

ACQUISITION AND TRANSFER OF ISOMETRIC FORCE REPRODUCTION

by

Shelagh R. Kleven

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APPROVAL

Name: Shelagh R. Kleven

Degree: Master of Science (Kinesiology)

Title of thesis: Acquisition and Transfer of Isometric Force Reproduction

Examining Committee:

Chairman: Professor M. Savage

~~Dr.~~ J. Dickinson
Senior Supervisor

Dr. D. Goodman

Dr. V. Modigliani
External Examiner
Department of Psychology
Simon Fraser University

Date Approved: 13 August 1986

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Acquisition and Transfer of Isometric
Force Reproduction

Author:

(signature)
Shelagh Klevan
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Aug 13/86
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ABSTRACT

This study examined the acquisition of the ability to reproduce an isometric force accurately, and the influence that prior experience of producing an isometric force has on the learning of similar and different forces. A proactive transfer paradigm was used. The selection of similar (23.54 N) and different (34.34 N) transfer forces was based on the stimulus generalization curve for 19.62 N (2 kg). The similar force was located under the generalization gradient, while the different transfer force was situated outside the gradient. The demonstration of a stimulus generalization gradient for isometric force has not been reported before. The isometric forces were generated by the wrist flexor muscles of the right forearm. The subjects ($n=40$) were given 40 trials, each lasting 1.5 seconds, to learn an isometric force. At the end of each trial the subjects were informed of their performance. Two experimental groups, E-24 and E-34, initially learned 19.62 N, and following a five minute rest, E-24 learned 23.54 N and E-34 learned 34.34 N. The control groups, C-24 and C-34, only learned 23.54 N and 34.34 N, respectively, by completing the same procedure as the experimental groups. The control groups completed a second set of 40 trials in order to control for the effect of practice on the equipment. Each set of 40 trials was grouped into blocks of 5 trials and three dependent measures calculated to assess accuracy and consistency in performance. These included the constant error (CE) and variable error (VE) for all 8 blocks of trials and the Root Mean Square (RMS) error for the first 7 blocks of trials. The dependent variables were analyzed by ANOVA. The analyses revealed significant block effects for CE, VE, and RMS error, ($F(7,259)=3.56$, $F(7,259)=39.82$, $F(6,222)=24.22$), significant group effects for VE and RMS error, ($F(2,37)=14.47$, $F(2,37)=18.73$), and a significant group times block interaction effect for VE, ($F(14,259)=4.08$). The results indicate that subjects significantly improved their abilities to reproduce an isometric force accurately and consistently over the learning trials, and that the degree of proficiency attained is dependent upon the magnitude of the force produced. The degree of accuracy and consistency acquired in learning to reproduce an isometric force decreased as the magnitude of the force increased. The second set of analyses examined the influence of learning to reproduce 19.62 N on the acquisition of 23.54 N and 34.34 N. The first and second sets of all blocks and the first block of trials of C-24 and C-34 were compared to

the blocked transfer trials of E-24 and E-34, respectively. The analysis of all blocks of trials revealed significant group differences only between E-24 and C-24 on the first set of trials for VE, ($t(18)=4.02$). The analysis of the first block of trials showed significant group differences between E-24 and C-24 for VE, ($t(18)=5.40$), and between E-34 and C-34 for RMS error, ($t(18)=3.36$). The findings are discussed in relation to Newell and Barclays's (1982) hierarchical concept of schemata. The results suggest that the cognitive components acquired in learning to reproduce 19.62 N positively transferred to 23.54 N and 34.34 N whereas the motor components did not influence the acquisition of the transfer forces.

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CHAPTER I

INTRODUCTION

One of the most commonly applied principles in our educational system is the principle of "transfer of training" which suggests that previously learned skills will influence subsequent learning of similar tasks. Prior learning may either facilitate (positive transfer) or hinder (negative transfer) the acquisition of new skills. Educators attempt to potentiate positive transfer and eliminate negative transfer in order to fully utilize the previous training of their students. It is important, therefore, to determine and understand the cognitive and motor components that transfer between skills and the conditions that promote positive and negative transfer.

Since 1890, when William James examined the influence of memorization practice on the ability to learn poems, psychologists and motor behaviourists have examined the phenomenon of transfer of training extensively. These studies have focused on how the similarity between task components affects transfer of training, and how complexity and organization, as well as how the amount of previous experience, influence transfer.

Motor skills examined in many studies have centered on tasks involving only one movement parameter; the change of limb position in space. Force is an additional parameter common to the acquisition of skill, but, it has not received the same attention in motor learning research. While biomechanists and neurophysiologists have examined isotonic force reproduction, usually under ballistic conditions, I am not aware of any research investigating the acquisition and transfer of isometric force reproduction. Since isometric force reproduction is a prevalent movement parameter, it is important to understand the processes involved in the acquisition of this skill component. The objectives of this thesis, then, are to examine the acquisition process of learning to reproduce an isometric force, to determine how prior experience at reproducing an isometric force influences the acquisition of similar and different forces, and to study the acquisition processes that transfer between similar and different forces. With these objectives in mind, the following two chapters provide a historical review of transfer of training.

CHAPTER II

HISTORICAL REVIEW OF TRANSFER OF TRAINING PARADIGMS

A great deal of research has been devoted to transfer of training and though the type of tasks and learning situations have varied, the studies have centered on two basic experimental paradigms designed to investigate proactive and retroactive transfer. Proactive transfer is the influence that previously learned skills have on the acquisition of succeeding tasks, whereas retroactive transfer is the effect that newly acquired skills have on the retention of previously learned tasks. The basic paradigms involve an experimental group learning two successive tasks, A and B, while a control group learns only Task A or B.

The proactive transfer paradigm requires the control group to rest while the experimental group learns Task A. Both groups then learn Task B and the performance scores are compared. If the scores of the experimental group are superior to the control group then positive transfer is said to have occurred from Task A to Task B (proactive facilitation). If the scores of the experimental group are inferior to the control group then Task A interfered with the acquisition of Task B (proactive interference). Finally, if there is no difference between scores, Task A did not influence the learning of Task B.

The retroactive transfer paradigm requires the experimental and control groups to learn Task A. The control group then rests while the experimental group learns Task B. Both groups are then retested on Task A and the retention scores are compared. If the experimental group's scores are superior to the control group then Task B enhanced the retention of Task A (retroactive facilitation). If the experimental group's scores are inferior to the control group's then Task B interfered with the retention of Task A (retroactive interference). Lastly, if there is no difference between scores, Task B had no influence on the retention of Task A. (See Table 2.1.)

Table 2.1: Experimental Designs used in Transfer Studies

Design	Group	Procedure
Proaction	Experimental Control	Task ATask B rest.....Task B
Retroaction	Experimental Control	Task A...Task B...Task A Task A.....rest.....Task A

Retroactive Transfer Paradigm and Memory Research

Transfer paradigms have also been extensively used in memory research to investigate proactive and retroactive interference in verbal and motor short term memory (STM) and long term memory (LTM). Short term memory is theorized to have the capacity to store 7 ± 2 items (Miller, 1956) for approximately 20 to 30 seconds while LTM is considered to have an indefinitely large storage capacity and duration (Peterson & Peterson, 1959; Adams & Dijkstra, 1966). To examine proactive interference in memory, the transfer paradigm is modified slightly so that the control group rests while the experimental group learns Task B. Both groups then learn Task B and are retested on Task B. The study of retroactive interference requires both groups to be retested on task A.

Proactive interference has been demonstrated in verbal STM and LTM using the Brown–Peterson version of the retroactive transfer paradigm (Keppel & Underwood, 1962; Gorfein & Jacobson, 1973; etc.). This procedure requires subjects to learn several items, each of which is recalled before the next item is presented, prior to learning a criterion task. The length of the retention interval between the presentation and recall of the criterion is dependent on the memory structure (STM and LTM) under investigation.

Although the Brown–Peterson design consistently showed proactive interference in verbal memory, it failed to demonstrate the phenomenon in motor memory (e.g., Montague and Hillix (1968), Schmidt and Ascoli (1970)). Evidence for proactive interference in motor STM was presented by Stelmach (1969) using

a reverse-order design. Stelmach had subjects move to either zero, two, or four locations on a curvilinear slide apparatus before moving to the criterion location. After a retention interval of either 5, 15, or 20 seconds the subjects were asked to recall the locations in reverse order (i.e. the criterion location was recalled first). Proactive interference was observed when there were four prior movements and a retention interval of at least 15 seconds. Several other studies have also presented evidence for proactive interference in motor STM using the reverse-order design (Ascoli & Schmidt, 1970; Craft, 1973; Dickinson & Higgins, 1977; Williams, 1971). To date, data are not available to suggest the existence of proactive interference in motor LTM (Duncan & Underwood, 1953; Hick & Conn, 1975; Bolter & Dickinson, 1980).

Retroactive interference has been repeatedly demonstrated in verbal STM and LTM (e.g. Petrich, 1974; Briggs, 1954; Underwood, 1948) and in motor STM (e.g. Williams, Beaver, Spence, & Rundell, 1969; Patrick, 1971; Zahorik, 1972). Supportive data for retroactive interference in motor LTM has also been presented (Magill, 1985), however, the methodological difficulties of controlling a subject's activities during a long retention interval appears to have limited the number of studies on this topic.

Inter-Task and Intra-Task Transfer of Training

Transfer of training between tasks has been studied by using different skills and variations of the same skill. Investigations examining inter-task transfer are not numerous, but they consistently report that little transfer occurs between skills. Negative transfer almost never occurs, and if there is positive transfer, it is minimal (Nelson, 1957; Lindeburg, 1949; Coleman, 1967; Toole & Arink, 1982). Intra-task transfer is most commonly studied by varying the rate at which the task is performed. The experimental group initially learns to perform the task at a rate that is different from the criterion and then transfers to the criterion speed. The results of the investigations repeatedly demonstrate positive transfer. For optimal skill acquisition the studies suggest that the task should be practiced under the conditions in which it is normally performed. Practice at different performance rates, however, is more beneficial than no practice at all (Baker, Wylie, & Gagne, 1950; Ammons, Ammons & Morgan, 1956; Jensen, 1976). Furthermore, if

the task requires different rates of performance then practice under varying rates will be more advantageous than practice at one speed (Seigel & Davis, 1980).

Measures of Transfer of Training

Although studies of transfer of training have generally used similar experimental paradigms, the methods of quantifying transfer have varied. The simplest measure of transfer is the difference between the mean performances of the experimental and control groups on the transfer task ($E-C$). While the absolute score is easy to compute, it is meaningless when comparing the results of studies using different experimental procedures.

A relative score that allows comparisons across studies is calculated by dividing the absolute score by the mean performance score of the control group ($(E-C)/C$). While this measure of transfer is more useful than the absolute score, it has its drawbacks as there is no maximum positive, or negative score.

A transfer formula that avoids the problems confronted by the above calculations was developed by Murdock in 1957. Murdock modified the denominator in the previous transfer formula so that the transfer score has a maximum value of plus or minus 100%. The Murdock formula is: $(E-C)/(E+C)*100\%$. Even though the Murdock formula is the most frequently used index of transfer (Magill, 1985) there is no universally employed measure. Obviously, when different indices of transfer are used, it is difficult to make quantitative comparisons across studies, but comparisons of general effects may still be valuable.

For the present study a transfer formula was not used to analyze the performances of subjects. Instead, the experimental and control groups' scores were compared, and where the experimental group's scores are superior to the control group's scores, then positive transfer is inferred. Where the experimental group's scores were inferior to the control group's scores, then negative transfer is inferred. This method of assessing transfer of training has been used extensively over the past decade in studies investigating the Schema Theory of motor learning (e.g., Magill and Reeve (1978), Kelso and Norman (1978), Newell and

Shapiro (1976)).

CHAPTER III

THEORIES OF TRANSFER OF TRAINING

Theory of Formal Discipline

For several centuries prior to the 1900's the Theory of Formal Discipline dominated the educational system in Europe and the United States. Fundamental to the Theory of Formal Discipline was the concept of faculty psychology which suggested that the mind is composed of several faculties such as reason, will, attention, and judgement. Proponents of Formal Discipline likened the faculties to muscles which become stronger, quicker, and more flexible with practice, and therefore, reasoned that by studying difficult subjects, such as Latin and Mathematics, the faculties could also be developed and strengthened for future use. The skills from well developed faculties were assumed to transfer and to be helpful in all situations.

The Theory of Formal Discipline was first objectively studied in 1890 by William James when he tried to determine if mental exercises had any effect on improving the mind. James and his students tested their memory ability by learning Victor Hugo's poems before and after an extensive training period of memorizing poems by different authors. The difference between the performances on the two tests was not significant and this led James to conclude that memory abilities are not affected by practice. James suggested that to improve memorization abilities, as much information as possible should be learned about the material to be remembered. The Theory of Formal Discipline was challenged again at the beginning of the 20th century when educators became interested in experimentally testing the theory. The majority of studies compared the performance scores on aptitude tests between high school students enrolled in Latin and Mathematics, and those who were not. Latin and Mathematics were usually chosen because it was strongly believed that these subjects were important in developing the psychological faculties. The students in Latin and Mathematics usually recorded superior performance scores which suggested, to the educators, that these disciplines were responsible for the superior intelligence. There is a major flaw in the design of the studies, however, which limits the conclusions that can be derived from the data. The results

of the investigations only demonstrated that the high school students enrolled in Latin and Mathematics were more intellectually inclined than the other students. Latin and Mathematics are difficult subjects to learn, and therefore, only students with high intellectual abilities may have enrolled in the courses. In experimental terms, there was no random assignment to groups and hence no judgements concerning causalities are possible.

Thorndike and Woodworth (1901) also investigated the allegations that the study of difficult subjects strengthened the psychological faculties. Thorndike and Woodworth tested the reasoning powers of students enrolled in Latin and Greek, and students enrolled in alternative courses, before and after completing the classes. A comparison of the scores showed that there was no difference in the development of reasoning abilities which suggested that the courses did not differentially influence the students' faculties, if such faculties indeed existed.

Studies completed a few decades later provided further evidence against the Theory of Formal Discipline. Following the investigations by James (1890) and Thorndike and Woodworth (1901) Latin was no longer advocated for mental discipline. A few educators believed, however, that Latin enhanced the knowledge and vocabulary of the English language. Investigations into this allegation examined the English vocabulary of students before and after studying Latin. Douglass and Kittleson (1935) and Pond (1938) reported no gains in the English vocabulary. Hambleton (1925) showed an increase in English vocabulary, but the new words were almost all of Latin origin. Hambleton suggested that a course in English would have been more beneficial to the students.

Theory of Identical Elements

The studies by James (1890) and Thorndike and Woodworth (1901) provided doubts concerning the Theory of Formal Discipline. In response to this failure in support for the earliest hypothesis of transfer of training, Thorndike (1903) formulated the Theory of Identical Elements. Thorndike suggested that only specific skills, knowledge, and techniques are transferred between tasks, and that these elements occupy the

same cellular actions in the brain. Thorndike's theory implied that transfer of knowledge would only occur if identical stimulus-response bonds were used in future tasks.

In Thorndike's original proposal of the Identical Elements Theory, he described transfer of training in terms of transfer of "substance" and "procedure". The substance of a task refers to the abilities required to handle spoken and written numbers, words, and symbols. The procedure describes the "habits of observation and study, attitudes of neglect or pleasure, and feelings of dissatisfaction and failure" (Oxendine, 1984). This definition of transfer of training implies a generalized view of transfer, but, because of Thorndike's belief that transfer is localized to identical cortical areas and functions, the Theory of Identical Elements has proven to be limited in its ability to account for all aspects of transfer of training (e.g. negative transfer).

