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INCIDENTAL AND INTENTIONAL PSYCHOMOTOR LEARNING

by

Peter R. E. Crocker

B.A. (Psychology) Simon Fraser University 1980

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ABSTRACT

The three experiments found herein were conducted to investigate some of the factors that influence incidental and intentional psychomotor learning. Learning was called incidental when subjects received no formal instructions to learn the experimental task, which was a movement sequence. Incidental subjects were exposed to the experimental task by means of a choice reaction-time task. The movements to the targets in the reaction-time task comprised the movements of the movement sequence. Intentional learners also performed the choice reaction-time task but were additionally instructed to remember the order of the movements.

The first experiment tested the effects of movement sequence size on the two types of learning. Sixty subjects, ten in each group, received two trials of a movement sequence composed of either four, seven, or eleven movements. The findings indicated that intentional learning was superior to incidental learning. The results also demonstrated that as the size of the sequence increased, the percentage of movements recalled decreased. Furthermore, the results indicated that when the information load exceeded the "memory span" incidental learning remained at a chance level.

The second experiment investigated the effects of practice under incidental and intentional learning conditions. Forty subjects, ten in each group, received either two or ten trials of a sequence of fifteen movements. The results showed that

intentional learning was superior to incidental learning. The findings also indicated that both intentional and incidental learners showed a significant increase in recall with increased learning trials.

The third experiment attempted to determine the effects of rehearsal blocking activities on incidental and intentional learning. Twenty-eight subjects, seven in each group, performed a four movement sequence for two trials under conditions in which rehearsal blocking activity was either presented or not presented. The results indicated that the initial superiority of the intentional learners under unblocked rehearsal conditions disappeared when subjects engaged in rehearsal blocking activities.

The findings from the three experiments are discussed in relation to previous psychomotor and verbal learning literature. In general, there does not seem to be strong evidence to suggest that incidental and intentional learning are distinct types of learning. Furthermore, it was concluded that 'intent to learn' per se is not a significant factor in psychomotor learning. Rather, it serves to direct subjects to engage in appropriate cognitive processes such as rehearsal that produces learning.

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I. INTRODUCTION

Most human behaviour is learned. Learning, defined as any relatively permanent change in behavior which occurs as a result as experience or practice (Morgan & King, 1956), still occupies a central position in the field of psychology. Few psychologists would disagree that most aspects of human behaviour are affected by the learning process. Interestingly, the analysis of learning dates back to the ancient Greek Philosophers (Boring, 1950), and yet, the study of learning remains one of the most perplexing problems in psychology. The study of learning is perplexing because most psychologists firmly believe the processes involved in the acquisition and retention of even the most complex behaviour must be based on a finite set of fundamental principles (Logan & Ferrano, 1978). Nevertheless, despite decades of systematic analysis, complex theory construction, and a vast collection of empirical data, there exists few, if any, well accepted laws for learning.

The field of learning may be divided, somewhat arbitrarily, into many specific categories. A few of these are verbal learning, concept learning, problem solving, and perceptual skill or psychomotor learning. Psychomotor learning, the area of principal interest for this thesis, is concerned with activities that are primarily movement oriented (Singer, 1980). Unlike the verbal domain which traces its origins to the philosophical works of Aristotle, the associationist views of the British Empiricists such as Hume and Locke, and the empirical psychometrics of Ebbinghaus, the psychomotor domain has no clear identifiable origins (Irion, 1969). Nevertheless, "motor skills" research can be traced back to the works of Woodworth (1899), Bryan and Harter (1897), and Swift (1905). Many of these early investigations were influenced by the general learning theories of the day. Although the psychomotor learning area went through a period of time where a large proportion of research was directed towards solving practical problems, many theoretical studies were, to some degree, influenced by the proponents of the major theories of learning.

Psychomotor learning research has been greatly influenced by three prominent theoretical positions. Two of these theoretical positions, namely the reinforcement and contiguity theories, are included by many authors under the category label of stimulus-response (S-R) theories (Hilgard, 1956; Oxendine, 1968). Stimulus-response theories, also called connectionist theories (Hill, 1977), hold that the basic unit of learning is the connection between a particular stimulus and a specific response. Reinforcement theories hold that reinforcement is a necessary condition for the S-R connection (Hull, 1943; Skinner, 1957; Thorndike, 1927, 1932). Contiguity theories, on the other hand, argue that the contiguity between stimulus and response is the principal condition in the formation of a stimulus-response connection and that reinforcement is not a necessary condition for learning (Guthrie, 1952; Watson, 1924).

The third historically prominent position is the cognitive learning theories. The cognitive theorists attempted to account for the role of cognition in the learning process (Kohler, 1925; Tolman, 1932, 1959). Within the cognitive learning framework the learner is seen as taking an active role in the learning process. The learner organizes stimuli, devises and employs strategies, and behaves in a goal directed manner (Hill, 1977; Jung, 1968; Oxendine, 1968).

Contemporary psychomotor learning theories, which have evolved from the historical positions, have attempted to account for the underlying processes and mechanisms that affect the learning of movement oriented activities. The two most prominent contemporary psychomotor learning theories were proposed by Adams (1971) and Schmidt (1975). Both theories have had a profound impact on the psychomotor learning discipline.

