis, it was anticipated that late KR withdrawal would produce different effects on $\overline{AE}$ and AV, the behavioural indices of the two traces.

In addition, $\overline{CE}$ and VE, the behavioural indices of the criterion level and sensitivity of the error detection mechanism will be discussed in terms of signal detection theory, concerning their effects on the accuracy and strength of the memory and perceptual traces. Since KR was the independent variable expected to functionally differentiate the two traces in memory, the results will be discussed under each level of KR and support or lack of support for Adams' model will be considered. Then the present findings concerning sensory fb and KR will be reviewed in relation to Adams' model, followed by a brief discussion of timing.

No Knowledge of Results

As predicted by Adams' model, learning did not occur in the absence of KR. For learning to occur, the subject must use KR to make his next response different from his previous one. Since KR was not available, the subject lacked the necessary information to form either a correct memory or correct perceptual trace for the required response and hence the error correction process could not occur. The fact that sensory fb was available in two out of three groups and still performance failed to improve supported Bilodeau's (1969) concept that learning could be viewed as a scale relationship between sensory fb and KR. Since KR was not provided, the subjects could not utilize their available sensory fb, due to a lack of information essential to make appropriate transformations in the processing of sensory fb.

Further empirical support of the importance of KR in the acquisition and maintenance of skilled performance was demonstrated by the movement time-AP correlations. While the two groups receiving sensory fb were not timing their responses, the high positive mean correlation, evidenced in the distorted sensory fb group, indicated that subjects deprived of fb were using some kind of internal timing mechanism to aid in their estimation of a six inch line. Since KR and sensory fb were both unavailable, this resulted in a complete lack of information which could have been utilized for error correction and consequently subjects turned to a timing mechanism to act as a guide in the estimation of a six inch line.

It was interesting to look at the error detection mechanism under these deprived conditions. According to signal detection theory, the error detection mechanism should remain static, in the absence of KR, since it has no basis upon which to alter either its criterion level or sensitivity to that criterion level. Contrary to this expectation, the criterion level for detecting errors in movement in a 120 degree direction, for groups with distorted and heightened fb, shifted from positive to negative, while the criterion level for detecting errors in a movement six inches in length for the same fb groups became more accurate in detecting errors from biological noise, inherent in the system. Moreover, the sensitivity of the error detection mechanism for extent showed a slight improvement for the normal and heightened fb groups, over the twenty blocks of trials, which suggested an increased ability to detect errors. Since KR was not available, these changes must have been the result of alterations in the error detection mechanism, made by the subjects, on the basis of previous representations in memory of a 120 degree angle and six inch line. Detection of errors would be possible through a comparison of these representations in memory and the efferent copy of the motor program sent out to the effectors. However, these changes in the criterion level and sensitivity of the error detection mechanism did not result in an improvement in either the recall of a 120 degree angle or the recognition of a six inch line. It appeared that the lack of KR prevented the subjects from effectively transmitting these changes in their error detection mechanisms to improvements in the actual recall and recognition of the desired response. This is not surprising, inasmuch as subjects without explicit information concerning their error state, could have had no confidence in their altered error detection mechanism and hence failed to transmit the changes to the appropriate controlling trace.

Early Knowledge of Results Withdrawal

Contrary to predictions from Adams' model the expected performance decrements in both accuracy and precision for movement direction and extent were not statistically supported when KR was withdrawn early in practice. The marked performance decrements, observed in the absolute accuracy of responding, which reflected the strength of the memory trace in a ballistic response (Schmidt and White, 1972; Schmidt and Wrisberg, 1972) did not occur in the present experiment. However, there are several possible explanations why the recall of movement in a 120 degree direction did not deteriorate when KR was withdrawn early in learning. It is possible that the imprecision of the measurement unit of the memory trace (degrees) masked the decrement in direction performance. While the subjects' recall of a movement in a 120 degree direction did deteriorate when KR was withdrawn early in learning, from a mean of 5.08 degrees in block 5 to a mean of 6.59 degrees in block 9, the decrement was decidedly small. However, in view of the fact that over the entire twenty blocks of trials, the recall of direction improved from a mean of 9.40 degrees to a mean of 4.40 degrees, a difference of only 5 degrees over 100 trials, the decrement of 1.41 degrees over the 25 KR withdrawal trials became decidedly more meaningful. The most likely explanation of the lack of a decrement in the accuracy of the memory trace for the recall of movement in a direction of 120 degrees was the stabilization in the criterion level and sensitivity of the mechanism detecting errors in that movement. Since an error detection mechanism, which was able to maintain both its criterion level and its sensitivity to that criterion level, had developed in twenty practice trials with KR, the fact that the memory trace was able to maintain its accuracy and strength in the recall of direction was not surprising. Quite in opposition to predictions from Adams' model, the present data attested to the fact that both a strong and accurate error detection mechanism and memory trace for the recall of a movement in a 120 degree direction were in operation after only 20 practice trials. The fact that 55 more trials with KR produced a mean improvement of only 2.19 degrees offered further support for this line of reasoning. Recent research by Hall (1974) concerning the codability and retention characteristics of distance and direction cues provided another avenue of support for a strong and accurate memory trace after only 20 practice trials, when he found that direction cues were easily codable in memory.

There are also several explanations concerning the insignificant decrement in the recognition of a six inch line, when KR was withdrawn early in practice. Although both Schmidt and White (1972) and Schmidt and Wrisberg (1972) were able to demonstrate decrements in the objective-subjective correlations, reflecting the strength of the perceptual trace in a ballistic response, the present error scores, reflecting the strength and accuracy of the perceptual trace in a slow self-paced graded response may have been masked by the fb effect. While the distorted fb group showed a decrement in extent performance over the five early KR withdrawal trials, the heightened fb group exhibited a performance decrement only to block 8 and the normal fb group revealed no deterioration in extent performance, whatsoever. Moreover, despite the fact that the distorted fb group was the least accurate in the recognition of a six inch line and the heightened fb group was the most accurate, these differences failed to reach significance and thus judgement must be suspended on the prediction from Adams' model that the accuracy and strength of the perceptual trace grows as a positive function of experiencing fb stimuli on each trial. In contrast to Schmidt and Wrisberg (1972) who manipulated fb channels and found that when KR was withdrawn, in comparison to groups denied vision and audition, groups with both these fb channels intact exhibited a much smaller decrement which emerged over trials, the present experimenter manipulated both the quality and intensity of only one fb channel, namely proprioception. The present data failed to support the assumption that the perceptual trace grows as a positive function of experiencing fb stimuli when it was shown that there was no difference between the two groups differing in the quality and intensity of these fb dimensions. On the other hand, the fact that the group with distorted sensory fb exhibited a decrement emerging over trials provided weak support for Adams' assumption that the perceptual trace developed as a positive function of the quality of fb stimuli. An alternate, although less likely explanation for the lack of a significant decrement in the accuracy and strength of the perceptual trace was a corresponding stabilization in the criterion level and sensitivity of the mechanism detecting errors in the recognition of movement extent. Although it is possible that a strong and accurate error detection mechanism and perceptual trace, capable of maintaining performance when KR was withdrawn had developed over just 20 practice trials, previous research failed to support this possibility. Adams (1972) was forced to conclude that the error detection mechanism was not a function of practice and Hall (1974) concluded that distance cues were not as exactly represented in memory as direction cues. Consequently, it was unlikely that a strong and accurate error detector had developed. A third and even more remote possibility concerning the lack of a decrement and the size of the expected decrements in terms of fb groups again involved the manipulation of fb. It is possible that the intended difference between fb levels had not materialized in the present thesis, that is, vibration did not distort the incoming sensory fb to the point at which subjects were unable to decode it and heightened fb did not increase the subject's kinesthetic awareness of movement as much as expected.

In summary, the present data provided very little support for Adams' model of motor learning. Contrary to predictions, a strong and accurate error detection mechanism and memory trace for the recall of direction had developed over 20 practice trials with KR and were able to sustain performance when KR was withdrawn early in learning. Similarly, neither the error detection mechanism nor the perceptual trace for the recognition of movement extent exhibited the expected deterioration in performance for normal and heightened fb groups. While a deterioration over blocks was evidenced for the distorted fb group, it was felt that the perceptual trace was not developing as a positive function of the intensity of fb stimuli. However, early KR withdrawal affected both traces in the same way, as expected.

Late Knowledge of Results Withdrawal

As mentioned earlier, support for the functional independence of the two traces would be obtained if late KR withdrawal resulted in different effects on the behavioural indices of the two traces. The present data provided mixed evidence for this contention. On the one hand, it was observed that KR, when withdrawn late in learning, resulted in different effects on the accuracy of the two traces. On the other hand, the different effects observed were not entirely in the predicted direction. While recall of a movement in a 120 degree direction stabilized when KR was withdrawn late in learning, as predicted by Adams' model, recognition of a six inch line for groups receiving normal and heightened sensory fb failed to exhibit continued learning through subjective reinforcement. However, the observed decrement emerging over blocks was, as predicted, for the distorted fb group. When KR, which was their major source of error information over the 75 practice trials was withdrawn, the perceptual trace which had developed during this time was necessarily inaccurate since the sensory consequences of movement laid down on each trial were distorted. This deterioration in recognition supports Adams' contention that the accuracy and strength of the perceptual trace grows as a positive function of the quality of fb stimuli. The present findings were also in line with those of Adams, Goetz and Marshall (1972) who also observed that during KR withdrawal trials, minimal sensory fb, that is the reduction in the number of fb channels available to the subject, resulted in the development of a weak perceptual trace. Similarly, Adams, Marshall and Goetz (1972) and Burwitz (1972) observed that reduction in the number of fb channels resulted in a weak perceptual trace that was not resistant to decay over a retention interval. Therefore, it appeared that the perceptual trace was a positive function of both the amount and quality of sensory fb available.