Thorndike referred to studies (e.g. Swift, 1903) on bilateral transfer to support his Theory of Identical Elements. Bilateral transfer describes the influence that the learning of a task with one limb will have on the acquisition of the same task with the contralateral or ipsilateral limbs. Typically, the investigations showed that the rate of acquisition of the skill is faster if the skill is first learned by another limb, thus suggesting that identical movements transfer between limbs. Beyond learning the same skill with different limbs it was difficult, however, to expand Thorndike's concept of identical elements to the acquisition of different motor skills unless it was assumed that some degree of transfer would also occur if the skills were similar. For example, transfer of training would then be expected between such skills as an overhand throw in baseball and a serve in tennis, soccer and a field-goal kick in football, and snow skiing and water skiing. The evolution of Thorndike's identical elements hypothesis to a theory of "similar" elements created a new focal point for research in transfer of training.

Skaggs- Robinson Hypothesis

During the next few decades investigators studied the effects that task similarity had on the type (positive or negative) and amount of transfer of training. The findings of these studies were initially confusing as some reported that positive transfer resulted between similar skills while others found that

negative transfer occurred. In 1927 Robinson proposed the Skaggs–Robinson hypothesis of transfer of training as a solution to the perplexing results. Robinson suggested that when successively practised skills are identical, maximum positive transfer will occur. As the similarity between tasks decreases, the amount of positive transfer declines toward neutrality (no transfer of training effects), and, at a point between identical and slightly similar tasks, transfer becomes negative. At moderate task similarity transfer is maximally negative. Further decreases in task similarity results in a decrease in negative transfer towards neutrality, only reaching neutrality at complete task dissimilarity. (See Fig. 3.1.) The Skaggs–Robinson hypothesis described positive, negative, and absent transfer of training between skills varying in degree of similarity. However, because the hypothesis did not quantify task similarity or the locus of transfer, it was quickly dismissed as an adequate explanation of transfer of learning (Osgood,1949). Robinson defined only two points of similarity on the transfer curve; identity and neutrality. Maximum positive transfer occurs at task identity and no transfer results at task neutrality. The points of transition from facilitation to interference and maximum negative transfer can therefore lie anywhere between task identity and neutrality. If the measurement of similarity between tasks is disregarded, studies by Cheng (1929), Dreis (1933), Harden (1929), Hovland (1938), and Robinson (1927) provide evidence for the Skaggs–Robinson description.

In a series of studies (Johnson, 1933; McGeoch & McDonald, 1931; McGeoch & McGeoch, 1937) McGeoch and his colleagues produced evidence which conflicted with the Skaggs–Robinson hypothesis. Using a retroactive paradigm and meaningful word lists, they found that interference increased as the similarity between the learned and interpolated word lists increased. The highest degree of similarity they could obtain was when close synonyms appeared on both lists. McGeoch offered two explanations for the difference between his data and the Skaggs–Robinson hypothesis. Firstly, McGeoch distinguished between the similarity of the elements of the task and the similarity of the meaning of the elements, and suggested that they have two different transfer functions. This was proposed because some of the studies (Harden, 1929; Kennelly, 1941; Robinson, 1927), supporting the Skaggs–Robinson hypothesis, used word and number combinations and indexed the similarity between the lists by the number of identical elements.

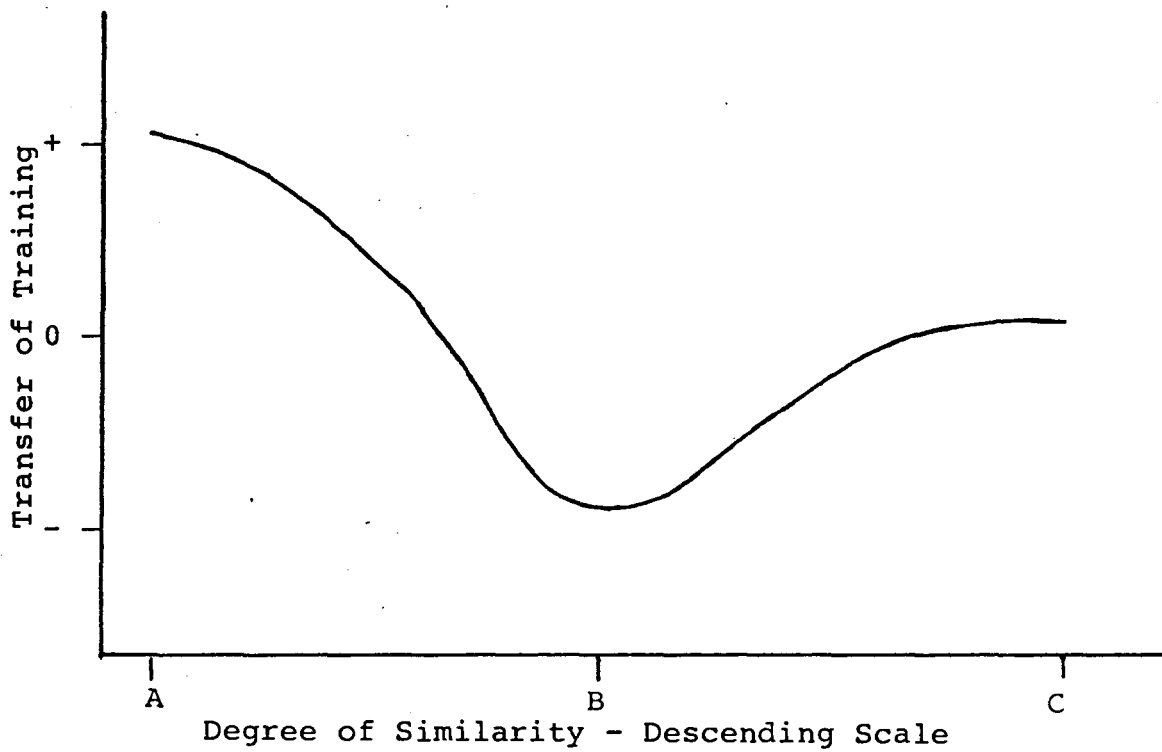


Figure 3.1: Skaggs-Robinson Transfer Curve

Unfortunately, the other supporting studies used materials in which the identical elements between the tasks (e.g. card sorting and card substituting) were no more readily specifiable than between meaningful words. Later, McGeoch suggested that the results of the studies only applied to the right-hand region of the Skaggs–Robinson curve because the similarity attained between the word lists only reached a moderate level. This argument is incapable of proof or disproof, however, because Robinson never defined task similarity. Not only could any data be fitted to a portion of the curve, but it could always be argued that the similarity between tasks could fall anywhere between task identity and neutrality.

The second short-coming of the Skaggs–Robinson hypothesis is that it did not define the locus of transfer between tasks. In 1919 Wylie distinguished between stimulus and response components in learning a skill. Wylie suggested that transfer of training is positive when old responses must be associated with novel stimuli and negative when old stimuli must be associated with new responses. Although the principle is grossly over generalized it does indicate that the type and amount of transfer between tasks is dependent on whether the stimuli and/or responses are varied. Therefore, depending on whether tasks are differentiated by stimuli and/or responses, different results of transfer could be found for the same degree of similarity.

Osgood's Transfer Surface

In the years following Robinson's proposed hypothesis of transfer of training, investigators continued to focus on determining how different degrees of task similarity influenced transfer. An important development evolved in these studies, however, that separated them from the pre–Robinson era. The locus of transfer was more critically examined. Researchers separated the stimulus and response components of a skill and examined the influence that varying one or both had on transfer.

In 1949 Osgood completed a critical review of the transfer studies on task similarity. Based on his review, Osgood formulated three empirical laws of transfer of training and expressed these laws in a three-dimensional graph. Osgood separated the review of his studies into three categories based on the type of proactive and retroactive transfer paradigms used. (See Table 3.1.) Since Osgood published his

Table 3.1: Proactive and Retroactive Transfer Paradigms Indicating the Locus of Variation between Successively Learned Skills

Paradigm	Task A	Task B	Task A
A	S_1-R_1	S_2-R_1	S_1-R_1
B	S_1-R_1	S_1-R_2	S_1-R_1
C	S_1-R_1	S_2-R_2	S_1-R_1

————Proactive Transfer————>

<————Retroactive Transfer————

paper conventions in terminology have changed. While Osgood referred to proaction transfer paradigms as transfer paradigms, it is preferable to use transfer to indicate net facilitation or interference in proaction and retroaction transfer paradigms.

The first empirical law of transfer refers to the transfer paradigm where stimuli are varied and responses are held constant. Osgood proposed that proactive and retroactive facilitation will be obtained where responses are identical, the magnitude of both increasing as the similarity between the stimuli increases. The second principle describes the situation where responses are varied and stimuli are held constant. Osgood suggested that proactive and retroactive interference will result, the magnitude of both decreasing as the similarity between responses increases. Finally, the third law describes the transfer paradigm where both stimuli and responses are varied. Osgood suggested that proactive and retroactive interference will occur, the magnitude of both increasing as stimulus similarity increases.

Because the Skaggs–Robinson hypothesis was incapable of accommodating all the data from transfer studies, Osgood formulated a new hypothesis by incorporating his three empirical laws onto a topological map. (See Fig. 3.2.) The horizontal (long) plane represents the degree of similarity between responses and the median (short) plane depicts the degree of similarity between stimuli. Positive and negative transfer is represented by the vertical dimensions, above and below the horizontal plane, respectively. The degree of similarity between stimuli and responses is maximal at the left front corner of the surface and as

you move towards the right and/or back of the surface the similarity between stimuli and/or responses declines. Maximal dissimilarity between stimuli and responses is represented at the right rear corner of the surface.

At the time Osgood proposed his hypothesis of transfer of training the stimulus-response (S-R) theory of learning was in vogue. The S-R theory suggested that learning is composed of building associations between stimuli and responses, and that these habits are only formed when recurrent stimuli and responses are identical. Any deviation from identity will interfere with learning, the amount of interference increasing with the degree of stimulus and/or response similarity. Osgood argued that this concept does not hold true, however, when applied to actual learning situations because conditions are never precisely identical from trial to trial. The hypothetical condition for maximal interference, then, is actually the situation for maximal facilitation of learning.

As a solution to this transfer paradox Osgood suggested that maximal facilitation of learning occurs when recurrent stimuli and responses are functionally identical. Functional identity describes the range of similarity at which stimuli or responses are perceived to be identical. Therefore, by changing the criterion for maximal facilitation of learning from identical to functionally identical stimuli and responses, Osgood was able to account for the inherent variation in the learning environment.

The second concept Osgood incorporated into his transfer curves was that of stimulus generalization. Pavlov (1927) initially formulated the concept of generalization to describe the findings of his response conditioning studies. Pavlov repeatedly demonstrated that stimuli, different from a learning stimulus, evoked conditioned responses and that the probability of prompting the conditioned responses was related to the degree of similarity between stimuli. Pavlov suggested that conditioned responses become attached to a zone of stimuli surrounding the stimulus present in the original learning. As stimuli become increasingly dissimilar from the original stimulus, the degree of response strengths to the novel stimuli decreases, thereby producing generalization gradients of decreasing response strength to increasingly dissimilar stimuli.

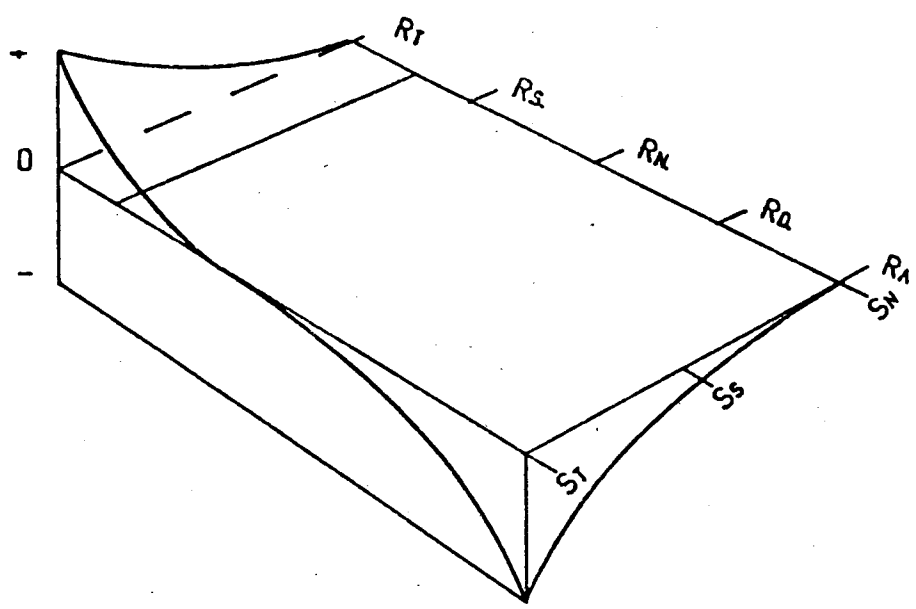


Figure 3.2: Osgood's Transfer Surface

Gibson (1940) adapted Pavlov's theory of stimulus generalization to explain human learning. Gibson suggested that learning was governed by two laws: "(1) if responses are identical, facilitation is obtained, its amount increasing with the degree of stimulus generalization (similarity); (2) if responses are different interference is obtained, its amount increasing with the degree of stimulus generalization (similarity)" (Osgood, 1949). Osgood argued that although these laws fit much of the data, they were insufficient as they did not define response similarity and suggested an abrupt shift in transfer at some point of response similarity. The sudden change in transfer would be expected because facilitation and interference are proposed to increase as stimuli become more similar.

The back median plane of Osgood's proaction and retroaction transfer surface represents the paradigm where responses are held functionally identical and stimuli are varied. Osgood proposed that when responses are functionally identical positive transfer occurs with the amount being dependent upon the degree of stimulus generalization. Maximum positive transfer occurs at stimulus functional identity, and as the similarity between stimuli decreases towards neutrality, (the edge of the generalization curve), transfer declines to zero as an inverse function of stimulus generalization. The paradigm in which stimuli are held constant and responses are varied is defined by the front horizontal plane. Osgood suggested that maximal facilitation of learning and recall occurs at response identity and as the similarity between responses decrease facilitation declines to interference; the point of transition lying between response identity and high similarity. Further decreases in similarity result in gradual increases in interference until response similarity equals that between neutral responses where interference then sharply rises, reaching a maximum value at antagonistic responses. Finally, the paradigm where stimuli and responses are simultaneously varied is represented by the area encompassed by the back and front median planes and the left and right horizontal planes. Osgood implied that stimuli and responses are functionally independent. Therefore, the amount and type of transfer generated (when stimuli and responses are both varied) is equally dependent on the laws that govern transfer when only stimuli or responses are varied. The degree of facilitation or interference of learning is determined by the point of intersection between stimulus and response similarities.

Holding's Transfer Surface

Despite the fact that the major attempts to confirm the accuracy of Osgood's transfer surface have completely or partially failed (Bugelski & Cadwallader, 1956; Dalost, 1962; Wimer, 1964), the proaction and retroaction surface has become one of the most well-known graphs in the psychology of learning, and although this surface was designed to represent verbal learning it has been used to describe motor learning. In terms of perceptual-motor learning, Holding (1962) suggested that a number of variables also influence motor transfer independently of the similarity relations. Some of these factors include control parameters, display-control relationships, augmented feedback, and part-whole relations. Holding (1976) argued that a three-dimensional graph could not represent all the variables that affect transfer of training. A graph considering only two similarity variables would, therefore, only roughly estimate the amount and type of motor transfer. Following a critical examination of the transfer studies, Holding questioned the validity of Osgood's front horizontal plane as a representation of transfer in verbal and motor learning. Osgood proposed that as responses become increasingly dissimilar, negative transfer increases. In verbal learning, however, when response similarity is varied, the results are often the reverse of Osgood's prediction. Bugelski and Cadwallader (1956) found that as responses became increasingly similar, negative transfer increased, to a point short of identity. Their data approximated the Skaggs-Robinson transfer curve. Other studies (e.g. Kanungo, 1967), however, obtained results that supported Osgood's transfer surface. Holding explained the conflicting data by suggesting that as the word lists became more similar, the previously learned lists would prompt the recall of the new lists more readily, thus enhancing positive transfer. At the same time, however, they would more likely be confused with the new response thus increasing negative transfer. The motor learning studies also did not consistently support Osgood's predictions for negative transfer. For example, Noble (1968) reported that for mathometer learning, the acquisition of different responses for the same stimuli did not consistently produce negative transfer. Lewis, McAllister, and Adams (1951) found that for laboratory tasks (e.g. the Mashburn complex coordination test) where the hits and errors are tallied independently, it was possible to obtain positive transfer on one score and negative transfer on the other. From these studies Holding concluded that

generally verbal and motor learning follow the same transfer principles. When responses are held constant and stimuli varied, positive transfer results; the amount decreasing with declining stimulus similarity. In direct contrast to Osgood, however, the data indicate that when stimuli are held functionally identical and responses varied, negative transfer occurs, the amount increasing with increasing response similarity. In addition, Holding concluded that a transfer surface could not accurately represent both facilitation and interference, because as Lewis, McAllister, and Adams (1951) demonstrated, both facilitation and interference vary independently of each other.

Holding also suggested that there were two problems with the scoring techniques used. Positive transfer was normally inferred if the experimental group obtained higher performance scores than the control group, and negative transfer was inferred if performance scores were inferior. The transfer scores were represented as a percentage of the total learning available to the control group; a negative percentage score suggested negative transfer and a positive percentage score implying positive transfer. Holding argued that although this definition of transfer was unequivocal, it did not accurately represent negative transfer. Holding proposed that negative transfer is prior learning incorrectly applied to a new task. It is not an opposing process to positive transfer, but is positive transfer misapplied. The opportunities for the misapplication of prior learning in a new task are sporadic causing negative transfer to "appear in the form of isolated, intrusive errors" (Holding, 1976). Therefore, depending on the weight given to error in the scoring system, negative transfer may, or may not, bring the performance scores of the experimental group below the level of the control group. This definition of negative transfer supports Bilodeau and Bilodeaus' (1961) conclusion that "negative transfer (a) is difficult to produce, (b) when produced obtains in small amounts, and (c) rapidly converts to positive transfer" (Holding, 1976).

Negative transfer between tasks will usually occur when the two tasks are similar enough to interact but differ in an important obscure manner. Holding suggested that the obscurity in the differences between tasks arises as a result of stimulus and/or response factors. In an artificial environment the procedure of re-pairing stimulus and response items creates confusion as to which response is appropriate to which stimulus. Negative transfer will only be absent if the subject is informed in advance of the

different response requirements. In real life situations negative transfer occurs between tasks when there are insufficient discriminative cues. Learning to drive in England may provide a real life example of negative transfer. If there are no other cars on the road there may be a tendency to drive on the "right" side of the road. Cars are discriminative cues which may help to differentiate between driving in England and North America, and hence, eliminate negative transfer.

Holding also indicated that negative transfer resulting from obscure differences between stimuli is a function of the amount of practice. Mandler and Heinemann (1956) and Siiploa and Israel (1933) observed that most negative transfer occurs after small amounts of practice on the original task. These findings agree well with the evidence presented by Gagné and Foster (1949) showing that generalization broadens during the early stages of practice, giving way to increased discrimination in the later stages.

Obscurity resulting from response factors is dependent on the similarity between responses and the amount of practice. Negative transfer will not occur if subjects can reliably differentiate between responses. However, as responses become more similar and the amount of training on the first response increases, it becomes more difficult to differentiate between responses and to suppress the initially learned response. Therefore, in the early stages of learning, maximum negative transfer will occur due to response generalization. Maximum negative transfer will be maintained in the later stages of learning as a result of the inability to repress the strengthened initially learned response.

The second problem with the scoring system arises from its influence on the shape of the surface. Subjects, once trained to respond in a specific way will respond to similar circumstances in the same way. When the response is appropriate, transfer is scored as positive, but when the response is inappropriate, transfer is deemed negative. Therefore, negative transfer will occur when the experimenter has differentiated between the tasks but the subject has not. At task identity the scoring criterion of the subject and experimenter will agree and maximum positive transfer will occur. At a point of similarity just beyond functional identity, the experimenter will discriminate between the tasks but the subject will not and maximum negative transfer will result. The implication, then, is not a gradual reversal from

facilitation to interference (Robinson, 1927) but a step change to interference at the point where decreasing similarity exceeds functional identity.

Although Holding argued against Osgood's transfer surface as a rigorous, predictive model of transfer of training he implied that it was a useful instructional device and could be improved for general use. Holding changed Osgood's surface to model interference, with facilitation playing a secondary role. Because Lewis, McAllister, and Adams' (1951) study indicated that facilitation and interference vary independently, Holding did not believe that a three dimensional graph could accurately represent both factors and used the transfer of training surface to explicate negative transfer.

The interpretation of Holding's transfer of training surface (see Fig. 3.3) is similar to Osgood's surface. The primary differences between the two surfaces lie along the back median and front horizontal planes. If responses are functionally identical and stimuli varied (the median plane) Holding proposed that facilitation occurs, with the amount decreasing only slightly with decreasing stimulus similarity. Holding believed that the Osgood surface underestimated the degree of facilitation from learned responses. If stimuli are held constant and responses varied (the horizontal plane) it is assumed that the production of different responses, in the absence of any stimulus change to indicate that new responses are required, will lead to maximum interference regardless of the degree of response differentiation. The implication, then, is not a gradual reversal from facilitation to interference, but a step change to maximal interference at the point where decreasing response similarity exceeds functional identity. (See Fig. 3.3.)

The major drawback with Holding's transfer surface is that it under-represents positive transfer. Holding suggested that because most transfer is positive the center of the surface could be raised so that it peaks either where "high stimulus similarity and intermediate response differentiation offer the best trade-off between facilitation and interference" (Holding, 1976), or where "stimulus and response similarities and differences tend to cancel out" (Holding, 1976).

In 1985, Kleven, Herring and Dickinson tested the validity of Osgood's and Holding's front horizontal planes as representing transfer in motor learning when stimuli are held constant and responses

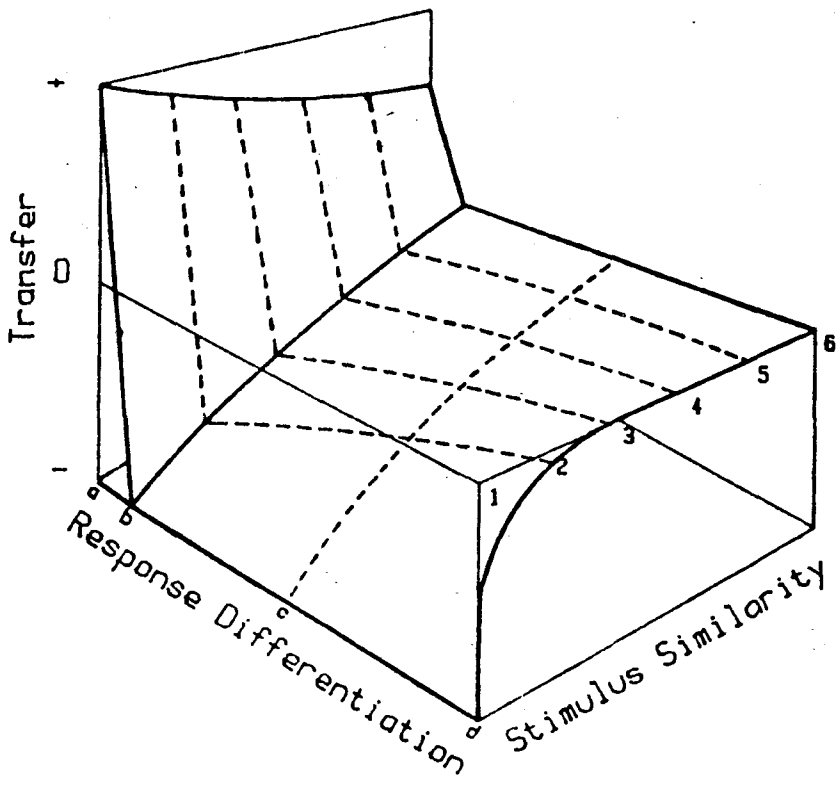


Figure 3.3: Holding's Transfer Surface

varied. A retroactive transfer paradigm was used to study the recall error in producing simple, linear arm movements. The data supported both Osgood's and Holding's predictions. Maximum positive transfer occurred at stimulus and response functional identity and as response dissimilarity just exceeded functional identity positive transfer declined to negative transfer. The transition, however, was not a gradual reversal to maximal interference as suggested by Osgood but was a sharp decline as postulated by Holding. As response dissimilarity increased towards neutrality, negative transfer did not remain maximal but declined toward zero transfer and finally reverted to positive transfer. Because the interpolated movements were all longer than the criterion it was suggested that the substantial learning enhancement observed at large response differences was not a direct result of facilitation from the interpolated response but may instead have resulted from changes in the adaptation level (AL) that were induced by the interpolated movements.

Fundamental to the AL theory (Helson, 1947, 1964) is the idea that when a movement or range of movements are learned a psychological reference of the mean response (the AL) is formed. Additional movements are then acquired as a function of the AL, being greater than, the same, or less than a given number of units from the psychological mean. The AL is also a dynamic reference; it is continually subject to change with each new movement. A criterion movement is learned as being equivalent to the associated AL. When the interpolated task is experienced the AL is pulled toward the new movement length so that, upon recall of the criterion movement, the magnitude of the response is greater or less than the criterion length but equal to the adjusted AL. In addition, as the difference between criterion and interpolated movement lengths increases, the discrepancy between actual and recalled criterion lengths also increases. Kleven, Herring, and Dickinson suggested that transfer surfaces should incorporate an adaptation level component for motor tasks whose natures are sensitive to biasing effects imposed by interpolated responses. Such modifications may apply to tasks involving changes in position, velocity, acceleration, or force.

Theory of Generalized Principles

The Theory of Generalized Principles was initially formulated by Judd in 1908. Judd was the first to take exception to the extent and nature of Thorndike's theory of identical elements. Judd believed that basic principles and laws, as well as specific skills were transferred between tasks. Much of Judd's theory was supported by his classic study (1908) in which he had two groups of grade five and six boys throw darts at small targets placed underwater. The study was designed to determine if the knowledge of a principle could enhance the learning of a task where the principle was applicable. Prior to testing, one group was given a theoretical explanation of the principle of refraction while the other group was given no information. The target was initially placed twelve inches underwater. In the first few trials there was no appreciable difference between groups. As the number of trials progressed, however, a difference eventually emerged in favor of the group who had been taught the principle of refraction, which suggested that a certain amount of practice was needed before the principle could be effectively used. The target was then raised to four inches below the surface. The group with the theoretical knowledge immediately demonstrated greater accuracy at hitting the target. Judd proposed that the superior performance resulted from the understanding that the angle required to hit the target twelve inches below the surface would not apply when the target was placed at a four inch depth.

Hendrickson and Schroeder (1941) attempted a general replication of Judd's dart throwing study. Eighth grade boys were required to shoot an air gun at targets submerged six and two inches underwater. Experimental groups were given an explanation of the theory of refraction prior to testing. The authors reported that the experimental groups performed better than the control group at both target depths. They concluded that the knowledge of refraction was beneficial in facilitating transference, and aided performance in the initial trials which was contrary to Judd's (1908) findings.

Several investigators have reported that the acquisition of a motor task was enhanced when the subjects were instructed in the biomechanical principles related to the skill. Mohr and Barrett (1972) found that swimmers who were taught the biomechanics of swimming made significantly greater

improvements in their swimming proficiency than those who had not received instructions. The authors concluded that subjects who are exposed to and understand the biomechanical principles related to the sport they are learning will demonstrate faster and greater improvement than subjects receiving instructions with no reference to biomechanics. Eighth grade boys were reported (Papcsy, 1968) to have learned handball faster, and performed better on a bunting skill after being instructed in the mechanical principles involved. Finally, Werner (1972) demonstrated that teaching fourth, fifth, and sixth grade students four principles of physics (levers, Newton's first and third laws, and work) improved their performance on a variety of gross motor skills.

Additional evidence supporting the transfer of principles comes from studies which have examined the influence of small pattern motor practice on large pattern learning. Cratty (1962) examined the effect of prior practice on three small patterned mazes on learning a large pattern maze. It was found that prior practice on a similar small pattern maze resulted in positive transfer to the large maze while reversed tracking on a smaller maze caused negative transfer. In 1968 Vincent classified two criterion tasks (a hop-and-jump task and a static balance task) by their motor and perceptual components. The experimental groups practised tasks to a high degree of proficiency that were similar to a criterion task in perceptual make-up but not motor demands. They then learned the criterion task. The control group first practised unrelated tasks. The results showed that the experimental groups attained superior performance levels to the control on the criterion tasks. Vincent suggested that the perceptual abilities of the experimental groups were improved through training on the practice tasks and these improvements transferred to the criterion task.

Judd's Theory of Generalized Principles proposes a great deal more transfer between skills than Thorndike's theory of identical elements, since Judd proposed that basic principles, as well as specific skills are transferred between tasks. The theories of Thorndike and Judd have often been viewed as being mutually exclusive. Research has shown, however, that transfer may occur through both identical elements and generalized principles. Based on these findings, a new contemporary view of transfer has developed which suggests that transfer effects are best explained as a result of a combination of elements,

both specific and general.

Schema Theory

Motor Learning Perspective

The notion that knowledge is structured in schemata was first introduced by Head in 1926. Head suggested that schemata were relations or rules, developed through experience, that define prototype characteristics of populations. When stimuli are perceived in the environment they are stored in memory in two forms— as they appeared in the environment and as abstracted concepts related to the populations they represent. These abstracted concepts form the basis of schemata which become more defined as additional members of the population are encountered. Therefore, in order to identify a stimulus, it does not have to have been perceived before. By using the schema, the population to which the stimulus belongs can be correctly identified.

The schema was first integrated into motor memory by Bartlett (1932) as a means of explaining how correct motor responses could be made to novel stimuli. Bartlett viewed memory as a constructive–reconstructive system. The schemata provide the pre–programmed generalized movements which are then adjusted to meet the environmental demands. Thus, when movements are produced they are never identical replicas of previous movements, but at the same time, they are not entirely novel.

The concept of schemata for motor memory was not well accepted as Bartlett did not clarify how schema would operate and how learning would occur. It was not until four decades later that the schema was revitalized as a viable explanation of motor memory (Pew, 1974; Schmidt, 1975, 1976).

In 1975 Schmidt reintroduced the concept of schema into motor memory. Schmidt proposed that when a movement is produced only specific aspects of the responses are stored. These include the initial conditions of the muscular system and environment, response specifications (e.g. force), sensory consequences, and response outcome. The data set is stored temporarily in memory while groups of

relationships are extracted for permanent storage in recall and recognition schemata.

The recall schema is comprised of the association between the initial conditions, movement parameters, and response outcome, whereas the recognition schema is the relationship between the initial conditions, sensory consequences, and response outcome. While the two schemata do share the initial conditions and actual outcome as variables, they are independent because the recall schema is the relationship between these variables and the response specifications, whereas the recognition schema is the relationship between these variables and sensory consequences. Schmidt has likened the development of schemata to linear regression analysis. The initial conditions and response outcomes resemble the dependent and independent variables, while the response specifications and sensory consequences are the data points. When movements are produced relationships are developed based on the response specifications and sensory consequences. As more movements in the same class are experienced, the number of data points increases which strengthens the accuracy of these relationships. Therefore, Schmidt's analogy suggests that the strength and reliability of the schemata depend on the number and variety of movements produced in the response class.

When an individual is required to produce a type of response, for which schemata have been developed, they begin by inputting the the initial conditions and desired outcome to the recall schema. From the relationship between past initial conditions and outcomes, a set of movement parameters is determined that will produce the desired outcome. The individual then executes the response. During and/or after the movement, the proprioceptive and exteroceptive feedback is compared with the expected sensory consequences (ascertained from the recognition schema) and the information is sent back to the schemata. If there is a discrepancy between the expected and actual sensory feedback, the movement schemata are corrected. Schema Theory has gained popularity over the past decade because it can explain how correct motor responses are made in novel situations, it does not demand a large storage capacity, and it is supported by a large number of studies on transfer of training (Shapiro & Schmidt, 1982).