However, failure of groups receiving normal and heightened sensory fb to continue learning through subjective reinforcement, when KR was withdrawn late in practice, directly contradicted predictions from Adams' model. In contrast, while Schmidt and Wrisberg (1972) observed that the amount of fb determined how well the response was maintained, the present experiment provided evidence that the maintenance of the response by means of subjective reinforcement was not affected by the intensity of sensory fb. Nevertheless, closer inspection of the data showed that while the normal sensory fb group became less accurate over blocks in the recognition of a six inch line, the heightened sensory fb group demonstrated a stabilization in the accuracy of extent performance. The fact that the predicted continued improvement during trials 76 - 100 did not occur possibly could have been the result of boredom and lack of sustained attention on the part of the subjects. Consistent with Adams' model and other studies manipulating sensory fb during KR withdrawal, both the normal and heightened fb groups were more accurate in the recognition of a six inch line than the distorted fb group. Similarly, Adams, Goetz and Marshall (1972) found that, during KR withdrawal trials, performance on a slow self-paced graded response was more accurate with augmented (audition and heightened proprioceptive fb) rather than minimal fb (normal proprioceptive fb). As a result they concluded that the strength of the perceptual trace was a function of the amount of sensory fb. Schmidt and Wrisberg (1972) also observed that groups with standard fb (vision and audition) maintained performance on a ballistic time estimation task significantly better than subjects with limited fb (minus vision and audition). Likewise, they concluded that greater amounts of sensory fb, in the absence of KR, contributed to a more accurate perceptual trace. Unfortunately, to the detriment of Adams' model, the observed differences in the accuracy of the perceptual trace, in the present experiment, although in the expected direction, were not statistically significant. However, both the lack of continued learning via subjective reinforcement and the insignificant differences in the accuracy of the perceptual trace as a function of sensory fb contrary to contentions from Adams' model were the result of the acquisition and maintenance of the perceptual trace not being a function of stimulus intensity. While the present findings confirmed Adams' contention that the acquisition and maintenance of the perceptual trace is a positive function of the quality of sensory fb available, it failed to support Adams' assumption that the accuracy of the perceptual trace is a positive function of the intensity of sensory fb. Also, interestingly enough, post-experimental reports from subjects indicated that they felt that the six inch line was more difficult to learn than the movement in a direction of 120 degrees. This is not surprising in light of recent evidence presented by Hall (1974) who found that while direction and distance movement cues both have access to central processing capacity, distance movement cues are not as exactly represented in memory as direction movement cues.

Also, contrary to Adams model, it was observed that late KR withdrawal resulted in the same effect on the strength of the two traces. Both the memory and perceptual traces maintained their strength when KR was withdrawn late in learning. While this stabilization in strength was expected for the memory trace, it failed to support Adams' assumption that the strength of the perceptual trace developed as a positive function of the intensity of sensory fb. However, it is possible that boredom and lack of sustained attention to the incoming sensory cues contributed to this phenomenon.

The fact subjects could have been bored and were unable to concentrate fully, on the incoming sensory cues was further corroborated by a significant deterioration in the sensitivity of the error detection mechanism for movement extent, at the adopted criterion level. While subjects maintained their established criterion level over blocks 16 to 20, their ability in separating the error signal from biological noise within the predetermined criterion level declined. This finding was consistent with signal detection theory, which states that the probability of detecting a correct signal declines over time. If the subject's attention shifts or his concentration lapses when a signal occurs, his performance is reduced. It was likely that the effects of boredom did not manifest themselves in either the error detection mechanism for direction or the accuracy and strength of the memory trace due to the more easily codable nature of direction cues.

Briefly recapitulating, late KR withdrawal resulted in different effects on the accuracy of the memory and perceptual traces but failed to differentiate the two traces in terms of strength. The memory trace for the recall of a movement in a direction of 120 degrees maintained its accuracy when KR was withdrawn late in practice and the perceptual trace for the recognition of a six inch line of the distorted fb group deteriorated but the perceptual trace of the normal and heightened fb groups failed to show continued learning. Consequently, reasons for departures from expectations in terms of Adams' model were twofold: firstly, the present findings indicate that while the accuracy of the perceptual trace grows as a positive function of the quality of sensory fb, its accuracy is not a function of the intensity of sensory fb; secondly, distance cues have been found to be less exactly represented in memory than direction cues, hence more difficult to code, with this phenomenon being compounded by possible boredom and lack of sustained attention on incoming sensory cues.

Effects of Sensory Feedback

Looking at the effects of sensory fb on the memory trace, over the entire twenty blocks, the present findings that sensory fb influenced both the accuracy and strength of the memory trace are flagrantly contradictory to Adams' model. While the fb effect did not manifest itself during the five blocks of early KR withdrawal and five blocks of late KR withdrawal, over the entire twenty blocks, it exerted a significant influence on the acquisition and maintenance of the memory trace with groups receiving normal and heightened sensory fb developing a more accurate and strong memory trace than the distorted fb group. This finding is crucial to the very essence of Adams' model, since Adams emphatically stated that

> "...... the memory trace is an open-loop motor program because it operates without fb" (Adams, 1971, p.126)

Later, Adams also stated

> "the perceptual trace is a function of fb but not the memory trace" (Adams, 1973).

The present data are the first to provide evidence that Adams' memory trace, rather than being open-loop is, like the perceptual trace, closed loop and operates on the basis of sensory fb. Moreover, the sensitivity of the mechanism detecting errors in direction performance was also affected by sensory fb, over the twenty blocks of trials, with the groups receiving normal and heightened sensory fb being more sensitive to signals over noise than the distorted fb group. Had Adams restricted the role of the memory trace to the mere selection and initiation of the response with control then shifting to the perceptual trace, he would have been correct in his lack of fb involvement since this selection and initiation would have occurred more rapidly than the minimum time for processing sensory fb. However, since he gives the memory trace the responsibility of the direction of the response, and since as the present data show, subjects were able to utilize sensory information in the intertrial interval to modify the direction of their response, a reconceptualization of the open loop nature of the memory trace is necessary.

In a similar view of the effects of sensory fb on the perceptual trace, over the twenty blocks of trials, the evidence that the perceptual trace was a function of the quality and intensity of sensory fb was conflicting. While the accuracy of the perceptual trace over the entire twenty blocks was not a function of the intensity of sensory fb, the earlier effects of the quality of sensory fb appeared to be masked by the intensity effects. Moreover, the strength of the perceptual trace over twenty blocks was found to be a positive function of the quality of sensory fb but was not affected by different intensities of the same sensory source. The present findings that the perceptual trace developed as a function of the quality of sensory fb was related to findings by Adams, Goetz and Marshall (1972), Adams, Marshall and Goetz (1972), Burwitz (1972) and Schmidt and Wrisberg (1972) who found that the perceptual trace developed as a positive function of the number of fb channels and hence the amount of fb. These findings, along with those of the present thesis, provide strong empirical support for the closed loop nature of the perceptual trace.

Moreover, since the sensitivity of the error detection mechanism for movement extent, like its direction counterpart, was shown to be a function of the quality of sensory fb, while the criterion level for detecting errors for both direction and extent were not, it is feasible that the error detection mechanism's sensitivity in detecting errors from biological noise is itself, by nature, closed loop, while the predetermined criterion level is open loop, operating without sensory fb. Consequently, it is seen that Adams' closed loop model of motor learning operates on two levels, with subjects using the first level (error detection, amplification and correction processes) to modify the second level, (the memory and perceptual trace). Moreover the closed loop nature of both levels of the model has received substantial support in the present thesis.

Effects of Knowledge of Results

Looking at the effects of KR on the memory trace, over the twenty blocks of trials, the present data, that both the accuracy and strength of the memory trace for the recall of movement direction improved as a function of KR, provide strong empirical support for the second level of Adams' model. Earlier findings that man attempts to correct his errors on the basis of KR (Thorndike, 1927; Trowbridge and Cason, 1932; Elwell and Grindley, 1938; Dyal, 1966; Nuttin and Greenwald, 1968) and that as the amount of practice with KR was increased, the amount of error progressively decreased (Bilodeau, 1969) were corroborated in the present thesis. However, predictions from signal detection theory that the criterion level and sensitivity of the error detection mechanism were a function of KR were not substantiated. Nevertheless, it is quite possible that subjects started with a strict criterion level for error detection and were sensitive to it throughout the twenty blocks of trials and that improvement in performance was evidenced in the increased ability of the subject to be accurate and precise at the adopted level.

Further support for Adams' model was obtained, when it was observed that over the twenty blocks of trials, the acquisition and development of the accuracy of the perceptual trace was a function of KR. Contradictory to Adams' model was the finding that practice with KR failed to strengthen the perceptual trace. Apparently, subjects were still not consistent although they had become more accurate, in their recognition of a six inch line. Consistent with signal detection theory, both the criterion level and sensitivity of the error detection mechanism for extent of movement also improved as practice with KR increased. Hence, both levels of Adams' closed loop model of motor learning were a positive function of KR.

Timing

The present timing data also provide several lines of support for Adams' model. Since, with the exception of the group denied KR and receiving distorted sensory fb, the mean correlations between the distance moved and the movement time required to move that distance were not significant, it was evident that subjects were doing exactly what Adams in his model predicted - that is, subjects were moving until the discepancy between incoming sensory fb and their perceptual trace within the criterion level established was zero.

Furthermore, an internal timing mechanism was not being used as a cue in the recognition of movement extent. Instead subjects were utilizing the cues provided, namely KR and sensory fb, to recognize movement extent.