Schema Theory suggests that positive transfer of training will occur between movements of the same response class, with the amount of transfer depending on the strength of the schemata. The experimental procedure designed to test this hypothesis involves comparing the transfer scores of a group that practised a number of movements from the same class, with a group that had practice on only one movement. Schema Theory predicts that variable practice will develop a stronger schema compared with constant practice, and therefore, the variable practice group should perform the transfer task better than the constant practice group. In the majority of studies variable practice produced significantly better transfer scores than constant practice, thus supporting the Schema Theory (Shapiro & Schmidt, 1982).

Cognitive Science Perspective

Cognitive psychologists have also developed a theory of motor memory that uses schemata for the storage of movements, and although the fundamental characteristics of the schemata are similar to the motor learning view, the nature of the knowledge about movements presented in the schemata differs. Cognitive psychologists suggest that it is the act that is stored, not the response specifications and sensory consequences of the movement (Rumelhart & Ortony, 1977).

The evidence supporting the cognitive science approach to motor memory has principally emanated from developmental studies. Psychologists observed for example (e.g. Connolly, 1973) that the power grip in infants changed to the precision grip through response differentiation, and that this grip was then generalized to many other skills throughout childhood. More recently, however, support for the more generalized schema has developed from research on the effect of mental practice on skill acquisition. Studies have reported that mental practice facilitates learning to produce an appropriate action (a generalized schema), whereas actual practice facilitates the acquisition of response specifications (a specific schema) (Minas, 1978).

Given that schemata were designed for response generalization, the variables of action they represent designate what is transferred between movements. The cognitive approach suggests that it is the act itself that is transferred between skills, while the motor learning view proposes that it is the

specifications of the movement pattern that are transferred. The two distinctive interpretations imply, therefore, that there are different levels of response generalization: "a broad class of generalization that reflects the transference of the act to a range of circumstances and a narrower range of response generalization that reflects the transference of details relative to the precision of the movement pattern"(Newell & Barclay, 1982).

Newell and Barclay (1982) proposed that the contrasting classes of schemata could be positioned at opposite ends of a continuum, ranging from abstract to concrete movement representation. With this perspective they suggested that movements would be generated by passing from an abstract representation of the act, through successive stages of differentiation, to the point where the response parameters are issued for movement production. Newell and Barclay also proposed that the continuum of schemata did not have to be entered at the most abstract level for reflexive behavior and highly automated responses could bypass that level of cognitive control.

CHAPTER IV

GENERAL STATEMENT OF THE PROBLEM

The previous two chapters reviewed the experimental methodologies, results, and interpretations of studies of transfer of training in the verbal and motor learning domain. While the experimental paradigms remained constant between and within the respective fields, two lines of theories based on different transfer mechanisms were developed. One school suggested that transfer occurs at the cognitive level of skill acquisition, whereas the other proposed that transfer occurs at the response specification level. Equally supportive data have been presented for both views. Thus, transfer of training may occur at both the cognitive and motor levels of skill acquisition. Newell and Barcle's (1982) recently proposed theory of a hierarchically organized transfer process is the clearest statement of this position.

The purpose of this thesis was to investigate the learning and transfer of isometric force reproduction at the 'cognitive' and 'motor specification' levels of skill acquisition. The study was designed to examine the transfer of motor responses in relation to Gibson's (1940) generalization theory of human learning. As mentioned previously, Gibson suggested that the degree of facilitation in human learning is a function of stimulus generalization. If responses are held identical, maximal facilitation of learning will occur at stimulus identity, with the amount of facilitation decreasing as an inverse function of stimulus generalization. As stimulus generalization approaches that of neutral stimuli, no facilitation of learning will occur. Recently, stimulus generalization curves were demonstrated in the motor domain using simple linear arm movements (Hedges, Dickinson, & Modigliani, 1983). Based on Gibson's concept of learning, then, the acquisition of transfer tasks will be enhanced by past experience if they lie within the stimulus generalization gradient of the initially learned task. Transfer tasks located outside the stimulus generalization gradient will not be influenced by past experience. A subsidiary objective of the study was to produce a stimulus generalization gradient for isometric force.

The thesis is comprised of three experiments. The first experiment was designed to produce a generalization gradient for isometric force. The selection of similar and different transfer forces used in

the second experiment was based on this curve. The second experiment was designed to test the degree of similarity between the criterion and transfer forces. It was ensured that the criterion and similar transfer forces were noticeably distinct from one another. The third, and final, experiment was designed to investigate the acquisition process of learning to reproduce an isometric force, and to examine the effects of similar and different experiences on these learning processes.

CHAPTER V

EXPERIMENT I

In the motor learning domain, stimulus generalization curves have only been produced for movement length (Hedges, Dickinson, & Modigliani, 1983). Therefore, the first purpose of Experiment I was to generate a stimulus generalization curve for isometric force. The second purpose of Experiment I was to determine the transfer forces used in Experiment III.

The classification of the transfer forces was based on Gibson's theory of transfer of training. Isometric forces located within the stimulus generalization curve were operationally defined as being similar to the criterion force, while forces located outside the curve were operationally defined as being different from the criterion force.

Methods

Subjects

Five right-handed males and five right-handed females ($n=10$) were recruited from the student population of Simon Fraser University. The subjects were informed of the purpose and experimental procedure of the study and were required to sign a consent form.

Apparatus

The isometric forces were produced by wrist flexion. The right forearm was positioned on a padded support so that the forearm was perpendicular to the arm and the palmar surface of the hand was in the vertical plane. The forearm was strapped to the support frame approximately 5 cm above the wrist and 5 cm below the elbow.

The hand and wrist were not supported. The palmar surface of the hand was centered immediately beside a 10 cm x 15 cm x 0.6 cm aluminum plate, also positioned in the vertical plane. The location of the

plate ensured that the wrist angle was maintained at 180 degrees to the forearm. A force transducer (Load Cell Type #UIT-30100, Hottinger Baldwin Measurements Inc., Framingham, MA.) was attached to the center backside of the plate and to the support frame. When a force was exerted on the plate, through the palmar surface of the hand, the analog signal from the force transducer increased linearly with an increase in force. The analog signal was produced by strain gauges in a Wheat Stone Bridge circuit. The analog signal from the force transducer was amplified 750 times and then digitized by a 12 bit A/D converter (AI13, Interactive Structures, Inc., Bala Cynwyd, PA). The digitized signal was recorded by an Apple-like computer. (See Figs. 5.1a and 5.1b.)

Two data analysis programs were used for this study. The sampling rate of both programs was 250 Hz. The first program provided the subject with concurrent knowledge of results (KR). The digitized signal was sampled and the values were transformed into Newtons and compared to a target value. If the sampled values were equal to the target value, or within a specified range of the target value, a tone was sounded. The tone was maintained as long as the force produced was within the target range. A 'beep' sounded at the end of each trial. The target value, error range, and sampling time were specified by the experimenter.

The second program provided the subject with terminal KR. The sampling time of this program was 1.5 seconds, and therefore, the subject had 1.5 seconds to reproduce the isometric force. A 'beep' sounded at the beginning and end of each trial. Following the second 'beep' the average force and error (average force - target force) over the last 0.1 seconds was calculated in kilograms and the results were displayed on the monitor. It was decided to provide KR in kilograms because the subject would be more familiar with describing the magnitude of force in kilograms rather than Newtons. The sampled data for the 1.5 seconds were stored on a floppy disc.

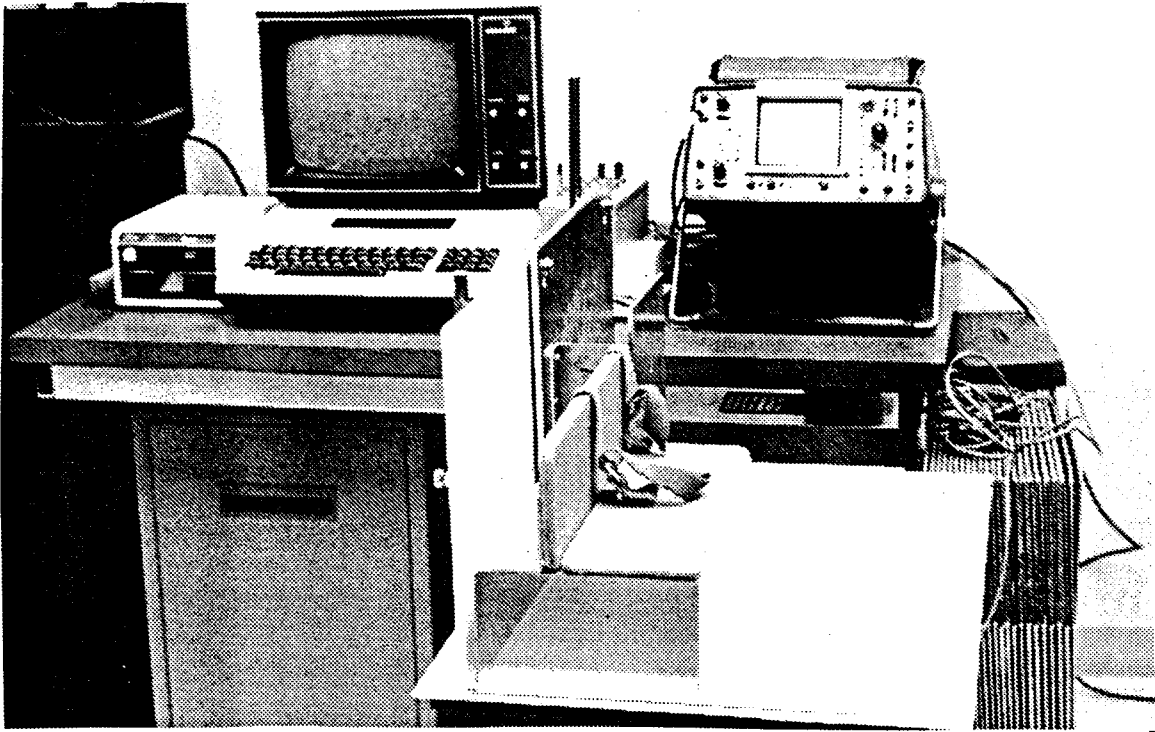


Figure 5.1a: Diagram of the Apparatus

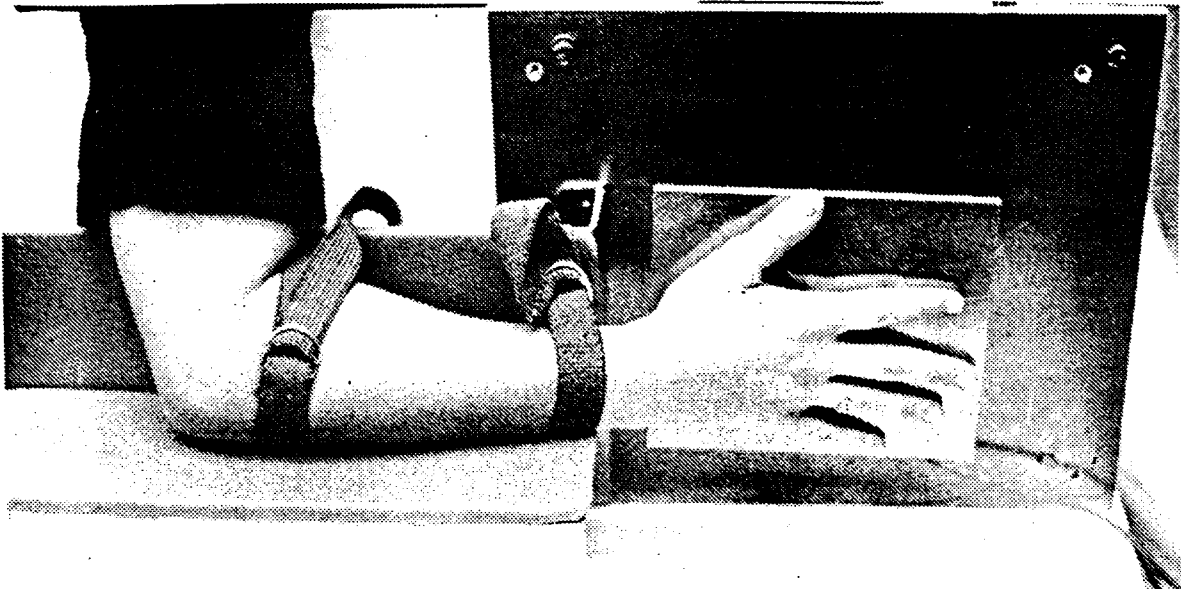


Figure 5.1b: Position of the right arm and hand on the apparatus

Procedure

Each subject was seated beside the apparatus and their right forearm was strapped to the forearm support. The height of the forearm support was adjusted so that the forearm was perpendicular to the arm. A monitor was positioned on a table in front of the subject. Each subject was tested to calculate an average stimulus generalization curve for 19.62 N (2 kg). The procedure that was used to determine the curve was similar to that used by Hedges, Dickinson, and Modigliani (1983).

The subject initially learned to reproduce 19.62 N accurately by completing 40 trials using the terminal KR program. Pilot studies indicated that subjects had learned to reproduce an isometric force accurately and consistently after 40 trials. (See Fig. 5.2 and 5.3.) At the start of each trial a beep sounded. At the sound of the beep the subject started to exert force on the plate. The subject increased the amount of force exerted on the plate until he/she felt they were exerting 19.62 N of force. The subject maintained the force until a second beep sounded. At the sound of the second beep the subject relaxed his/her forearm muscles. Immediately following, the results of the trial were displayed on the monitor. The subject used the information to make corrections in his/her response for the next trial. Approximately 10 seconds separated each trial. During this time the subject rested his/her hand just beside the plate.

Following the 40 trials, the subject was presented with 21 different forces ranging from 9.81 N (1 kg) to 29.43 N (3 kg) in 0.98 N (0.1 kg) steps. The concurrent KR program was used to present the 21 forces. The subject compared the similarity of each force to 19.62 N. To maintain a strong and accurate reference of 19.62 N in memory, the subject reproduced 19.62 N, using the concurrent KR program, before each force was presented. The order of presentation of the 21 forces was randomized with a random number table. Ten different lists of the 21 forces were produced so that each subject received a different order of presentation. For each of the 21 forces, the subject slowly exerted force on the plate until he/she heard a tone. The force he/she was producing when he/she heard the tone was the force he/she compared to 19.62 N. The subject was asked to verbally state if the force was the same or different from 19.62 N, and to state on a scale of 1 to 5 (1 being a guess and 5 being absolutely sure) how confident he/she was of the

decision. The subject used the above procedure to reproduce 19.62 N, but was not asked to comment on the force produced.

Results and Discussion

The stimulus generalization curve for 19.62 N was derived from the "same" verbal responses only. Of the 210 forces presented to the 10 subjects, 56 forces were perceived as being the same as 19.62 N. The average confidence rating for each of the 21 forces was calculated. The average confidence rating was calculated by summing the confidence ratings for each force and dividing the total by the number of subjects (10). The average confidence rating for each force was then averaged with the next smallest and next highest forces. The resulting average confidence ratings were then graphed. Fig. 5.4 depicts the stimulus generalization curve for 19.62 N. The gradient spans from 10.79 N to 28.45 N, and although the curve peaks at 20.60 N, the confidence ratings for 18.64 N, 19.62 N, and 21.58 N were similar. The gradient declines sharply on both sides from 18.64 N and 21.58 N. (For reference purposes the generalization gradient for dissimilar verbal responses is shown in Fig. 5.5. These data were not used in determining the similar and different transfer forces.)

The stimulus generalization curve is similar to the stimulus generalization curves for movement length (Hedges, Dickinson, & Modigliani 1983). Although the stimulus generalization curve for force was not further investigated to determine whether it reacted to experimental manipulation in the same way as curves in other modalities (e.g., peak shift), the curve suggests that stimulus generalization also occurs for isometric force reproduction.

The similar and different transfer forces were chosen to be 23.54 N and 34.34 N respectively. The selection of these forces was based on the stimulus generalization curve for 19.62 N. 23.54 N is located approximately halfway between the criterion force and the edge of the gradient, and therefore, conforms to the operational definition of a force similar to 19.62 N. However, 34.34 N is located outside the gradient, and therefore, conforms to the operational definition of a force different from 19.62 N. The production of

a generalization gradient for isometric force therefore enables the application of Gibson's (1940) theory of learning based on stimulus generalization to be applied to the transfer of acquired isometric forces.

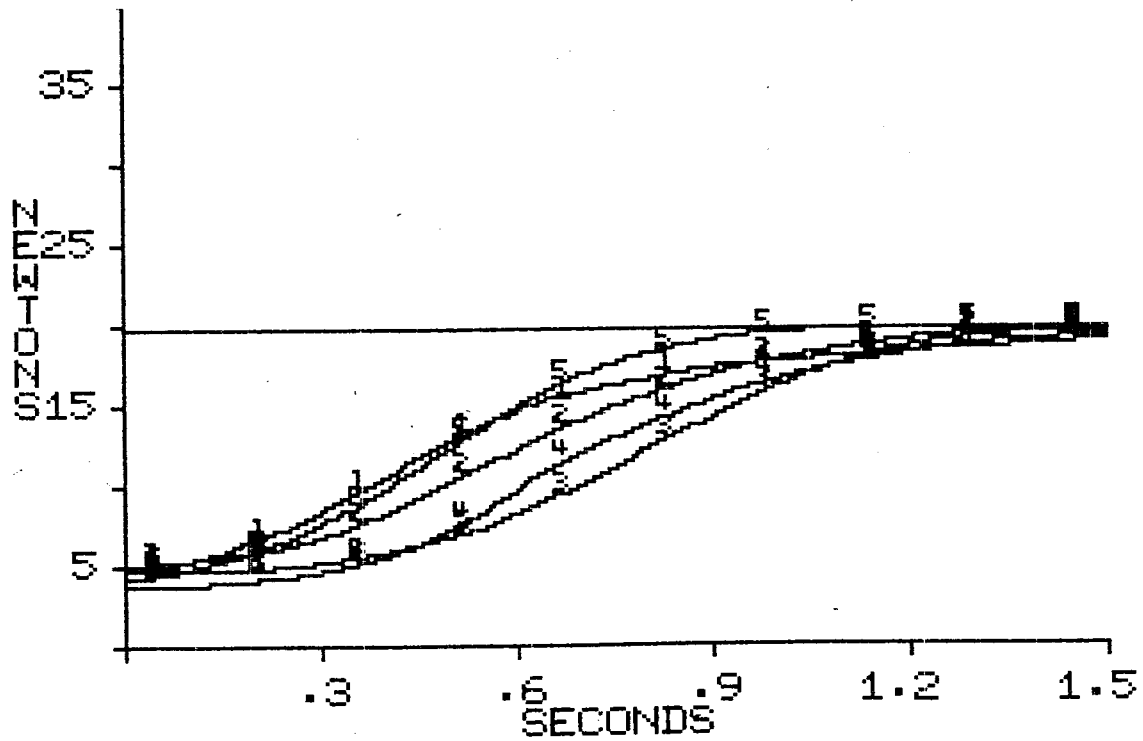
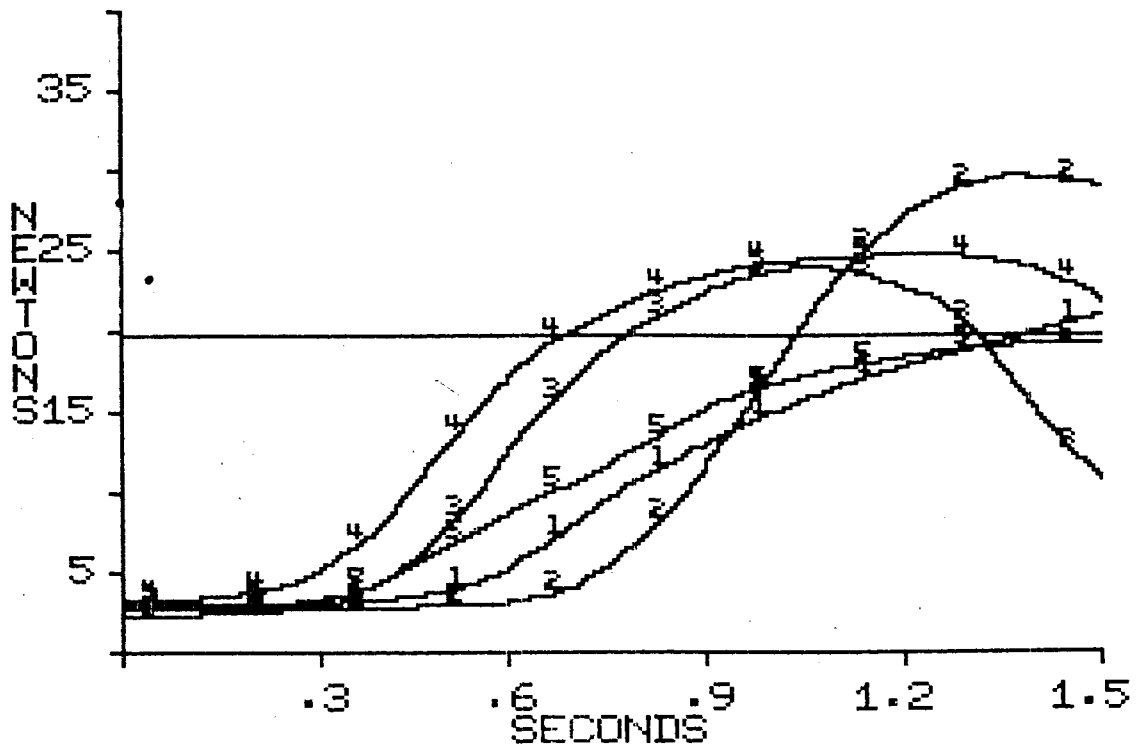


Figure 5.2: First five and last five trials from a pilot study in which the subject was told to reproduce 19.62 N (2 kg) in 1.5 seconds.

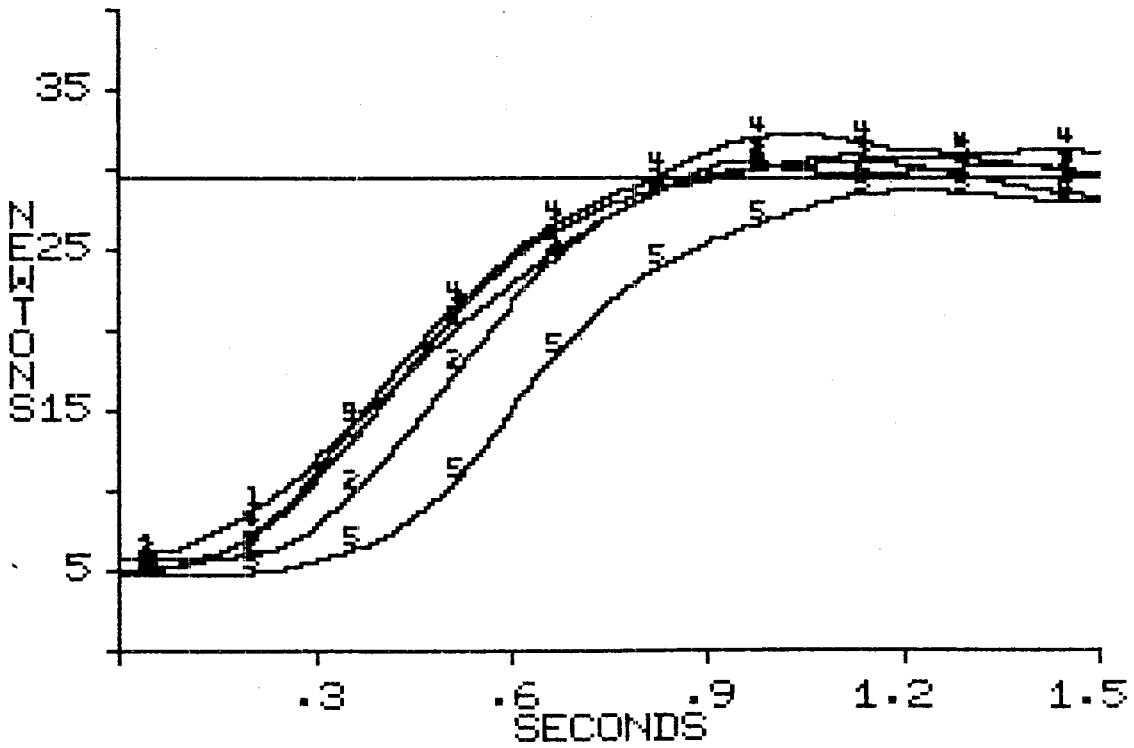
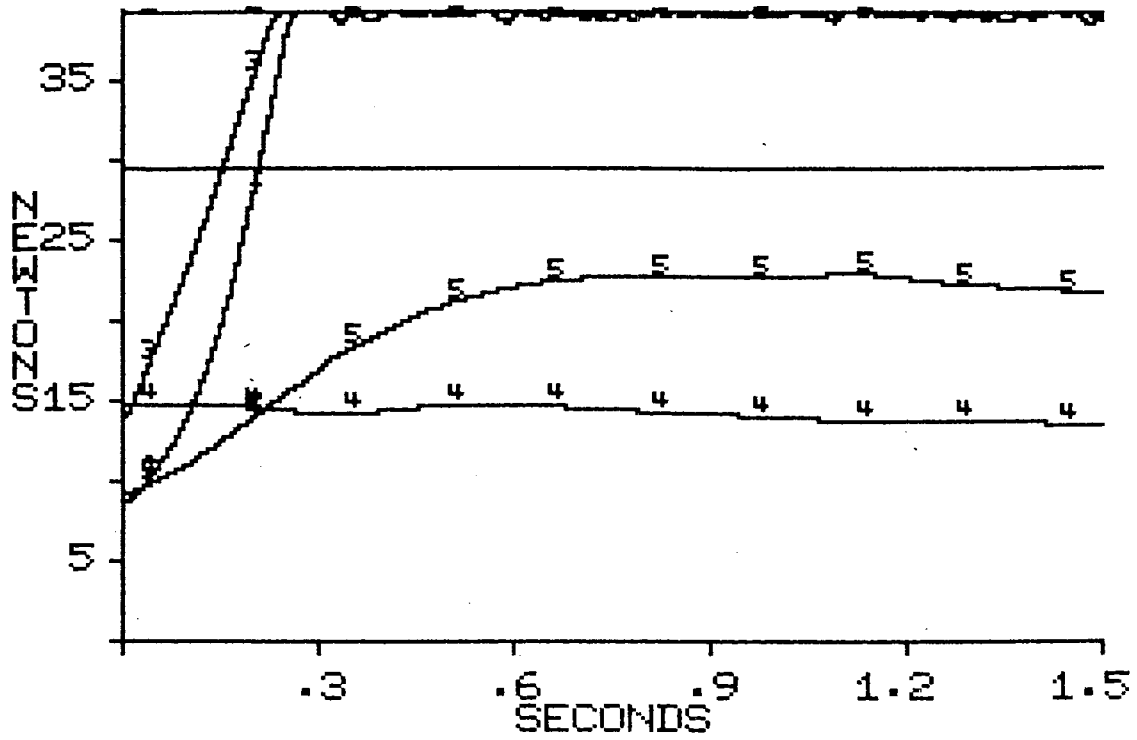


Figure 5.3: First five and last five trials from a pilot study in which the subject was told to reproduce 29.43 N (3 kg) in 1.5 seconds.

Stimulus Generalization Curve for 19.62 N

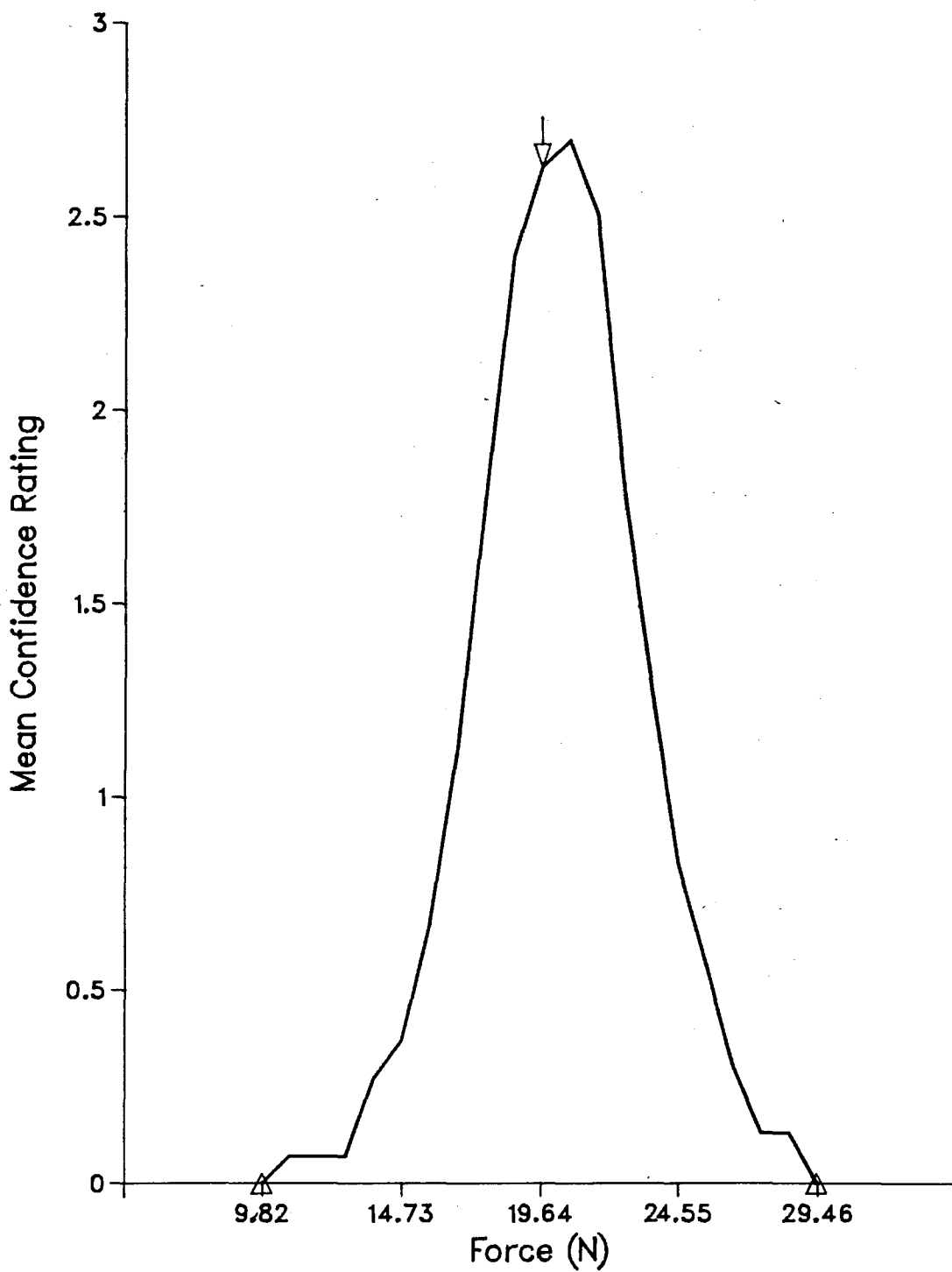


Figure 5.4: Stimulus generalization curve for 19.62 N.