Adams' Model Reconceptualized

Since the present data have revealed a need to reconceptualize Adams' closed loop model as originally presented, an attempt to this end has been made by the present author. (Figure 13). The present closed loop model of motor learning has expanded from Adams' original model and operates on two distinct levels. The first level, namely the error detection, amplification and correction processes is structurally identical to Adams' original model. The criterion level, established by the subject for detecting error signals from biological noise inherent in the system, is open loop in nature, operating without sensory fb. Its

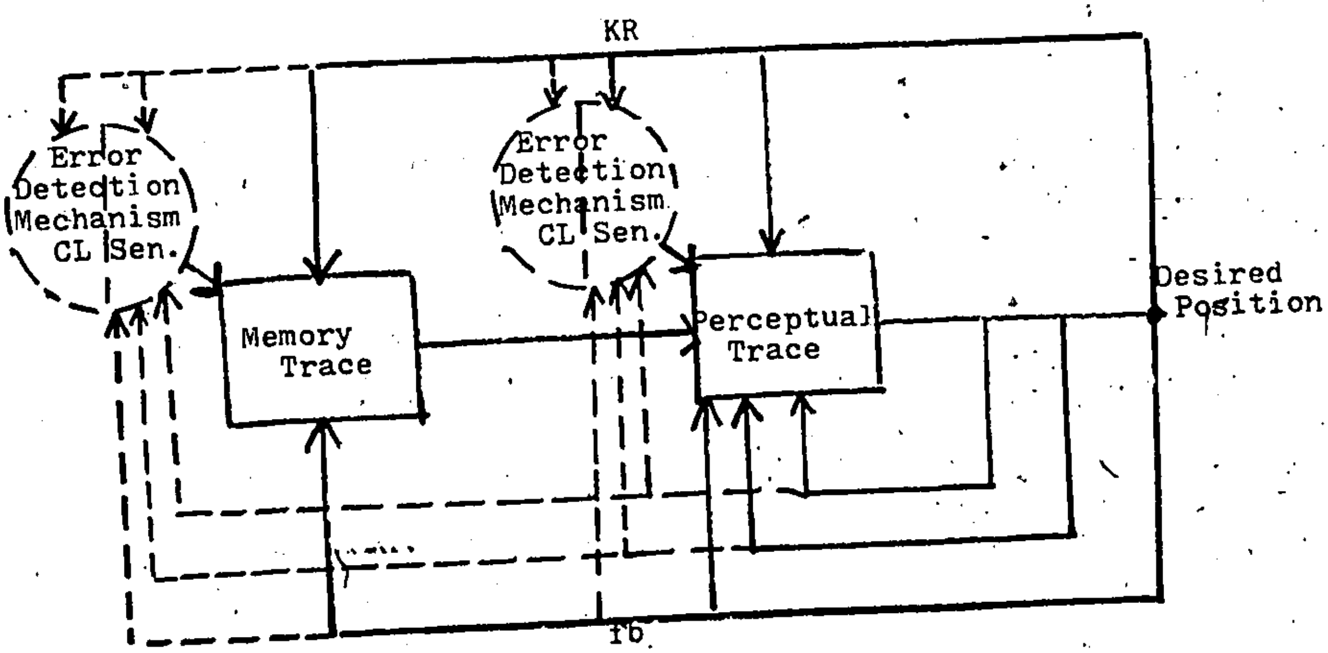


Figure 13 A Dual Closed Loop Model of Motor Learning

accuracy is a positive function of practice with KR but can be affected by the efference copy when KR is unavailable. In contrast, the sensitivity of the error detection mechanism to the criterion level established for detecting errors is closed loop in nature, being continually modified by incoming sensory fb, its strength growing as a positive function of practice with KR and fb.

The second level of the model, namely the controlling agents of direction and extent performance, deviates from Adams' original model in that it is completely closed loop. Both the memory and perceptual trace develop as a positive function of practice with KR and fb.

While several aspects of Adams' original closed loop model of motor learning have been refuted in the present thesis, the closed loop nature of the model has received very strong empirical support. Since it was shown that both the memory and perceptual trace are self-regulatory agents of movement recall and recognition respectively, on the basis of incoming sensory fb, and that the error detection mechanisms underlying each of these controlling agents are also closed loop in nature, control of skilled performance via a closed loop system via sensory fb is considerably enhanced as the superior theory of movement control.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Summary

This study was proposed to investigate the functional independence of the memory and perceptual traces in Adams' (1971) closed loop model of motor learning. The frame of reference was the slow self-paced graded response, the same frame of reference for which the model had been originally proposed. Constant and variable error were used to measure the criterion level and sensitivity of the error detection mechanism, while absolute error and average deviation scores were employed to measure the accuracy and precision, hence strength of the two traces in memory. The independent variables manipulated were sensory fb, KR and practice, with the third level of the KR variable, namely late KR withdrawal, expected to result in different effects on the behavioural indices ($\overline{AE}$ and AV) of each trace, thus demonstrating their functional independence. Each of the 72 subjects were tested under only one level of KR and fb, but over all twenty blocks of practice trials. The sample was drawn from a student population of the University of Windsor, with the only restrictions that subjects were right handed and that there were an equal number of male and female subjects per cell.

Subsequent to a review of the pertinent literature thirty-eight experimental hypotheses were formulated. Data were collected and analyzed using a KR x fb x blocks analysis of variance with repeated measures on blocks, a fb x blocks analysis of variance with repeated measures on blocks and a single factor analysis of variance with repeated measures on blocks. Significant main effects were further analyzed by means of the Tukey (a) procedure. Timing data were also collected and correlations were computed between AP for extent and the mean movement time for each block of trials over the twenty blocks. The results were discussed in terms of Adams' model, pertinent research in the area and signal detection theory, which eventually lead to the more controversial issue of the control of skilled performance, in explanation of which Adams originally proposed his closed loop model.

Conclusions

In light of the findings of the present thesis the following conclusions concerning the validity of Adams' model and some of its ramifications were drawn.

In Support of Adams' Closed Loop Model

1. Learning did not occur in the absence of KR.
2. The memory trace for the recall of movement direction maintained its accuracy when KR was withdrawn late in learning.
3. The acquisition and maintenance of a strong and accurate memory trace for the recall of movement direction is a positive function of experience with KR.
4. The acquisition and maintenance of an accurate perceptual trace for the recognition of movement extent is a positive function of experience with KR.
5. The acquisition and maintenance of an accurate and strong perceptual trace is a positive function of the quality of sensory fb. This conclusion when considered with earlier

findings that the perceptual trace develops as a positive function of the number of fb channels and hence the amount of fb provides strong support for the closed loop nature of the perceptual trace.

6. Subjects, rather than using an internal timing mechanism as a cue in the recognition of movement extent, were moving until the discrepancy between incoming sensory fb and their perceptual trace at the established criterion level was zero.

7. Adams' closed loop model of motor learning is actually a dual closed loop model with the error detection mechanism responsible for the detection, amplification and correction processes operating on the first level and the actual controlling agents in the recall of movement direction and the recognition of movement extent on the second level. The adopted criterion level of the error detection mechanism is open loop in nature operating without sensory fb while the error detection mechanism's sensitivity to the adopted criterion level is closed loop in nature, adjusting itself on the basis of ongoing sensory fb. Both the memory trace and perceptual trace are also closed loop in nature.

Contradictory to Adams' Closed Loop Model

8. Recall of movement direction did not deteriorate when KR was withdrawn early in learning. A strong and accurate memory trace, able to maintain direction performance was in operation after only 20 practice trials.

9. The memory trace, rather than being open-loop is, like the perceptual trace, closed loop and operates on the basis of sensory fb.

10. The acquisition and maintenance of an accurate and strong

perceptual trace is not a positive function of the intensity of sensory fb. Furthermore, the maintenance of accurate recognition of movement extent by means of subjective reinforcement is not affected by the intensity of sensory fb.

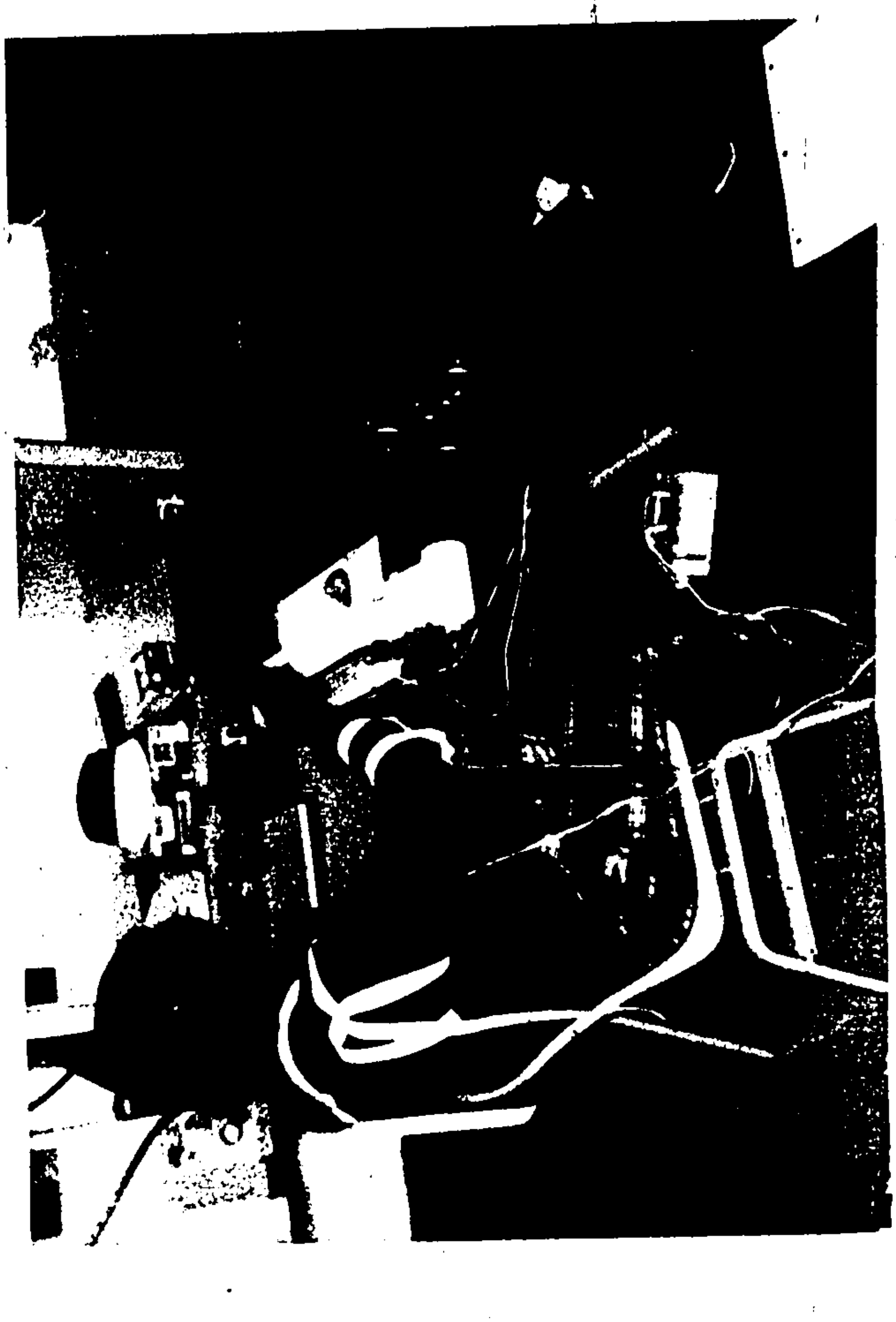
11. The memory trace and perceptual trace were not shown to be functionally independent, in the late KR withdrawal condition. Now that it has been shown that the memory trace is, like the perceptual, self-regulating on the basis of sensory fb, the functional independence of the two traces will be infinitely more difficult to empirically establish since both the recall of movement direction and the recognition of movement extent can improve through the process of subjective reinforcement.