Stimulus Differentiation Curve for 19.62 N

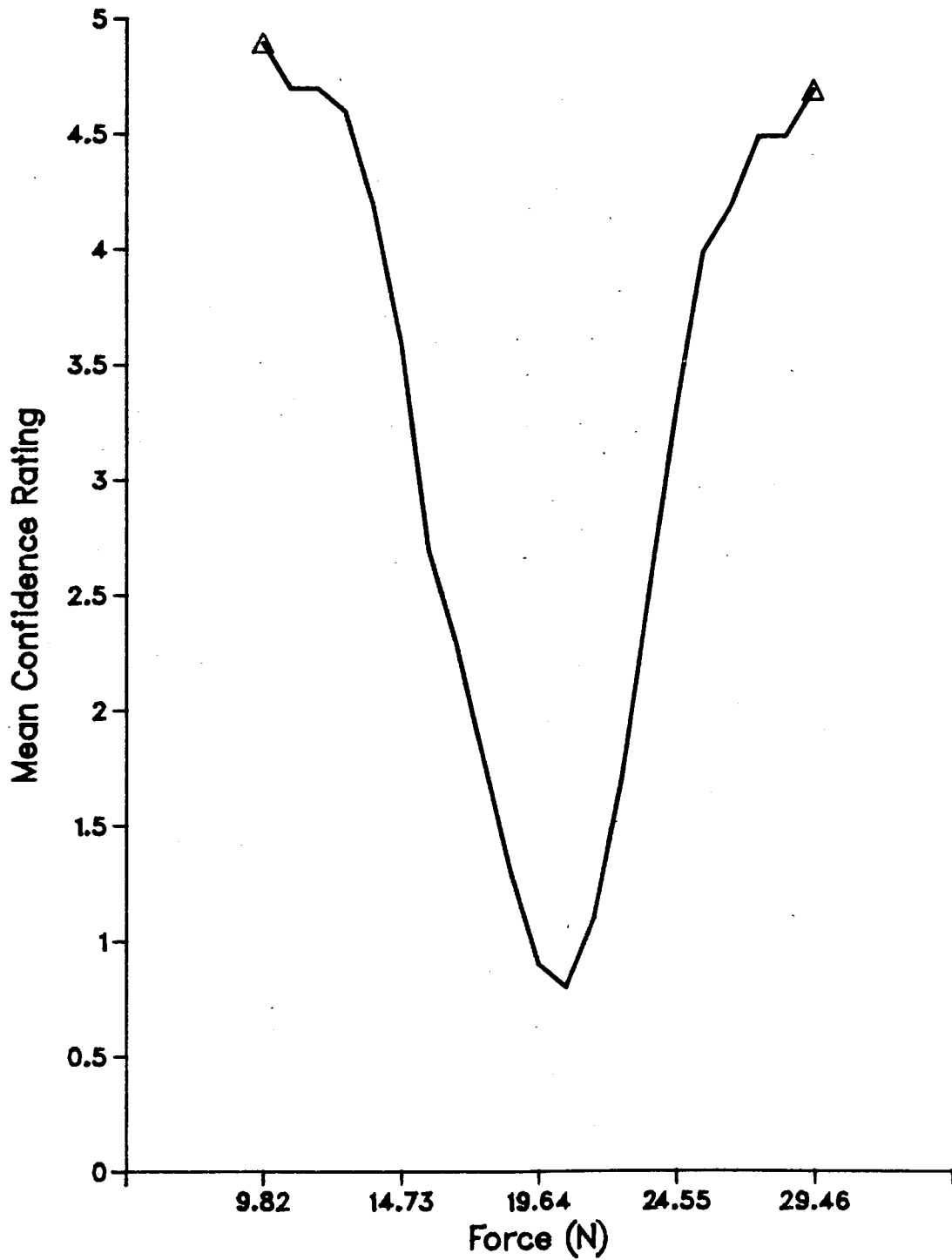


Figure 5.5: Stimulus differentiation curve for 19.62 N.

CHAPTER VI

EXPERIMENT II

In all stimulus modalities, a range of similarity exists in which similar stimuli are perceived to be identical. This zone of similarity is referred to as 'functional identity'. The purpose of Experiment II was to ensure that the similar transfer force and criterion force were not functionally identical. Previous studies in force (weight) discrimination (see Dickinson, 1974 for a review) have shown that just noticeable differences (JND) tend to be on average 10% of the magnitude of the force. Although 23.54 N is 20% greater than the criterion force, it was felt necessary to ensure that the two forces presented in the context of this experimental procedure were indeed noticeably different.

Methods

Subjects

Two right-handed males and two right-handed females ($n=4$) were recruited from the student population of Simon Fraser University. The subjects were informed of the purpose and experimental procedure of the study, and were requested to sign a consent form.

Apparatus

The apparatus was the same as that used in Experiment I.

Procedure

The apparatus was fitted to the subject as described in Experiment I. The procedure for learning and experiencing an isometric force was also the same as that used in Experiment I.

Each subject initially learned 19.62 N by completing 40 trials using the terminal KR program. The subject was then presented with the similar transfer force (23.54 N) and criterion force (19.62 N), 10 times

each, with the concurrent KR program. The presentation of the 20 forces was randomized using a random number table. The subject was asked to state verbally if the force was the same or different from 19.62 N. The subject reproduced 19.62 N using the concurrent KR program, before experiencing each of the 20 forces.

Results and Discussion

The percentage of 'different' responses to 23.54 N was calculated for each subject to determine whether 23.54 N was perceived as being noticeably distinct from 19.62 N. The resulting scores were 70%, 70%, 80%, and 90%. The percentage of 'same' responses to 19.62 N was 80%, 90%, 90%, and 100%. The scores indicated that although 23.54 N was perceived as being similar to 19.62 N, it could be differentiated from 19.62 N. The fact that 19.62 N was perceived as being the 'same' as 19.62 N on 90% of the presentations also supports the finding that 19.62 N and 23.54 N could be differentiated. Based on these results, 23.54 N was accepted as the similar transfer force for Experiment III. It should be noted in this context that standard psychophysical measures suggest that a "just noticeable difference" (JND) is a difference which is detectable on 50% of the presentations (Kling & Riggs, 1971). Hence, the forces of 19.62 N and 23.54 N may be regarded as being separated by more than 1 JND.

CHAPTER VII

EXPERIMENT III

The purpose of Experiment III was to examine the acquisition process of learning to reproduce an isometric force accurately, and to investigate the influence of similar and different past experiences on future force reproduction. In addition, because the selection of transfer forces was based on the stimulus generalization curve of the initially learned force, part of the aim of the experiment was to determine whether stimulus generalization influences the production of novel isometric forces.

The standard technique used to assess the acquisition of motor skills is to measure the accuracy and consistency in performance over time. If the accuracy and/or consistency in performance improves, then learning is inferred. Therefore, one experimental hypothesis was that the accuracy and consistency in reproducing an isometric force would increase over trials.

Transfer of training theories (e.g., Newell & Barclay, 1982) predict that the motor and cognitive skills acquired in learning a motor task will transfer to novel tasks. Thus, it was expected that subjects with prior experience at reproducing an isometric force would demonstrate superior learning and performance over subjects with no prior experience. In addition, it was expected that subjects transferring to a similar isometric force would show superior learning and performance over subjects transferring to a different force. In accordance with the operational definitions, the similar transfer force was located under the stimulus generalization curve of the initially acquired force, while the different transfer force was located outside of the curve. Stimulus generalization theory would predict, therefore, that motor components learned during the acquisition of the first isometric force would enhance the learning of the similar transfer force more than the different transfer force.

Methods

Subjects

Twenty right-handed males and twenty right-handed females ($n = 40$) were recruited from the student population of Simon Fraser University. The subjects were informed of the purpose and experimental procedure of the study, were required to sign a consent form and were paid for their participation.

Apparatus

For Experiment III an oscilloscope (Tektronix #455) was added to the apparatus used in Experiments I and II. (See Fig. 5.1.) The oscilloscope was positioned in front of the experimenter and displayed the maximum force subjects could produce with their right wrist flexor muscles.

Procedure

The subject population was limited by handedness and the maximum voluntary force produced by the right wrist flexor muscles. The apparatus restricted the subject population to right-handed people. The results of studies on perception of effort, however, were the basis for limiting the subject population by strength.

Jones and Hunter (1982) demonstrated that in a force matching experiment in which subjects had to match isometric forces exerted by their right arm with their left arm, subjects over-estimated the reference force at forces less than 25% of their maximal voluntary contraction (MVC), and under-estimated the reference force at forces greater than 80% of their MVC. In addition, Banister (1979) reported that sensitivity to effort decreases exponentially as effort increases (See Fig. 7.1.) These studies suggest, therefore, that perception of effort will be relatively accurate between 25% and 80% of maximum effort. Thus, in order to control for possible differences in isometric force perception between subjects, the maximal voluntary isometric force had to be greater than 125% of the maximum force reproduced, and less

than 400% of the minimum force used in the study. Therefore, the magnitude of the forces reproduced were within 25% and 80% of the maximum forces produced by all subjects.

The apparatus was fitted to each subject as described in Experiment I. The subjects were then instructed to exert as much force on the plate as they could using only their wrist flexor muscles. The subjects were instructed not to use their arm adductor muscles. The force exerted on the plate was displayed on an oscilloscope. If the maximum force produced was between 44.14 N and 78.48 N the subject completed the rest of the experiment. Two subjects did not meet the criteria of the study and were replaced.

A proactive transfer paradigm, consisting of 2 experimental (E-24 and E-34) and 2 control (C-24 and C-34) groups, was used. The subjects were randomly assigned to one of the 4 groups with the stipulation that each group contained an equal number of males and females. E-24 and E-34 initially learned to reproduce 19.62 N. Subjects reproduced 19.62 N 40 times using the terminal KR program. The procedure for learning to reproduce an isometric force was the same as that described in Experiment I. Following a 5 minute rest, E-24 then learned to reproduce 23.54 N and E-34 learned to reproduce 34.34 N. C-24 and C-34 only learned to reproduce 23.54 N and 34.34 N, respectively. (See Table 7.1.)

Analysis of Data

Three dependent variables were calculated from the sampled data to obtain measures of accuracy and consistency in learning to reproduce an isometric force. The variables were the constant error (CE) and variable error (VE) of the force produced at the end of each trial, and the Root Mean Square (RMS) error for trials 1 to 35. To calculate CE an error score was first calculated for each trial by subtracting the target force from the actual force produced over the last 0.1 seconds. The trials were then grouped into blocks of 5 trials and the average error score was calculated for each block of trials. VE was also calculated from the error scores for each block of trials. Eight CE and VE measures were obtained for each set of 40 trials for each subject. To determine the RMS error, an average force curve was calculated from the last 5 trials and the resulting curve used as a reference for trials 1 to 35. (See Fig. 5.2 and 5.3.) The RMS error was not

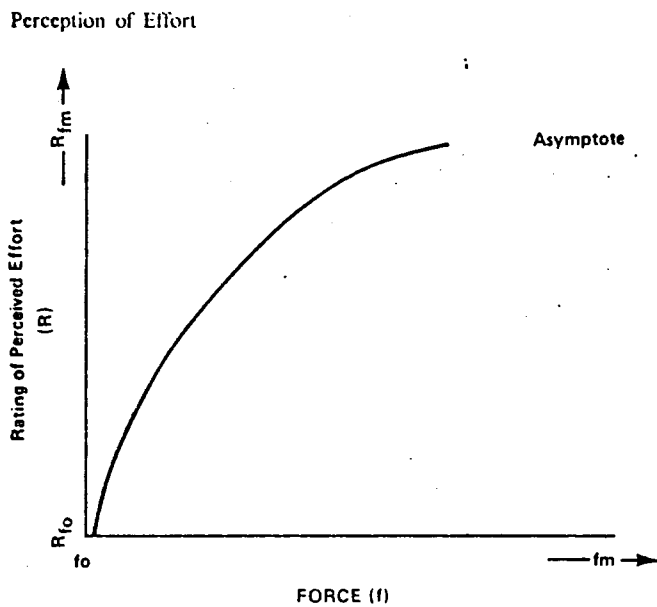


Figure 7.1: Diagrammatic representation of the hypothesized way in which the perception of any effort grows to maximum (Banister,1979)

Table 7.1: Proactive Transfer Paradigm

Group	Force A (N)	Force B (N)
E-24	19.62	23.54
C-24	23.54	23.54
E-34	19.62	34.34
C-34	34.34	34.34

calculated for trials 36 to 40 because these trials were used to determine the average force curve. Again, the trials were grouped into blocks of 5 trials and the average RMS error was calculated for each block. Seven RMS error measures were obtained for each set of 40 trials for each subject. Thus, for the purpose of this investigation, the average force curve was considered to represent the acquired process of accurately reproducing an isometric force, CE was used to assess the terminal accuracy in reproducing an isometric force, VE was used to assess the consistency in reproducing the terminal force, and RMS error was used to determine the consistency in using the same process to reproduce

Results and Discussion

The analysis of learning to reproduce an isometric force is discussed first, followed by the analysis of transfer of training. For the purpose of the analysis, all values in the ANOVA were considered statistically significant at $p < .05$. The t-tests were considered statistically significant at $p < .0125$ because 4 t-tests were completed for each dependent variable. The overall chance of producing a Type I error for each dependent variable was maintained at $p < .05$.

Analysis of Learning

For the analysis of the acquisition process of learning to reproduce an isometric force, only the first set of blocked trials of each group were analyzed. In addition, the scores from E-24 and E-34 were combined to form one group since both groups learned 19.62 N under identical experimental conditions. The three dependent variables were analyzed by ANOVA.

The analysis of CE revealed significant block effects; $F(7,259)=3.56$. The findings, depicted in Fig. 7.2, show that CE significantly decreased over blocks. The majority of improvement in performance occurred from block 1 to block 2. For 19.62 N and 23.54 N the magnitude of CE remained consistently low for the remaining 6 blocks. For 34.34 N, however, the highest CE occurred at block 8. Because the CE for 34.34 N was relatively low for the first 7 blocks, the large CE at block 8 may be a factor of fatigue. The results suggest, therefore, that subjects acquired the skill of accurately reproducing an isometric force within the initial 5 learning trials.

The analysis of VE revealed significant group, block, and group times block interaction effects; $F(2,37)=14.47$, $F(2,257)=39.82$, $F(14,259)=4.08$. The results are shown in Fig. 7.3. Subjects significantly improved their ability to consistently produce an isometric force over the 8 blocks. With the exception of 34.34 N, the improvement in performance occurred between block 1 and block 2 indicating again that the skill of reproducing an isometric force was acquired within the first 5 trials. The results also show that the magnitude of VE increased as the magnitude of the force increased. The average VE for 19.62 N, 23.54 N, and 34.34 N was 2.55 N, 4.43 N, and 5.17 N, respectively. A magnitude-dependent VE for force has also been reported by Schmidt, Zelaznik, and Frank (1978). Schmidt *et al* found that when subjects were instructed to reproduce an isometric force every 800 ms, within subject variability increased as force increased.