Future Direction

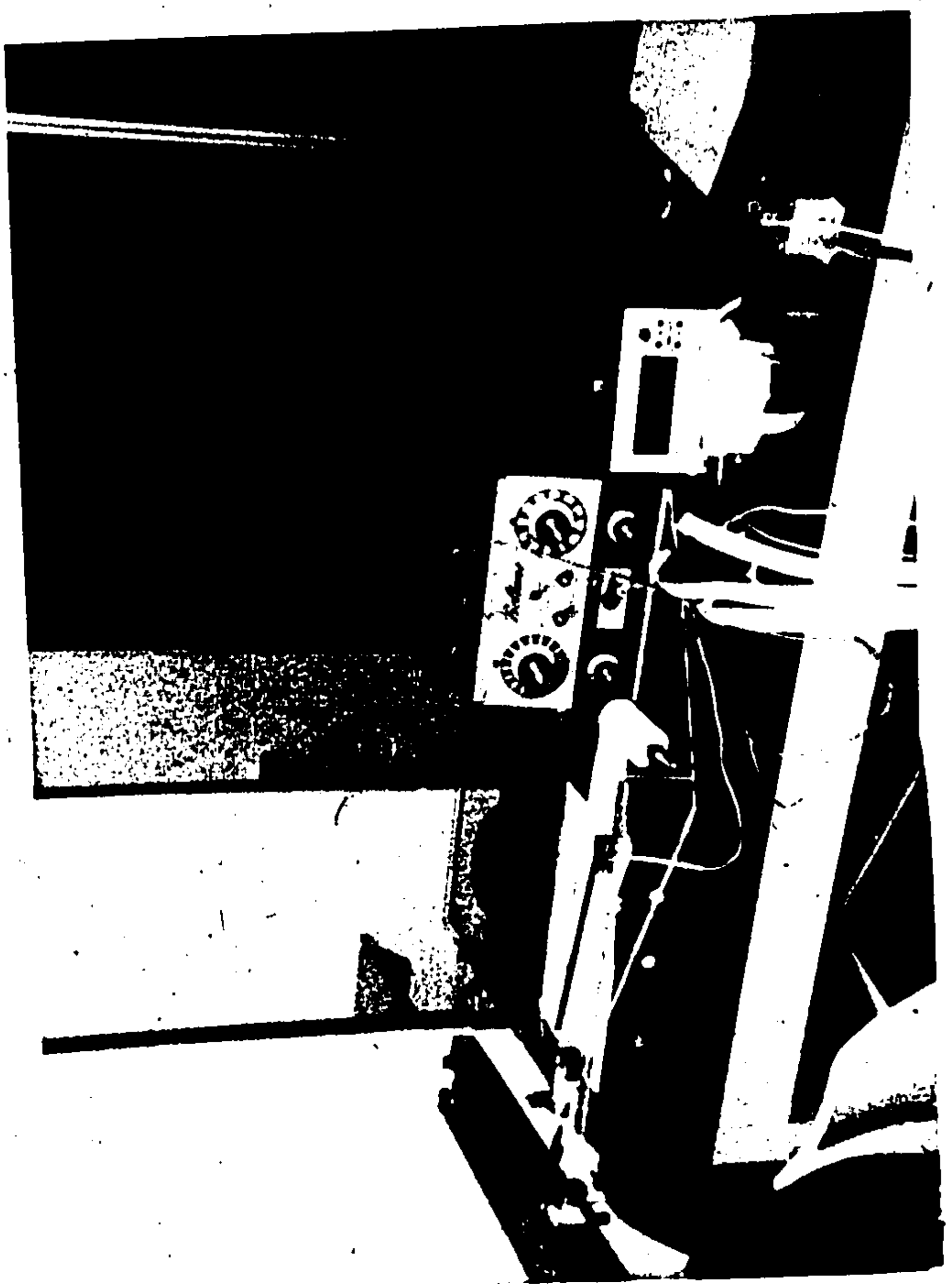
It is evident from the results of the present study that Adams' closed loop model of motor learning, proposed as the superior explanation of movement control, needs a great deal more careful investigation. While the closed loop nature of the model has received strong support in the present thesis and consequently enhances the closed loop theory of movement control, Adams' model, as originally proposed, has received far from total empirical substantiation. First and foremost, future research should further investigate the closed loop nature of the memory trace. Since the present thesis was the first to be concerned with the memory trace's responsibility of the selection and initiation of the slow self-paced, graded response and its direction, corroboration of the role of sensory fb in this function would greatly contribute to the knowledge of how motor performance is initiated. Furthermore, while the modification of the memory trace by sensory fb was by experimental design limited to the intertrial interval, future research should investigate the modification of the memory trace by sensory fb while the response is in progress. Secondly, since it was shown, in the present study, that the intensity of one channel of sensory fb did not affect the acquisition and maintenance of the perceptual trace, future research should concern itself with the codability and retention characteristics of sensory fb at different intensities.

While Adams has stated that the perceptual trace grows as a positive function of experiencing fb stimuli on each trial, the present study has indicated that ongoing self-regulation of movement through a comparison of incoming sensory fb to the perceptual trace is selectively sensitive to the characteristics of the fb stimuli, rather than merely growing as a positive function of available fb stimuli as Adams originally proposed.

APPENDIX A



THE APPARATUS see page 37 for description



APPENDIX B

Instructions to Subjects

The following instructions were read to each subject.

"You will be blindfolded so that you cannot see and noise will be transmitted through earphones so that you cannot hear for the entire experiment. Your signal to begin will be the onset of noise. As soon as it is switched on, you will place your pen at the starting point, making sure that the pen is pressing into the corner of the plastic boundaries. From this point draw a six inch horizontal line, using the fixed plastic boundary as a straight edge and then without stopping or removing your pen from the page, draw a 120 degree angle in a sideward direction. The 120 degree angle is an extension of the six inch horizontal line and is drawn sidewards to the right , away from the straight edge. This task is to be done slowly, with accuracy rather than speed being important." Subjects receiving KR were given these additional instructions.

The subjects in the three early KR withdrawal conditions received the following instructions.

"You will be given KR about your performance during trials 1-20 and trials 46-100. You will receive no KR during trials 21-45 but you are to try to reduce errors on the basis of your own evaluation. KR for the length of your line will be given in terms of how far in 1/20 inch units, which is the size of one square on the graph paper, your line deviated from the required six inch line. The direction of your error will be indicated. For example, your line was

10 units short. Therefore, you know that your line was 10/20 of ½ inch short of the required six inch line. KR for the direction of your angle will be given in terms of how far in degrees your angle deviated from the required 120 degree angle. The direction of your error will be indicated. For example your angle was 10 degrees short. Therefore, you know that your angle was 10 degrees short of the required 120 degree angle or 110 degrees."

The subjects in the three late KR withdrawal conditions received the following instructions.

"You will be given KR about your performance during trials 1-75. You will receive no KR during trials 76-100, but you are to try to reduce errors on the basis of your own evaluation."

The same instructions concerning the meaning of KR that were given to the subjects in the early KR withdrawal conditions were repeated here to subjects in the late KR withdrawal conditions.

The subjects in the three distorted proprioceptive fb conditions were given these additional instructions.

"Vibrators will be strapped to your right forearm just below your elbow and on the front of your right shoulder. They will be switched on five seconds before you hear the noise, which is your signal to start and will be switched off upon completion of the task."

The subjects in the three heightened proprioceptive fb conditions were given these additional instructions.

"You will be pulling a weight when you draw the six inch horizontal line and the 120 degree angle. There may be a tendency to move quickly during the execution of this task. This must be counteracted by making a conscious effort to move slowly. There may also be a tendency for the line drawn to the right, away from the straight edge, forming the 120 degree angle to be curvilinear instead of straight, due to the weight. This tendency to draw a curved line sidewards to form the angle must be consciously counteracted and a straight line must be drawn."

The subjects in the three normal and three heightened proprioceptive fb conditions were told that the vibrators were being strapped to their right forearms and shoulders to provide additional resistance to their arm, while performing the task.

APPENDIX C

TABLE 19

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{CE}$ OF DIRECTION FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	22056.020	7	3150.8600		
WITH PEOPLE	8068.941	152	53.0851		
TREATMENTS	2579.831	19	135.7806	3.29	0.0000
RESIDUAL	5489.105	133	41.2715		
TOTAL	30124.960	159			

TABLE 20

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF DIRECTION FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	223.4453	7	31.9207		
WITH PEOPLE	849.7695	152	5.5905		
TREATMENTS	110.6796	19	5.8252	1.05	0.4118
RESIDUAL	739.0898	133	5.5570		
TOTAL	1073.2140	159			

TABLE 21

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF DIRECTION FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	3056.003	7	436.5717		
WITH PEOPLE	4222.660	152	27.7807		
TREATMENTS	663.230	19	34.9069	1.30	0.1909
RESIDUAL	3559.429	133	26.7626		
TOTAL	7278.664	159			

TABLE 22

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF DIRECTION FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	126.0429	7	18.0061		
WITH PEOPLE	580.4548	152	3.8187		
TREATMENTS	96.8499	19	5.0973	1.40	0.1362
RESIDUAL	483.6049	133	3.6361		
TOTAL	706.4978	159			

TABLE 23

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{CE}$ OF DIRECTION FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	10039.58	7	1434.225		
WITH PEOPLE	4071.91	152	26.789		
TREATMENTS	614.65	19	32.350	1.24	0.2322
RESIDUAL	3457.25	133	25.994		
TOTAL	14111.48	159			

TABLE 24

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF DIRECTION FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	195.6813	7	32.6135		
WITH PEOPLE	502.3654	152	3.7771		
TREATMENTS	47.2656	19	2.4876	0.62	0.8818
RESIDUAL	455.0998	133	3.9921		
TOTAL	698.0468	159			

TABLE 25

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF DIRECTION FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	2198.738	7	314.1054		
WITH PEOPLE	2136.761	152	14.0576		
TREATMENTS	296.109	19	15.5847	1.13	0.3326
RESIDUAL	1840.652	133	13.8395		
TOTAL	4335.500	159			

TABLE 26

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF DIRECTION FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	106.5693	7	15.2241		
WITH PEOPLE	315.7556	152	2.0773		
TREATMENTS	27.7434	19	1.4601	0.67	0.8387
RESIDUAL	288.0122	133	2.1655		
TOTAL	422.3249	159			

TABLE 27

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{CE}$ OF DIRECTION FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	9196.64	7	1313.805		
WITH PEOPLE	4957.98	152	32.618		
TREATMENTS	3732.89	19	196.468	21.33	0.0000
RESIDUAL	1225.09	133	9.211		
TOTAL	14154.62	159			

TABLE 28

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF DIRECTION FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	89.6892	7	12.8127		
WITH PEOPLE	526.8815	152	3.4663		
TREATMENTS	61.5786	19	3.2409	0.93	0.5518
RESIDUAL	465.3029	133	3.4985		
TOTAL	616.5708	159			

TABLE 29

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF DIRECTION FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	1392.304	7	198.9006		
WITH PEOPLE	2813.890	152	18.5124		
TREATMENTS	343.813	19	18.0954	0.97	0.4950
RESIDUAL	2470.078	133	18.5720		
TOTAL	4206.195	159			

TABLE 30

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF DIRECTION FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	37.3293	7	5.3328		
WITH PEOPLE	456.0549	152	3.0003		
TREATMENTS	66.2239	19	3.4855	1.19	0.2760
RESIDUAL	389.8310	133	2.9311		
TOTAL	493.3842	159			

TABLE 31

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{CE}$ OF DIRECTION DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	2631.252	23			
A	171.131	2	85.566	0.73	0.4936
SUBJ W GROUP	2460.121	21	117.149		
WITHIN SUBJ	1544.813	96			
B	102.694	4	25.673	1.65	0.1697
AB	133.900	8	16.738	1.08	0.3887
B X SUBJ W G	1308.220	84	15.574		

TABLE 32

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE VE OF DIRECTION DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	162.349	23			
A	36.941	2	18.471	3.09	0.0665
SUBJ W GROUP	125.406	21	5.972		
WITHIN SUBJ	332.626	96			
B	8.467	4	2.117	0.67	0.6183
AB	56.625	8	7.078	2.22	0.0335
B X SUBJ W G	267.536	84	3.185		

TABLE 33

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{AE}$ OF DIRECTION DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	499.273	23			
A	24.908	2	12.454	0.55	0.5843
SUBJ W GROUP	474.363	21	22.589		
WITHIN SUBJ	692.078	96			
B	50.229	4	12.557	1.77	0.1420
AB	46.709	8	5.839	0.82	0.5837
B X SUBJ W G	595.137	84	7.085		

TABLE 34

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE AV OF DIRECTION DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	59.446	23			
A	4.852	2	2.426	0.93	0.4090
SUBJ W GROUP	54.593	21	2.600		
WITHIN SUBJ	151.280	96			
B	6.807	4	1.702	1.14	0.3450
AB	18.695	8	2.337	1.56	0.1491
B X SUBJ W G	125.779	84	1.497		

TABLE 35

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{CE}$ OF DIRECTION DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	2730.648	23			
A	107.943	2	53.972	0.43	0.6548
SUBJ W GROUP	2622.705	21	124.891		
WITHIN SUBJ	949.358	96			
B	28.467	4	7.117	0.68	0.6051
AB	46.615	8	5.827	0.56	0.8077
B X SUBJ W G	874.276	84	10.408		

TABLE 36

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE VE OF DIRECTION DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	234.916	23			
A	58.186	2	29.093	3.46	0.0504
SUBJ W GROUP	176.728	21	8.416		
WITHIN SUBJ	178.883	96			
B	5.743	4	1.436	0.75	0.5600
AB	12.659	8	1.582	0.83	0.5802
B X SUBJ W G	160.484	84	1.911		

TABLE 37

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{AE}$ OF DIRECTION DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	734.145	23			
A	62.453	2	31.227	0.98	0.3932
SUBJ W GROUP	671.688	21	31.985		
WITHIN SUBJ	462.449	96			
B	53.998	4	13.500	3.07	0.0207
AB	38.871	8	4.859	1.11	0.3687
B X SUBJ W G	369.582	84	4.400		

TABLE 38

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE AV OF DIRECTION DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	108.361	23			
A	18.892	2	9.446	2.22	0.1338
SUBJ W GROUP	89.486	21	4.260		
WITHIN SUBJ	95.696	96			
B	1.694	4	0.423	0.46	0.7634
AB	17.013	8	2.127	2.32	0.0266
B X SUBJ W G	76.990	84	0.917		

TABLE 39

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE $\overline{CE}$ OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	53876.73	71			
A	71.14	2	35.571	0.05	0.9542
B	3088.40	2	1544.199	2.03	0.1402
AB	2714.13	4	678.533	0.89	0.4748
SUBJ W GROUP	48003.06	63	761.953		
WITHIN SUBJ	33960.93	1368			
C	1425.26	19	75.014	3.56	0.0000
AC	3425.01	38	90.132	4.28	0.0000
BC	1397.12	38	36.766	1.75	0.0040
ABC	2507.12	76	32.988	1.57	0.0020
C X SUBJ W G	25206.38	1197	21.058		

TABLE 40

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE VE OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	2785.082	71			
A	54.461	2	27.2305	0.79	0.4561
B	451.125	2	225.5625	6.58	0.0025
AB	120.391	4	30.0977	0.88	0.4820
SUBJ W GROUP	2159.106	63	34.2715		
WITHIN SUBJ	7400.043	1368			
C	891.152	19	46.9027	9.84	0.0000
AC	274.516	38	7.2241	1.52	0.0244
BC	224.883	38	5.9177	1.24	0.1464
ABC	304.445	76	4.0059	0.84	0.8569
C X SUBJ W G	5705.047	1197	4.7661		

TABLE 41

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE $\overline{AE}$ OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	17491.00	71			
A	7061.88	2	3530.938	25.15	0.0000
B	1180.19	2	590.094	4.20	0.0193
AB	403.19	4	100.797	0.72	0.5827
SUBJ W GROUP	8845.75	63	140.409		
WITHIN SUBJ	17269.75	1368			
C	1169.81	19	61.569	5.41	0.0000
AC	711.06	38	18.712	1.64	0.0091
BC	726.38	38	19.115	1.68	0.0068
ABC	1045.50	76	13.757	1.21	0.1093
C X SUBJ W G	13617.00	1197	11.378		

TABLE 42

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE AV OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	1278.844	71			
A	117.926	2	58.9629	4.37	0.0166
B	243.539	2	121.7695	9.03	0.0004
AB	77.273	4	19.3184	1.43	0.2333
SUBJ W GROUP	849.105	63	13.4779		
WITHIN SUBJ	4326.773	1368			
C	406.914	19	21.4165	7.54	0.0000
AC	147.207	38	3.8739	1.36	0.0696
BC	144.809	38	3.8108	1.34	0.0803
ABC	226.992	76	2.9867	1.05	0.3613
C X SUBJ W G	3400.852	1197	2.8411		

TABLE 43

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{CE}$ OF EXTENT FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	253091.80	7	36155.97		
WITH PEOPLE	46922.12	152	308.70		
TREATMENTS	23363.75	19	1229.67	6.94	0.0000
RESIDUAL	23558.37	133	177.13		
TOTAL	300013.90	159			

TABLE 44

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF EXTENT FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	1635.148	7	233.5926		
WITH PEOPLE	3492.609	152	22.9777		
TREATMENTS	792.449	19	41.7078	2.05	0.0096
RESIDUAL	2700.160	133	20.3019		
TOTAL	5127.757	159			

TABLE 45

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF EXTENT FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	63833.37	7	9119.050		
WITH PEOPLE	23052.62	152	151.662		
TREATMENTS	3055.50	19	160.816	1.07	0.3891
RESIDUAL	19997.12	133	150.354		
TOTAL	86886.00	159			

TABLE 46

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF EXTENT FOR THE DISTORTED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	797.285	7	113.8978		
WITH PEOPLE	1732.566	152	11.3985		
TREATMENTS	432.266	19	22.7508	2.33	0.0028
RESIDUAL	1300.300	133	9.7767		
TOTAL	2529.851	159			

TABLE 47

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE CE OF EXTENT FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	89814.25	7	12830.60		
WITH PEOPLE	11513.12	152	75.74		
TREATMENTS	705.00	19	37.11	0.46	0.9747
RESIDUAL	10808.12	133	81.26		
TOTAL	101327.30	159			

TABLE 48

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF EXTENT FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	100.652	7	14.3789		
WITH PEOPLE	1729.285	152	11.3769		
TREATMENTS	341.539	19	17.9757	1.72	0.0396
RESIDUAL	1387.746	133	10.4342		
TOTAL	1829.94	159			

TABLE 49

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF EXTENT FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	44528.25	7	6361.1750		
WITH PEOPLE	8080.38	152	53.1604		
TREATMENTS	715.38	19	37.6513	0.68	0.8334
RESIDUAL	7365.00	133	55.3759		
TOTAL	52608.62	159			

TABLE 50

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF EXTENT FOR THE NORMAL SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	50.363	7	7.1948		
WITH PEOPLE	1586.027	152	10.4344		
TREATMENTS	318.293	19	16.7523	1.76	0.0343
RESIDUAL	1267.734	133	9.5318		
TOTAL	1636.390	159			