The RMS error was calculated to assess whether the process of reproducing an isometric force changed with learning. The analysis of RMS error revealed significant group and block effects; $F(2,37)=18.73$, $F(6,222)=24.22$. The results, displayed in Fig. 7.4, show that RMS error significantly

CE Over Blocks Of 5 Trials

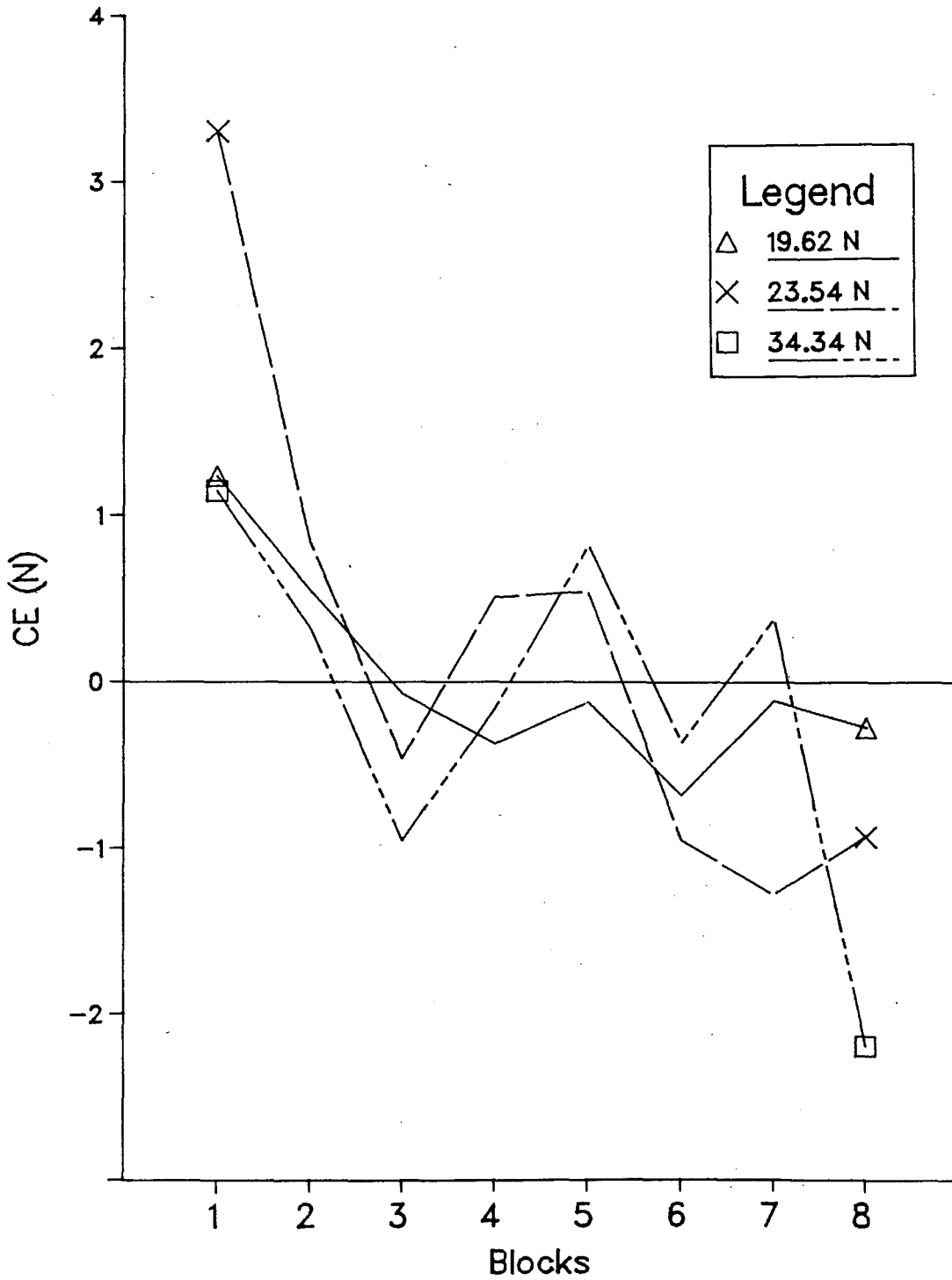


Figure 7.2: Change of CE over blocks of 5 trials

VE Over Blocks Of 5 Trials

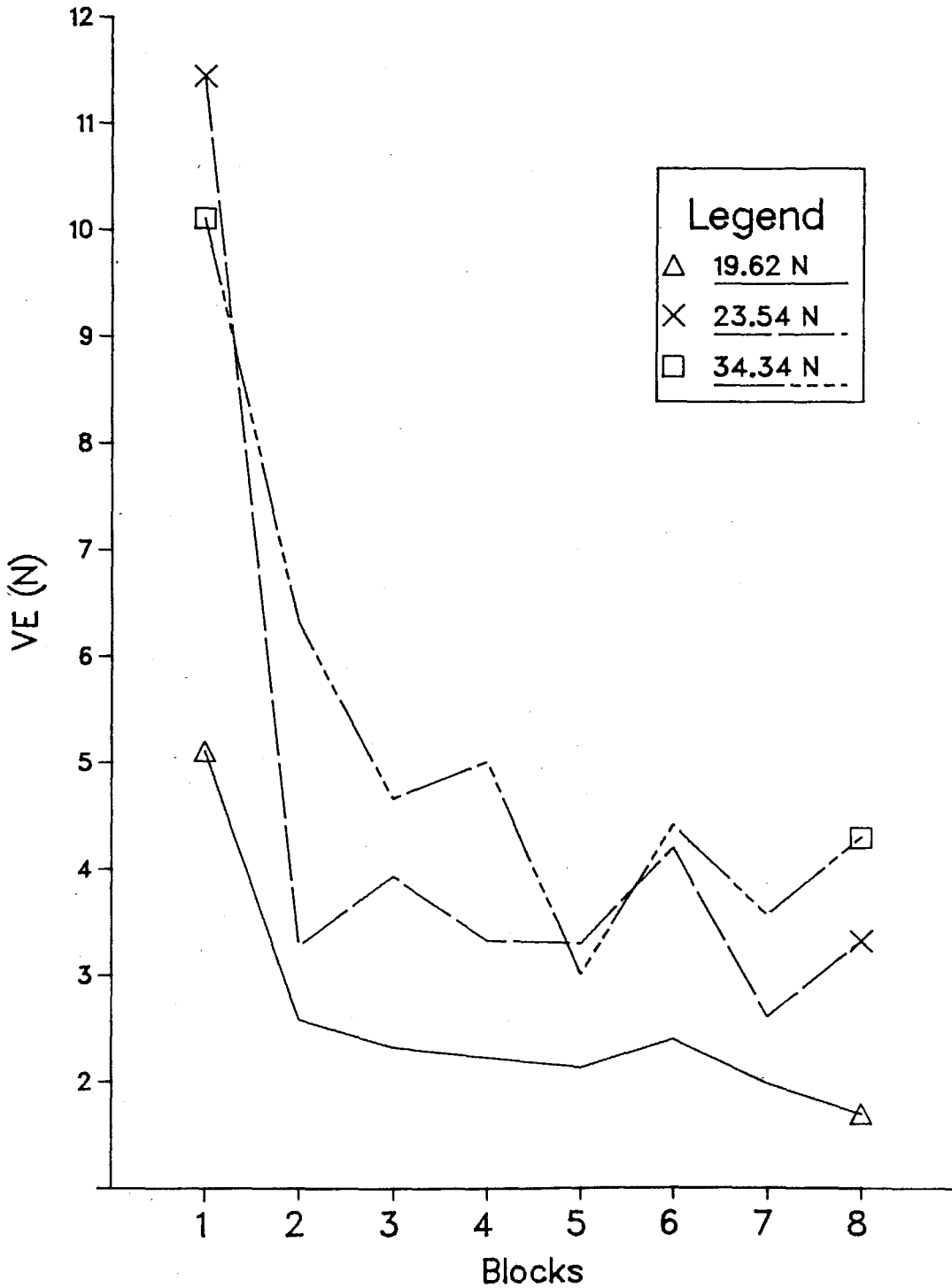


Figure 7.3: Change of VE over blocks of 5 trials

decreased over the 8 blocks. As with the previous 2 performance measures, the majority of improvement in performance occurred from block 1 to block 2. However, unlike the previous 2 performance measures, RMS error continued to decline over the remaining blocks. The results also show that the magnitude of the RMS error increased as the magnitude of the force increased. The average RMS error for 19.62 N, 23.54 N, and 34.34 N was 2.74 N, 3.89 N, and 5.35 N, respectively. The results suggest that the magnitude of the RMS error may also be dependent upon the magnitude of the response produced. The fact that there were group differences indicates that RMS error reflects not only consistency in the process of producing the force, but also is sensitive to the magnitude of the force. (See Table 7.2 for a summary of the learning analysis.)

The findings indicate that the process subjects used to reproduce an isometric force significantly changed with learning. The initial RMS error scores show that the initial force curves were highly deviant from the averaged force curve of trials 36 to 40. As the number of trials progressed the RMS error declined, indicating that the process of reproducing the forces became increasingly similar to the acquired process.

Subjects were only told to reproduce an isometric force accurately within 1.5 seconds, and were only given feedback about their performance over the last 0.1 seconds. Therefore, the significant change in the process by which subjects achieved the target force may be attributed to incidental learning because subjects were not instructed to reproduce the target force with a consistent process. They were only instructed to produce a specific force at 1.5 seconds. Pilot studies showed that different processes could be used to achieve the target force. (See Fig. 5.2 and 5.3.) Dickinson (1977, 1978) and Crocker and Dickinson (1983) have presented evidence for incidental learning in the motor domain. In his review of incidental learning, Dickinson pointed out that material learned under incidental conditions is seldom acquired to the same level as material learned under intentional learning conditions, when the amount of practice is held constant between conditions. The fact that RMS error continued to decline after trial 5 suggests that learning of the process was slower than the acquisition of accuracy. This is typical of components of tasks learned under incidental conditions.

RMS Error Over Blocks Of 5 Trials

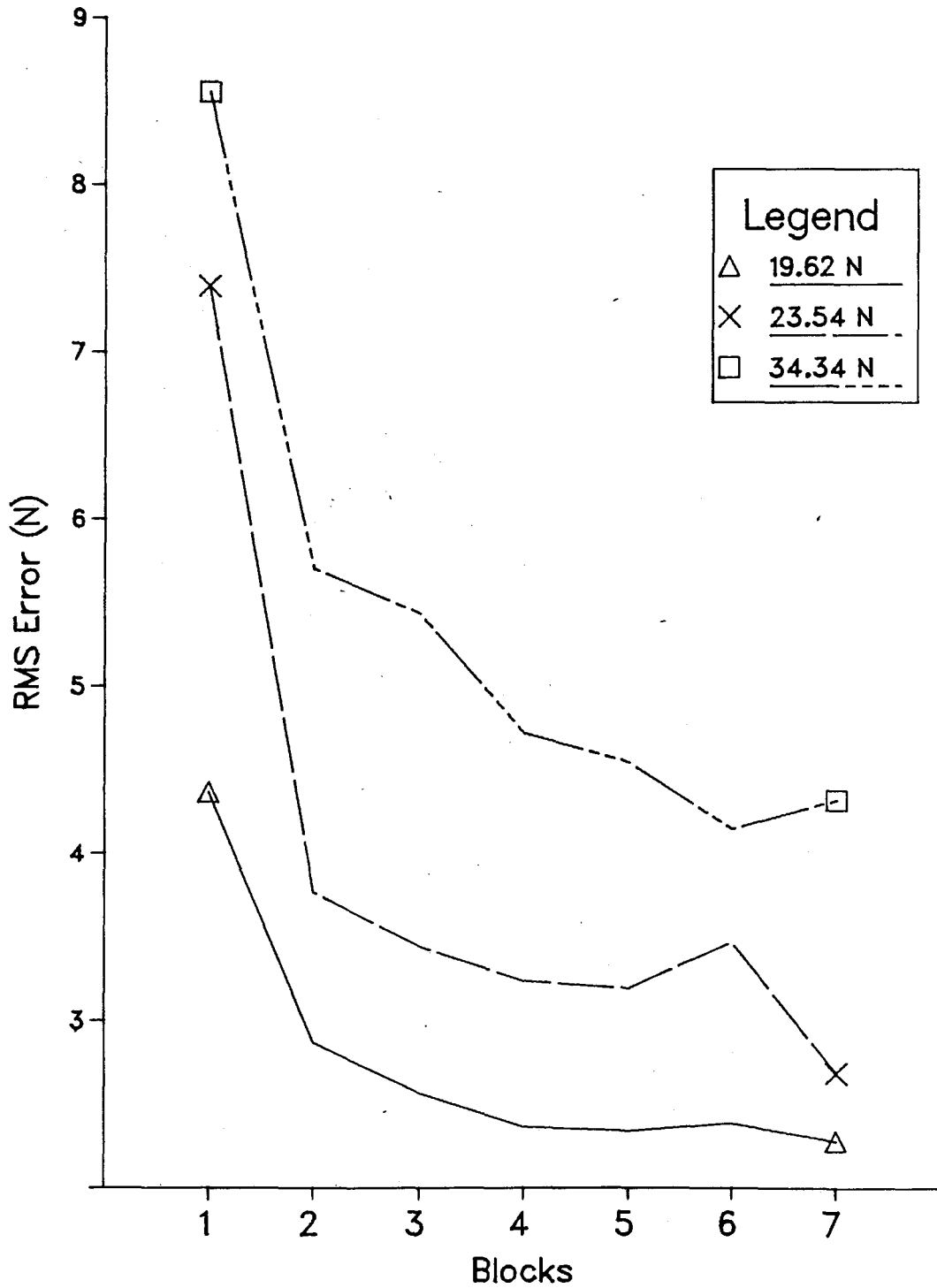


Figure 7.4: Change of RMS error over blocks of 5 trials

Table 7.2: Summary of Analysis of Variance

	Source	Group (G)	Block (B)	GxB
CE	MS	2.116	31.73	6.348
	F	.12*	3.56*	0.71
VE	MS	212.51	144.44	14.80
	F	14.17*	39.82*	4.08*
RMS Error	MS	176.37	55.07	3.33
	F	16.48*	19.34*	1.17

df=2 for Group; df=7 for CE and VE Block; df=6 for RMS Block;
df=14 for CE and VE GxB; df=12 for RMS GxB

* $p < .05$

The results of the experiment show that subjects learned to accurately (CE) and consistently (VE) reproduce an isometric force within 5 learning trials. Subjects also acquired the ability to use the same process (RMS error) to reach the terminal force within 35 trials. The level of consistency (VE and RMS error) subjects could attain in reproducing an isometric force appears to be dependent upon the magnitude of the force. As the magnitude of the response was increased, the degree of consistency subjects could attain in performing the task decreased.

Analysis of Transfer of Training

For the analysis of transfer of isometric force reproduction, the first and second sets of blocked trials of C-24 and C-34 were compared with the blocked transfer trials of E-24 and E-34, respectively, using independent t-tests. The standard proactive transfer paradigm requires that only the first set of trials of the control group be compared to the transfer trials of the experimental group. This design, although extensively used in transfer research, does not allow subjects equal practice on the experimental task. If subjects must learn to use the equipment, then the experimental group may perform better than the control group because of their previous experience with the equipment. Thus, in order to assess possible practice effects, the second set of blocked trials of the control groups was also compared to the blocked transfer

Table 7.3: Means and Standard Deviations of the Experimental and Control Groups for 8 Blocks and the First Block of Trials

		Force	Control-S1		Control-S2		Experimental	
			M	SD	M	SD	M	SD
CE	8 Blocks	23.54	.20	.914	-.61	.681	-.14	.993
		34.34	-.12	2.102	-.92	1.320	-.129	2.647
	1st Block	23.54	3.30	7.643	-1.48	3.196	-1.17	2.689
		34.34	1.15	7.55	-1.36	1.901	-3.36	4.075
VE	8 Blocks	23.54	4.43	1.561	3.13	1.455	2.35	.485
		34.34	5.18	1.909	3.57	.976	4.04	1.412
	1st Block	23.54	11.44	4.083	5.59	3.138	3.91	1.672
		34.34	10.10	4.62	4.46	2.283	5.10	3.431
RMS Error	8 Blocks	23.54	3.89	1.202	3.16	1.201	2.73	.984
		34.34	5.35	1.651	3.61	.536	4.13	1.005
	1st Block	23.54	7.39	3.765	4.52	1.365	3.62	1.630
		34.34	8.56	3.600	4.01	.859	4.36	1.630

$p < .0125$

trials of the experimental groups.

A second set of analyses was also completed using only the first block of 5 trials. The rationale behind this analysis was that transfer effects are believed to be best observed in the first few attempts at a novel task because subsequent learning may influence the retention of the initial task (retroactive interference or facilitation). In addition, the analysis of isometric force acquisition showed that subjects learned to reproduce an isometric force accurately within the first block of trials.