TABLE 51

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE CE OF EXTENT FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	554371.00	7	79195.81		
WITH PEOPLE	22579.81	152	148.55		
TREATMENTS	5556.16	19	292.43	2.28	0.0034
RESIDUAL	17023.59	133	127.99		
TOTAL	576950.80	159			

TABLE 52

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE VE OF EXTENT FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	475.352	7	67.9074		
WITH PEOPLE	1903.835	152	12.5252		
TREATMENTS	360.289	19	18.9626	1.63	0.0567
RESIDUAL	1543.546	133	11.6056		
TOTAL	2379.187	159			

TABLE 53

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE $\overline{AE}$ OF EXTENT FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	135295.60	7	19327.95		
WITH PEOPLE	13283.31	152	87.39		
TREATMENTS	549.00	19	28.89	0.30	0.9981
RESIDUAL	12734.31	133	95.75		
TOTAL	148579.00	159			

TABLE 54

SINGLE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES FOR THE AV OF EXTENT FOR THE HEIGHTENED SENSORY FB GROUP

Source	SS	df	MS	F	P
BET PEOPLE	441.738	7	63.1055		
WITH PEOPLE	1890.625	152	12.4383		
TREATMENTS	297.641	19	15.6653	1.31	0.1886
RESIDUAL	1592.984	133	11.9773		
TOTAL	2332.363	159			

TABLE 55

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{CE}$ OF EXTENT DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	18679.79	23			
A	347.91	2	173.957	0.20	0.8209
SUBJ W GROUP	18331.87	21	872.946		
WITHIN SUBJ	8757.13	96			
B	152.52	4	38.129	0.40	0.8104
AB	532.24	8	66.530	0.69	0.6972
B X SUBJ W G	8072.36	84	96.100		

TABLE 56

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE VE OF EXTENT DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	917.570	23			
A	41.293	2	20.646	0.50	0.6166
SUBJ W GROUP	876.273	21	41.727		
WITHIN SUBJ	1326.727	96			
B	46.660	4	11.665	0.83	0.5085
AB	102.406	8	12.801	0.91	0.5099
B X SUBJ W G	1177.660	84	14.020		

TABLE 57

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{AE}$ OF EXTENT DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	6230.957	23			
A	828.896	2	414.448	1.61	0.2234
SUBJ W GROUP	5402.051	21	257.240		
WITHIN SUBJ	4052.234	96			
B	247.629	4	61.907	1.54	0.1993
AB	418.059	8	52.257	1.30	0.2567
B X SUBJ W G	3386.543	84	40.316		

TABLE 58

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE AV OF EXTENT DURING EARLY KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	634.625	23			
A	43.986	2	21.993	0.78	0.4704
SUBJ W GROUP	590.645	21	28.126		
WITHIN SUBJ	734.043	96			
B	9.115	4	2.279	0.28	0.8916
AB	35.926	8	4.491	0.55	0.8174
B X SUBJ W G	689.008	84	8.202		

TABLE 59

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE CE OF EXTENT DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	5888.270	23			
A	167.043	2	83.521	0.31	0.7392
SUBJ W GROUP	5721.227	21	272.439		
WITHIN SUBJ	3474.590	96			
B	26.946	4	6.737	0.18	0.9484
AB	296.369	8	37.046	0.99	0.4517
B X SUBJ W G	3151.274	84	37.515		

TABLE 60

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE VE OF EXTENT DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	1337.004	23			
A	302.223	2	151.111	3.07	0.0678
SUBJ W GROUP	1034.781	21	49.275		
WITHIN SUBJ	873.023	96			
B	87.822	4	21.956	2.69	0.0364
AB	100.182	8	12.523	1.54	0.1573
B X SUBJ W G	685.035	84	8.155		

TABLE 61

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE $\overline{AE}$ OF EXTENT DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	2246.602	23			
A	328.080	2	164.040	1.80	0.1906
SUBJ W GROUP	1918.523	21	91.358		
WITHIN SUBJ	1397.637	96			
B	241.926	4	60.481	5.37	0.0007
AB	209.459	8	26.182	2.32	0.0264
B X SUBJ W G	946.262	84	11.265		

TABLE 62

TWO FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR THE AV OF EXTENT DURING LATE KR WITHDRAWAL

Source	SS	df	MS	F	P
BET SUBJ	642.511	23			
A	94.240	2	47.120	1.81	0.1891
SUBJ W GROUP	548.271	21	26.108		
WITHIN SUBJ	653.191	96			
B	46.266	4	11.566	1.96	0.1090
AB	109.826	8	13.728	2.32	0.0267
B X SUBJ W G	497.095	84	5.918		

TABLE 63

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE $\overline{CE}$ OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	1065759.0	71			
A	141319.5	2	70659.75	4.88	0.0107
B	3203.5	2	1601.75	0.11	0.8952
AB	9698.8	4	2424.69	0.17	0.9539
SUBJ W GROUP	911537.5	63	14468.85		
WITHIN SUBJ	163893.0	1368			
C	34626.2	19	1822.43	20.70	0.0000
AC	8437.4	38	222.04	2.52	0.0000
BC	7100.9	38	186.87	2.12	0.0001
ABC	8361.1	76	110.01	1.25	0.0756
C X SUBJ W G	105367.4	1197	88.03		

TABLE 64

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE VE OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	9254.38	71			
A	1390.25	2	695.1250	7.69	0.0010
B	1949.63	2	974.8125	10.78	0.0001
AB	218.44	4	54.6094	0.60	0.6610
SUBJ W GROUP	5696.06	63	90.4137		
WITHIN SUBJ	29759.38	1368			
C	7249.88	19	381.5723	24.79	0.0000
AC	2155.50	38	56.7237	3.69	0.0000
BC	730.00	38	19.2105	1.25	0.1409
ABC	1201.56	76	15.8100	1.03	0.4173
C X SUBJ W G	18422.44	1197	15.3905		

TABLE 65

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE $\overline{AE}$ OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	613094.6	71			
A	322976.3	2	161488.1	40.89	0.0000
B	12261.1	2	6130.6	1.55	0.2197
AB	29052.9	4	7263.2	1.84	0.1324
SUBJ W GROUP	248804.3	63	3949.3		
WITHIN SUBJ	85256.0	1368			
C	12827.3	19	675.1	13.11	0.0000
AC	4942.6	38	130.1	2.53	0.0000
BC	3111.8	38	81.9	1.59	0.0139
ABC	2739.6	76	36.0	0.70	0.9340
C X SUBJ W G	61635.3	1197	51.5		

TABLE 66

THREE FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "C" FOR THE AV OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	4229.88	71			
A	110.75	2	55.3750	1.24	0.2958
B	1178.25	2	589.1250	13.21	0.0000
AB	130.75	4	32.6875	0.73	0.5728
SUBJ W GROUP	2810.13	63	44.6051		
WITHIN SUBJ	21459.75	1368			
C	5528.25	19	290.9605	27.30	0.0000
AC	1738.25	38	45.7434	4.29	0.0000
BC	420.75	38	11.0724	1.04	0.4028
ABC	1016.94	76	13.3808	1.26	0.071
C X SUBJ W G	12755.56	1197	10.6563		

APPENDIX D

TABLE 67

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE DISTORTED FB GROUP PRACTICING WITHOUT KR

	Direction			
Error Score	$\overline{CE}$	VE	$\overline{AE}$	AV
Block Number				
1	8.2000	7.6784	18.2500	6.2548
2	5.2000	6.4736	13.9000	5.9099
3	6.2250	4.6204	11.4750	3.8084
4	2.9750	4.7563	10.6750	4.2623
5	0.2000	5.7489	11.0500	5.2443
6	-4.6750	5.3577	12.2250	4.5638
7	-3.1125	4.9886	9.1125	4.5467
8	-3.5000	4.5224	11.6000	4.0147
9	-5.1375	6.0373	14.5875	5.1432
10	-4.1500	5.1362	10.6500	4.7372
11	-3.2750	5.4191	10.3250	4.2845
12	-5.2750	5.2742	10.8250	4.1820
13	-3.3000	4.3034	11.2000	3.2357
14	-3.5250	4.9946	12.4750	5.1047
15	-3.7500	5.5876	12.6500	5.2482
16	-2.6000	3.4704	12.4500	3.1878
17	-2.9250	6.0438	14.6250	5.2682
18	-2.4750	5.0220	12.2250	3.9762
19	-4.3750	5.1977	15.0750	5.0104
20	-6.3250	5.8220	13.4250	4.4147

TABLE 68

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE NORMAL FB GROUP PRACTICING WITHOUT KR

	Direction			
Error Score	$\overline{CE}$	VE	$\overline{AE}$	AV
Block Number				
1	2.0500	6.1861	9.6500	3.6772
2	2.2750	4.8802	9.7750	3.9582
3	3.1000	3.6550	8.9500	2.9182
4	1.9750	4.3672	10.8250	4.0539
5	4.8000	4.0434	10.9500	3.6934
6	5.9750	3.6952	9.3750	3.3869
7	5.4000	3.6099	10.1000	3.0339
8	6.9250	3.9728	9.0250	3.9728
9	6.3250	3.7425	10.0750	3.5162
10	5.4250	3.6664	9.5750	3.0841
11	2.7500	4.5648	7.4000	4.0211
12	2.9000	3.4267	7.3000	2.8866
13	2.1000	4.1785	8.2500	3.8697
14	1.3750	3.6260	7.2000	3.5096
15	2.7500	3.6541	7.9500	2.7676
16	1.8750	3.9111	5.7500	3.3109
17	1.4250	4.3043	7.4750	3.8663
18	0.9500	4.0552	7.9500	3.6984
19	-0.0500	3.2233	9.9500	3.0028
20	1.1500	4.0807	7.6000	3.8739

TABLE 69

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE HEIGHTENED FB GROUP PRACTICING WITHOUT KR

Error Score	Direction			
Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	4.4250	5.8060	8.9750	4.4744
2	4.6250	3.7685	6.9750	3.3132
3	1.2875	4.2267	7.9875	3.3524
4	-0.8750	4.0892	8.7250	4.0199
5	0.4750	2.6319	7.5750	2.0873
6	-0.9750	4.2160	7.9250	3.1780
7	-3.0500	4.0561	8.8500	3.5258
8	-3.9250	4.6423	9.2750	3.4888
9	-5.8750	4.2020	9.3250	3.4399
10	-5.8250	3.5976	8.2750	3.5130
11	-6.4250	4.2463	8.8750	3.6701
12	-7.4250	3.7444	10.8750	3.2002
13	-7.6000	3.3905	10.6000	2.9262
14	-9.4250	3.7601	10.7250	3.5199
15	-8.2000	3.3299	10.2500	2.7938
16	-8.7000	3.5531	11.1000	3.1074
17	-8.7500	4.6983	10.2000	4.2415
18	-9.7000	4.2957	10.4000	3.9728
19	-10.6000	3.9142	10.8500	3.7019
20	-12.1000	3.9740	13.2500	3.8931

TABLE 70

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE DISTORTED FB GROUP DURING EARLY KR WITHDRAWAL

	Direction			
Error Score Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-4.4000	8.6933	11.8375	5.4254
2	-1.3250	5.7953	6.3750	3.5231
3	1.6250	5.2914	6.3250	3.7540
4	-2.7250	5.5586	6.5250	4.9774
5	-3.0750	4.0385	5.6250	3.2156
6	-1.8250	4.3394	6.8750	3.4021
7	-1.8875	5.1467	6.6375	4.3384
8	-3.2250	4.9433	8.5250	3.0748
9	-2.3250	3.3005	6.0250	2.5716
10	-1.7000	4.5033	5.6500	3.2402
11	-2.8000	6.2558	6.3000	5.0716
12	0.3250	4.7204	5.4250	4.4824
13	-1.2750	4.3836	4.1000	2.4661
14	-1.1750	3.8203	3.4250	2.9645
15	-1.6750	4.2784	4.3750	2.9076
16	-1.9250	3.6558	4.5250	2.8643
17	-2.7750	5.0027	5.1750	3.5391
18	-1.8750	5.2757	5.4250	4.5772
19	-1.7250	4.0777	4.6750	3.2115
20	-0.7000	4.9633	4.9000	3.7796

TABLE 71

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE NORMAL FB GROUP DURING EARLY KR WITHDRAWAL

	Direction			
Error Score	$\overline{CE}$	VE	$\overline{AE}$	AV
Block Number				
1	2.0750	7.2034	7.4250	4.7340
2	2.5750	2.8929	3.8250	1.9311
3	2.2500	4.2719	5.3500	2.8813
4	1.5250	4.8956	5.6250	3.0740
5	2.5750	4.3217	5.1750	3.1843
6	1.9750	3.6160	5.6250	3.0693
7	0.4750	3.1000	5.9750	2.9046
8	-1.3750	4.1711	6.5750	2.8724
9	-1.9500	3.0695	6.1000	2.8863
10	-1.4000	4.6247	7.2000	2.9055
11	1.1750	4.1816	5.3250	2.4993
12	0.6000	4.0580	4.4000	2.6954
13	-0.0250	3.8235	4.6750	2.9302
14	0.4000	3.8985	4.6500	2.8154
15	1.0250	3.1806	3.9250	2.3159
16	0.3750	4.2629	4.8500	2.6424
17	0.0000	4.2300	4.2000	2.5607
18	-0.0750	3.6714	3.3750	2.3518
19	1.2000	3.4629	3.1500	2.6060
20	0.5250	3.6863	3.5250	1.6233

TABLE 72

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE HEIGHTENED FB GROUP DURING EARLY KR WITHDRAWAL

	Direction			
Error Score	$\overline{CE}$	VE	$\overline{AE}$	AV
Block Number				
1	1.8250	7.4515	8.9250	4.7216
2	3.1250	3.7474	7.9750	5.4445
3	-1.8250	5.0162	6.2250	3.5975
4	0.0500	4.8185	5.1500	2.8415
5	0.9000	4.4004	4.4500	2.4831
6	-1.8250	4.8297	4.8750	3.6683
7	-3.9500	3.8283	5.7000	2.9472
8	-2.0000	5.3750	5.7500	3.1893
9	-2.0000	6.6392	7.6500	4.0679
10	-3.3000	4.9359	6.2500	3.7882
11	-1.7500	4.3394	4.7750	3.6705
12	-1.7500	4.8834	5.3500	3.2037
13	-1.1250	5.1726	4.6250	3.2233
14	-1.1750	4.7639	4.7250	3.1789
15	-1.4500	3.6416	4.5500	2.6759
16	-0.9250	4.8179	4.8250	3.3707
17	-1.3250	3.1791	4.0750	2.6790
18	-0.2000	4.0765	4.3000	2.7825
19	-2.2250	4.4495	4.7250	3.2835
20	-1.2500	4.3788	4.8000	2.5636

TABLE 73

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE DISTORTED FB GROUP DURING LATE KR WITHDRAWAL

Error Score Block Number	Direction $\overline{CE}$	VE	$\overline{AE}$	AV
1	-7.0750	11.5781	12.9250	9.0258
2	-4.0500	8.9430	11.2500	5.3164
3	-4.6500	6.6733	9.3500	4.3662
4	-2.3250	7.2997	9.0250	5.1557
5	-3.1750	8.5021	8.4750	4.5108
6	-1.8750	4.7042	6.1250	3.0520
7	-0.9750	5.5232	5.7750	3.4171
8	-1.1750	5.1248	6.2625	3.5982
9	-1.5000	6.2172	7.3000	3.8121
10	-0.1000	3.3071	3.3500	2.3380
11	-0.2250	5.3169	5.2250	3.6529
12	-0.2250	4.8691	5.3250	3.5294
13	-0.6500	5.3044	6.0500	3.4309
14	0.1000	5.8266	5.6500	4.5694
15	-1.1000	4.1162	4.8500	2.4262
16	-0.2500	4.0787	4.6500	2.5135
17	-0.2750	4.5971	4.4750	3.4556
18	-1.4500	4.7608	4.5500	3.8311
19	-0.1250	4.6618	4.6750	3.5462
20	-2.5250	3.5855	6.2250	2.3796

TABLE 74

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE NORMAL FB GROUP DURING LATE KR WITHDRAWAL

Error Score	Direction			
Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-1.5000	7.3715	6.9500	4.0297
2	-2.2750	4.9468	7.1250	3.7590
3	-2.2250	3.8728	5.1750	2.7515
4	-2.5000	3.8066	4.7500	2.5274
5	-0.2750	3.5552	3.2250	2.1194
6	-0.5500	3.7740	4.2000	2.6359
7	-1.3500	4.1232	4.3250	2.5390
8	-0.2500	4.7184	4.1000	3.1590
9	-0.5250	3.8345	3.4750	2.2872
10	-1.0500	2.6619	4.0500	2.0284
11	-0.9500	2.8428	3.7000	2.1409
12	-0.1250	3.0873	3.8750	2.1064
13	-0.5000	3.9832	4.4500	2.6696
14	-0.8750	4.2882	4.5750	2.9243
15	-1.0500	4.1173	4.1500	2.7311
16	0.3250	2.6741	3.2250	2.1275
17	0.9500	3.3540	4.5000	2.8221
18	-0.1000	2.8690	5.1500	2.4463
19	-0.9250	2.4359	5.7500	2.3134
20	-0.9125	3.1076	4.9875	2.3716

TABLE 75

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF DIRECTION FOR THE HEIGHTENED FB GROUP DURING LATE KR WITHDRAWAL

	Direction			
Error Score Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	2.7750	7.1782	13.9750	6.1183
2	-2.5125	5.6850	9.0500	4.2029
3	-0.6250	6.4075	9.6750	3.8819
4	-1.8000	5.3474	10.4250	3.6205
5	-0.6500	6.9642	9.7500	5.0854
6	-0.8000	6.1924	10.1750	3.9467
7	-0.6875	4.3179	6.2500	3.1713
8	-1.4750	6.2821	9.2250	3.5712
9	-1.3750	4.9385	7.4750	3.2295
10	-1.2750	5.8698	8.4000	4.3985
11	-0.8000	3.8438	5.5000	2.3756
12	-2.0000	4.5172	9.1250	2.5810
13	-0.3750	5.7646	8.4000	3.9078
14	0.2500	3.3050	5.6750	2.2659
15	-0.0000	4.8034	7.1750	2.2535
16	-2.7500	4.3931	6.0750	3.5105
17	-2.7000	4.9678	6.8250	4.0296
18	-3.2500	3.7740	7.1500	3.3744
19	-1.2000	4.2062	6.3000	2.9207
20	-2.2000	4.6199	7.4250	4.0744

TABLE 76

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE DISTORTED FB GROUP PRACTICING WITHOUT KR

	Extent			
Error Score Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-55.2000	8.7439	56.1000	7.2646
2	-46.7499	12.2046	48.5500	9.6411
3	-34.1999	5.5749	42.6500	5.0524
4	-29.4500	7.3694	40.0500	6.9455
5	-23.9750	7.7710	41.8250	5.8877
6	-20.3750	11.9100	43.8250	11.0856
7	-16.8750	9.4714	41.1375	7.5905
8	-20.6250	15.0621	41.2250	10.5916
9	-17.1625	9.9005	38.8125	9.3167
10	-14.7000	10.7693	34.9500	9.9604
11	-15.5000	8.1637	37.1500	7.8053
12	-12.2000	7.9857	39.5000	7.9857
13	-8.7250	9.2558	39.6250	9.2558
14	-8.1250	11.6987	38.5250	10.8655
15	-10.9500	8.6536	41.1500	7.2977
16	-11.9750	7.6292	41.5750	7.1504
17	-14.6000	6.9245	43.4500	6.2796
18	-15.5250	9.3873	46.0750	8.8366
19	-12.5500	8.0322	43.1000	8.0322
20	-16.2500	9.4129	43.9000	9.3268

TABLE 77

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE NORMAL FB GROUP PRACTICING WITHOUT KR