The analysis of CE did not reveal significant differences in performances between the experimental and control groups in either the first block of trials (C-24-S1/E-24 $t(18) = 1.75$; C-24-S2/E-24 $t(18) = -0.23$; C-34-S1/E-34 $t(18) = 1.66$; C-34-S2/E-34 $t(18) = 1.40$) or all 8 blocks of trials (C-24-S1/E-24

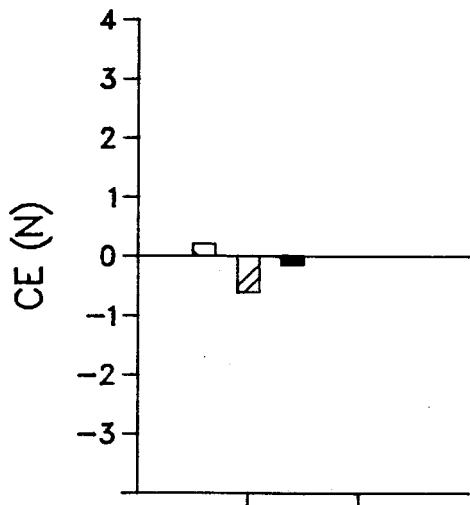
$t(18)=0.79$; C-24-S2/E24 $t(18)=-1.25$; C-34-S1/E-34 $t(18)=1.10$; C-34-S2/E-34 $t(18)=0.40$).

Although Fig.7.5 shows that E-24 performed better than C-24 in the first block of trials in the first session, and C-34 performed better than E-34 in the first block of trials in the first and second sessions, the variance in performance between trials was large (see Fig. 7.6). This rendered the group differences non-significant. Fig. 7.6 displays the results of VE over the first and 8 blocks of trials. The analysis of VE showed significant differences between E-24 and C-24 in the first and 8 blocks of trials in the first session; $t(18)=5.40$, $t(18)=4.02$. E-24 performed significantly better than C-24 in the first session, but after both groups had equal practice on the equipment, there was no difference in performances. The results of RMS error over the first and 7 blocks of trials are displayed in Fig. 7.7. Even though no significant differences were revealed over the 7 blocks of trials, ($t(18)=2.35$, $t(18)=0.86$, $t(18)=2.00$, $t(18)=-1.44$), a significant difference was shown between E-34 and C-34 in the first block of trials in the first session; $t(18)=3.36$. E-34 performed better than C-34 in the first session, but again, after both groups had equal practice on the equipment, there was no difference in performances. (See Table 7.3 for the means and standard deviations of the experimental and control groups.)

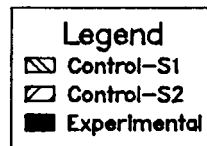
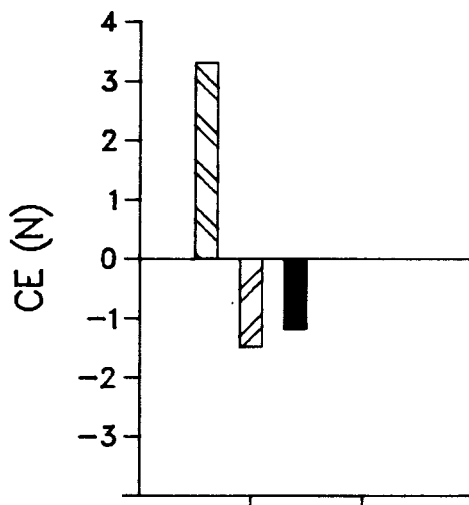
If it is assumed that VE and RMS error reflect the consistency in the process by which the individual achieves the target force, and if it is assumed that the process is largely cognitive in nature, then the findings suggest that the cognitive components acquired for reproducing 19.62 N transferred to the similar and different forces. It appears that subjects were able to apply the process of producing 19.62 N to producing 23.54 N and 34.34 N. This suggestion is based on the finding that differences between E-24 and C-24, and between E-34 and C-34 for VE and RMS error either were significant ($p<.0125$) or approached significance ($p<.05$). (See Fig. 7.6 and 7.7.) In addition, the finding that there were no differences between the experimental and control groups when both groups had equal practice on the task, supports the suggestion that the cognitive components transferred to 23.54 N and 34.34 N. The abilities of subjects to reproduce 23.54 N and 34.34 N were the same, no matter if they had prior experience at reproducing 19.62 N, or 23.54 N or 34.34 N, respectively.

Transfer Force – 23.54 N

8 Blocks

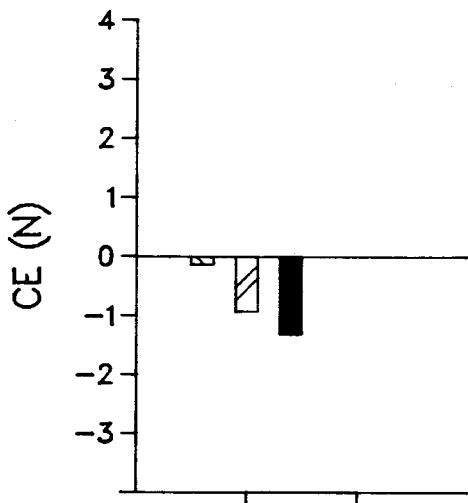


First Block



Transfer Force – 34.34 N

8 Blocks



First Block

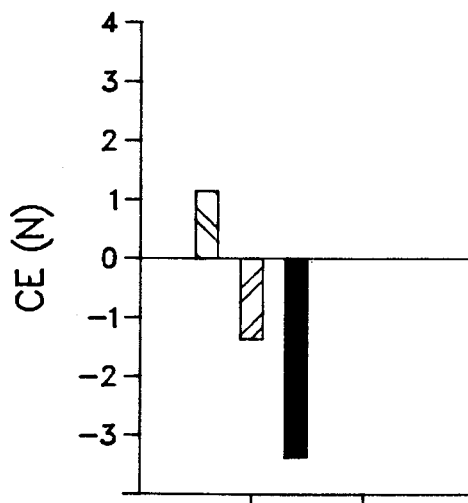
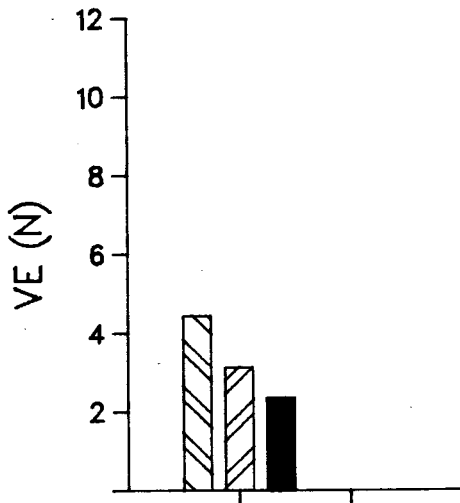


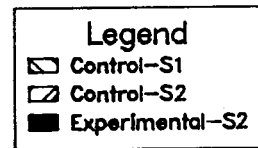
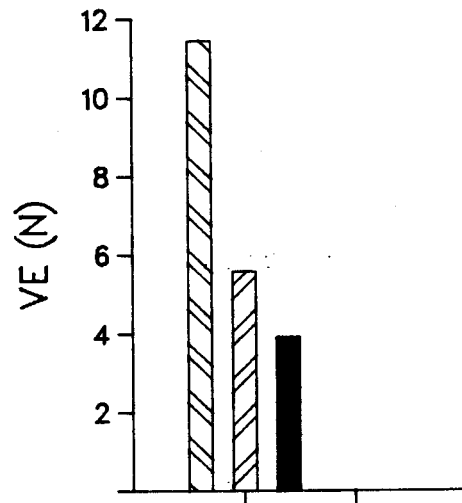
Figure 7.5: Differences in CE between experimental and control groups over 8 blocks and the first block of trials

Transfer Force – 23.54 N

8 Blocks

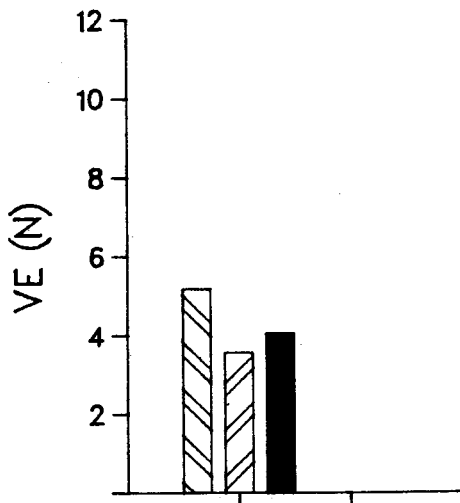


First Block



Transfer Force – 34.34 N

8 Blocks



First Block

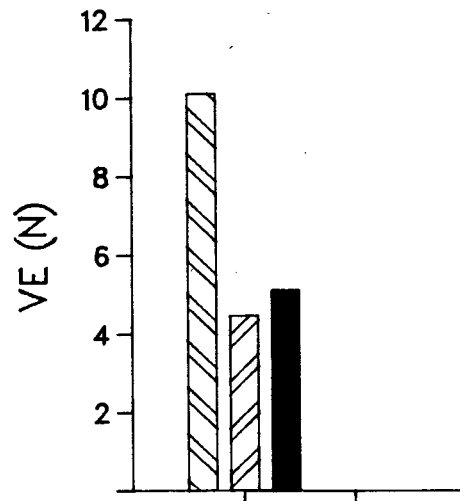
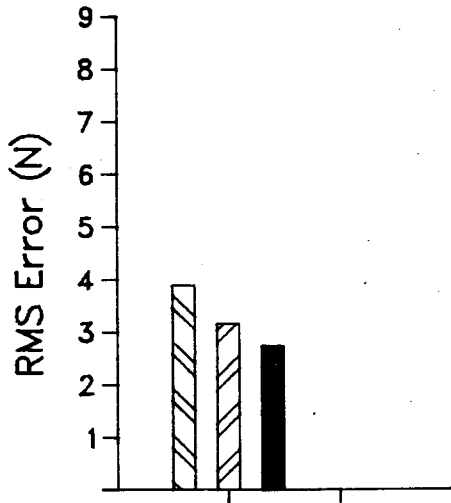


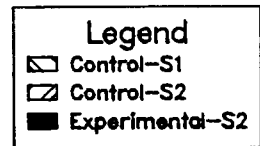
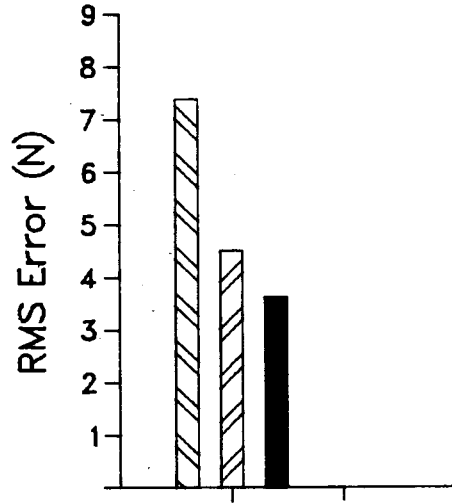
Figure 7.6: Differences in VE between experimental and control groups over 8 blocks and the first block of trials

Transfer Force – 23.54 N

8 Blocks

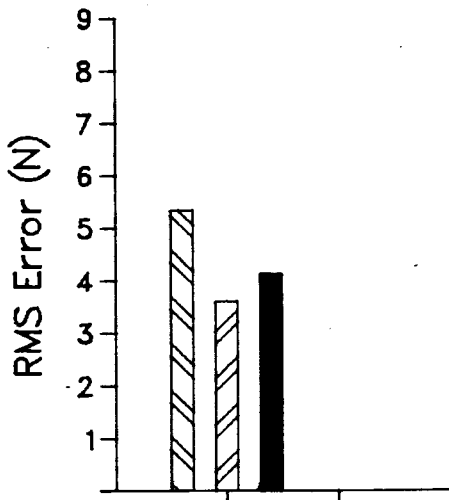


First Block



Transfer Force – 34.34 N

8 Blocks



First Block

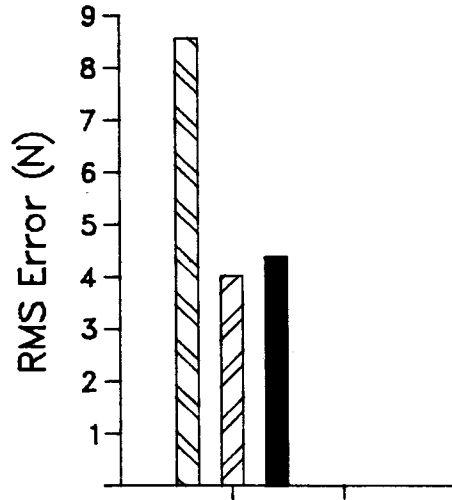


Figure 7.7: Differences in RMS error between experimental and control groups over 8 blocks and the first block of trials

If it is assumed that CE reflects the magnitude of the force produced, and if it is assumed that the magnitude of the force produced reflects the motor aspect of reproducing an isometric force, then the results suggest that the motor components acquired for reproducing 19.62 N did not transfer to the similar and different forces. It was hypothesized that the motor components acquired in learning to reproduce 19.62 N would facilitate the acquisition of 23.54 N and 34.34 N, with the amount of facilitation being greater for 23.54 N. 23.54 N lies within the stimulus generalization gradient of 19.62 N. Based on the stimulus generalization theory, subjects would have been expected to be able to generalize between 19.62 N and 23.54 N. The results show, however, that the experimental and control groups were equally accurate in reproducing 23.54 N and 34.34 N, thus indicating that the motor components acquired in learning to reproduce 19.62 N did not influence the acquisition of the transfer forces.

In one respect the results of the present study partially support the involvement of stimulus generalization in the learning of isometric forces. Gibson (1940) suggested that the amount of facilitation in human learning from past experiences is a function of stimulus generalization, with the amount of facilitation increasing as stimuli become more similar. No facilitation of learning will occur if stimuli are located outside the generalization gradient. The present findings show that prior experience of reproducing 19.62 N significantly improved the ability of the subject to consistently (VE) reproduce a force (23.54 N) located within the stimulus generalization gradient for 19.62 N, but not for a force (34.34 N) located outside of the gradient. This improved performance was maintained across all 8 blocks of trials. (See Fig. 7.6.)

The findings of the present study lend support to Newell and Barclays' (1982) heirarchical concept of transfer of training. Newell and Barclay proposed that movements are stored in memory in a continuum of schemata, ranging from abstract to concrete movement representation. They suggested that movements are produced by passing from an abstract representation of the act, through successive stages of differentiation, to the point where response parameters are issued for movement production. In addition, they suggested that as you pass from the abstract to concrete end of the continuum, the schemata influence an increasingly narrower range of responses. This implies that when 2 different movements are produced,

the cognitive responses may be generated from the same schema, while the motor responses may be generated from different schemata. Based on my interpretations of what the dependent variables represent the results from the present study show that the cognitive components acquired in learning to reproduce 19.62 N facilitated the acquisition of 23.54 N and 34.34 N. The motor components did not influence the acquisition of the transfer forces. This may suggest that the cognitive components for reproducing 23.54 N and 34.34 N were generated from the same schema as 19.62 N, while the motor components were generated from separate schemata.

Conclusion

The purpose of the experiments described was to investigate the acquisition of learning to reproduce an isometric force, and to examine the influence that prior experience has on the acquisition process. The findings demonstrated that isometric force reproduction can be learned. The degree of accuracy and consistency improved with trials. The level of consistency that can be attained for a given amount of practice was found to be dependent upon the magnitude of the force. An asymptote in accuracy and consistency is reached after 5 trials. The process of achieving the target force improves more slowly. Presumably this slower rate of learning is due to an absence of instruction to subjects to be consistent in this aspect of the task. When instruction is not provided to subjects informing them that they should try to improve in this aspect of the task, performance will still improve but at a slower rate and to a lower level of proficiency. In addition, as the magnitude of the force increases, the degree of proficiency in the process that can be attained decreases.

The present experiment also found that prior experience at reproducing an isometric force can influence the acquisition of a novel task. The amount of transfer to a novel task is dependent on the variables considered. In the current study it has been suggested that cognitive and motor components may transfer independently.

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