Error Score Block Number	Extent $\overline{CE}$	VE	$\overline{AE}$	AV
1	-30.4250	11.8059	34.1250	10.7330
2	-27.6000	8.8425	35.1500	8.2484
3	-28.3750	6.0584	31.4750	5.7948
4	-29.7250	5.0032	35.7750	5.0032
5	-25.6500	6.5150	32.8000	6.2821
6	-25.9500	7.6269	29.9000	7.2057
7	-25.7750	6.9671	28.8250	6.2676
8	-26.5750	7.0969	29.8000	6.3874
9	-25.1750	5.8631	34.8250	5.2222
10	-28.5250	6.6830	31.6250	5.3096
11	-24.3000	7.0050	29.6000	7.0050
12	-23.8750	8.2784	31.7750	7.6111
13	-25.0250	7.9573	30.9250	7.6315
14	-24.5000	7.6417	33.3000	6.3496
15	-24.7000	7.3330	28.0500	7.1119
16	-23.5500	6.0515	28.9500	5.8064
17	-26.5500	8.1776	32.0000	7.7320
18	-29.8750	8.2819	31.5250	8.0830
19	-25.3750	5.8917	31.6250	5.4479
20	-23.5250	5.5403	31.1750	4.4261

TABLE 78

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE HEIGHTENED FB GROUP PRACTICING WITHOUT KR

	Extent			
Error Score Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-31.6000	11.4358	50.4000	10.7862
2	-24.9500	8.8056	52.5500	7.6631
3	-19.0250	6.7862	51.8750	6.0568
4	-15.0000	6.9927	57.9999	6.9927
5	-16.1250	6.3486	53.2750	5.7264
6	-15.7750	5.5560	54.3750	5.4036
7	-13.3250	5.8732	54.3250	5.7664
8	-14.6250	6.5493	55.9749	6.4246
9	-11.7500	7.4705	54.1500	7.4705
10	-11.4500	5.4581	54.7500	5.4581
11	-10.0750	4.3832	55.2250	4.0411
12	-8.2500	6.2173	55.0500	6.2175
13	-7.1750	6.3538	51.0250	6.3538
14	-9.8000	5.7781	54.1000	5.5017
15	-6.5750	4.7899	52.4250	4.7899
16	-10.3500	6.3066	53.0000	6.0593
17	-8.4500	6.3168	50.4500	6.1560
18	-14.0750	6.2567	54.8250	6.2567
19	-11.2250	4.938[illegible]	52.6750	4.9383
20	-14.7000	7.54[illegible]	52.7500	7.4040

TABLE 79

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE DISTORTED FB GROUP DURING EARLY KR WITHDRAWAL

Error Score	Extent			
Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-32.3250	23.6534	36.3250	18.9210
2	6.0750	13.6987	15.3250	9.9432
3	1.2250	11.1778	11.3750	6.2217
4	2.8750	10.4950	11.0250	6.4474
5	0.6000	9.7603	14.1500	7.6793
6	3.4125	9.7095	16.1250	7.0401
7	5.2625	9.5265	18.1125	6.4869
8	9.5250	12.3650	16.1250	7.6332
9	6.1500	8.1704	22.8500	6.8872
10	8.6750	13.9003	14.9750	8.9271
11	-0.4750	12.5106	11.5750	5.8371
12	4.0750	8.9211	9.7250	5.9906
13	2.8000	7.6409	7.4500	4.5550
14	2.0000	8.5436	8.0500	5.8874
15	6.8500	10.1395	10.5000	8.0723
16	0.5750	10.4797	10.1750	5.7955
17	0.5000	10.4559	10.1000	6.6088
18	-0.8250	10.2269	9.9750	5.3383
19	0.3250	9.1648	8.4750	5.6114
20	2.2000	10.1277	9.4500	6.0732

TABLE 80

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE NORMAL FB GROUP DURING EARLY KR WITHDRAWAL

Error Score	Extent			
Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-17.9500	23.9688	27.2000	17.2796
2	1.0500	11.7961	11.6500	8.0194
3	1.3000	10.5208	10.3000	7.1089
4	-1.2250	10.4357	9.5750	5.8009
5	9.5750	10.2700	14.5750	7.5762
6	7.8000	8.3592	13.8500	6.8237
7	6.8500	7.8381	16.9500	6.8049
8	4.8500	10.1337	15.8000	7.9448
9	4.9750	7.9789	12.6250	6.3967
10	4.2500	11.1582	11.2000	7.0913
11	5.0000	8.3509	10.1250	5.9079
12	-0.1750	8.9565	8.7250	5.4418
13	1.5500	9.1556	8.2500	6.2690
14	2.8750	9.1743	9.3750	5.7699
15	3.6250	7.4838	8.0250	3.8340
16	2.2500	8.3466	6.5000	5.7299
17	2.0500	8.6960	7.3500	5.3100
18	3.1000	7.9471	7.7000	5.3213
19	3.9750	7.5860	7.7750	4.8847
20	2.8500	9.3936	9.5000	5.0148

TABLE 81

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE HEIGHTENED FB GROUP DURING EARLY KR WITHDRAWAL

	Extent			
Error Score Block Number	$\overline{CE}$	VE	$\overline{AE}$	AV
1	-15.1750	19.9103	20.9250	15.6670
2	3.2500	13.1999	13.0250	7.1289
3	2.2000	8.5934	9.0750	6.6293
4	-1.0000	8.0217	7.4000	4.4305
5	-1.5750	7.9162	7.9750	5.1249
6	4.7500	9.3804	9.6000	5.7788
7	3.5250	7.6256	11.3750	6.4968
8	4.3250	7.9104	15.0750	6.2195
9	2.2250	9.7151	11.2750	7.2867
10	-0.1000	7.6979	7.6000	5.1789
11	3.6500	10.2407	9.2000	7.6666
12	1.7000	8.6632	8.1500	4.8453
13	0.3500	8.1696	7.6500	5.1480
14	3.0250	9.0783	8.4750	5.8391
15	0.0750	5.2637	4.9250	3.4598
16	-0.1750	7.6303	7.0750	3.6063
17	0.6500	6.9101	6.7500	3.6875
18	0.4500	8.9971	8.0000	5.1529
19	1.1750	7.4063	6.9250	4.9373
20	0.5250	7.3678	6.7250	4.8547

TABLE 82

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE DISTORTED FB GROUP DURING LATE KR WITHDRAWAL

Error Score Block Number	Extent $\overline{CE}$	VE	$\overline{AE}$	AV
1	-24.4000	27.2028	33.8000	23.2756
2	-0.4750	13.0714	13.8875	8.4426
3	-0.1750	10.1342	9.5750	6.3582
4	6.8250	12.0153	14.0250	10.3748
5	7.8500	12.2949	15.2000	9.3024
6	7.0500	12.0369	12.2000	9.5437
7	0.4750	9.9281	9.4750	5.8087
8	0.7000	12.7648	11.9000	7.1738
9	-0.4000	11.9558	10.0000	6.7898
10	5.9000	11.9446	12.0500	8.1644
11	-1.2250	9.1459	9.6250	7.3597
12	1.5000	11.5486	11.3000	7.7319
13	0.3500	9.5555	9.9000	5.4591
14	-0.0750	9.8744	9.3250	6.7500
15	-2.2000	10.0843	9.7250	7.0817
16	-0.8500	10.7483	10.1000	8.8189
17	-4.4250	7.5767	9.5750	4.7036
18	0.5750	10.2858	11.8250	5.1629
19	-1.5250	12.4092	14.5250	8.0988
20	-1.2500	9.1347	10.8000	6.7204

TABLE 83

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE NORMAL FB GROUP DURING LATE KR WITHDRAWAL

Error Score Block Number	Extent $\overline{CE}$	VE	$\overline{AE}$	AV
1	-13.1250	17.5769	17.9250	14.7366
2	-0.6750	9.3887	9.5750	6.2429
3	1.2500	10.0883	8.7500	6.6193
4	-2.9500	7.1782	7.8000	5.4821
5	2.3000	8.7048	8.2000	5.6603
6	2.4250	10.8425	10.3750	4.9566
7	0.3750	7.0400	6.3750	4.2455
8	0.6250	7.1140	6.7750	3.8097
9	1.0000	6.4727	5.9500	4.4639
10	-0.3750	7.2156	6.7250	4.6661
11	2.1250	6.7858	6.2750	3.7665
12	2.3250	6.8476	6.8750	4.1536
13	3.5250	7.5910	7.5250	4.7484
14	3.7750	8.7715	8.5750	5.5603
15	3.0250	8.5749	9.0250	5.0898
16	0.7500	6.1729	6.5000	3.8871
17	-1.0250	6.2546	7.3250	4.4880
18	0.8000	6.4830	8.0000	5.3384
19	2.9750	7.6657	10.5750	5.5866
20	1.2750	8.3742	14.1250	6.7864

TABLE 84

MEANS FOR TWENTY BLOCKS FOR $\overline{CE}$, VE, $\overline{AE}$ AND AV OF EXTENT FOR THE HEIGHTENED FB GROUP DURING LATE KR WITHDRAWAL

Error Score Block Number	Extent $\overline{CE}$	VE	$\overline{AE}$	AV
1	-13.3000	18.3941	14.6500	14.5752
2	-0.3250	11.8237	7.1875	6.9633
3	-3.1250	11.7939	8.2250	6.1124
4	-1.3750	12.0443	6.9500	6.4845
5	1.2250	9.0523	6.2250	5.4716
6	3.1500	9.9440	6.7750	6.2431
7	3.4750	7.4458	4.4625	5.1538
8	3.3250	6.5289	6.7250	4.2840
9	3.5500	8.2190	4.7000	5.0186
10	1.4000	7.5445	5.0500	4.0843
11	-0.6750	5.8106	3.0250	3.9999
12	2.5000	9.1032	4.7250	5.4081
13	1.4000	8.7834	5.1750	5.7799
14	3.2500	6.6932	3.7250	4.5096
15	1.9750	7.0799	4.6500	4.1043
16	0.2750	5.3957	4.9500	4.0441
17	4.0000	5.6762	6.8750	4.2138
18	0.8000	8.4232	7.7000	5.3363
19	-1.8625	6.9743	6.3750	5.2995
20	2.0750	5.5969	8.6000	4.0403

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