Adams (1971), arguing that S-R theory is inadequate to describe psychomotor behavior, proposed a closed-loop theory of motor learning. Two hypothetical constructs, a memory trace and a perceptual trace, form the basis of this theory. The memory trace is primarily responsible for generating the movement. The perceptual trace is an internal reference mechanism used to guide movement production. Adams (1971) proposed that, when a movement is made, response produced feedback is compared to the standard (perceptual trace) of the desired movement. Any discrepency between the standard and the ongoing movement results in an error being detected. When an error is detected, a correction is made so that the movement mirrors the standard. Adams (1971) proposed that certain independent variables, such as practice and information supplied to the performer from an external source (i.e., knowledge of results), affect the development and strength of the perceptual trace and memory trace.

Schmidt's (1975) psychomotor learning theory, unlike Adams' notion of a one-to-one relationship between stored representations and correct movements, proposed the existence of schema. The concept of schema, found in the earlier work of Bartlett (1932) and Pew (1974), implies that there are generalized representations or sets of rules that govern a given class of movements. Schmidt proposed that a schema is developed from four sources of information: 1) knowledge of the initial conditions before movement execution ; 2) knowledge of the movement requirements ; 3) sensory consequences from the movement and; 4) the response outcomes. Schmidt argued that these sources of information contribute to the formation of a recall and a recognition schema. In this Schema theory, Schmidt attempted to account for how such factors as knowledge of results and the amount and variablity of practice affected the formation of the schema.

Adam's (1971) and Schmidt's (1975) theories have had a profound impact on the conceptualizations of psychomotor learning. The enormous number of studies that cite either of these theories is testimony to their influence. Although these theories have been concerned with determining how specific factors affect the learning process, they failed to address the role of motivation in psychomotor learning. Indeed, one of the most heated controveries in the history of psychology has centred around whether motivation affects learning or performance (Hull, 1943, 1951). A thorough comprehension of psychomotor learning is not complete unless the role of motivation is understood.

Traditionally, most investigative work in psychology on the role of motivation in learning has involved the manipulation of reinforcement. However, another important aspect of motivation concerns the person's intention to learn. Dickinson (1977) suggested that in most studies of psychomotor learning it is implicit that the subject's intention to learn the experimental material is desired, if not essential. It might be argued that the condition of an 'intention to learn' must be satisfied if learning will occur in the motor domain. It has been known for a long time, however, that people seem to acquire verbal information without an 'intent to learn' (Myers, 1913). This learning without an apparent intent to learn has been termed "incidental learning" (McGeoch, 1942; McLaughlin, 1965; Postman, 1964).

The investigation of incidental learning is important because it is concerned with the analysis of conditions which might bias the initial acquisition of information (Postman, 1964). The understanding of psychomotor learning would be advanced if the effects of the initial disposition of a learner that determines the immediate acquisition of information were known. Unfortunately, there has been little systematic analysis of incidental learning in the psychomotor domain.

The major objective of this thesis is to investigate some of the factors that affect incidental and intentional psychomotor learning. What are the differences between incidental and intentional learning? Under what conditions does incidental learning occur? Do independent variables have similar effects on incidental and intentional learning? With these questions in mind the following chapter briefly reviews the incidental learning literature.

II. INTRODUCTION TO INCIDENTAL LEARNING

There appears to be little doubt that incidental learning occurs in the verbal domain. Numerous studies have demonstrated the phenomenon of incidental learning in various experimental areas such as developmental changes (Ghatala, Carbonari, & Bobele, 1980; Maccoby & Hagen, 1965), general verbal learning (Murray, 1971; Postman & Adams, 1957, 1958), and the role of perceptual-cognitive operations in determining memorial consequences (Craik & Lockhart, 1972; Craik & Tulving, 1975; Gardiner, 1974). In general, incidental learning has been found to be inferior to intentional learning (McLaughlin, 1965). However, there is also evidence of equivalent levels of learning (Mechanic, 1964) and even incidental learning superior to intentional learning (Eagle & Mulliken, 1974).

Although many of the investigations of incidental learning have been in verbal learning, there is also evidence of incidental learning in the psychomotor area (Dickinson, 1977, 1978; Ho & Shea, 1979). Many of the conceptual and methodological issues, such as operational definitions and experimental designs, are common to both areas of study. The development of these issues occurred primarily in the verbal domain. In the following sections these conceptual and methodological issues were reviewed. In the last section the psychomotor incidental learning literature is discussed.

Definitions of Incidental Learning

The problem of identifying the relationship between incidental and intentional learning has been confounded by the failure to provide an acceptable definition of incidental learning. Indeed, Postman (1964) asserted that a systematic analysis of the variables that influence incidental and intentional learning was neglected because of difficulties in formulating a distinction between incidental and intentional learning.

One of the first formal definitions of incidental learning, as proposed by McGeoch (1942) is, "learning which apparently takes place without a specific motive or a specified formal instruction and set to learn the specific material in question" (p 299). As McGeoch's definition implies, the concept of set was often employed in explaining incidental learning. The concept of set was a nearly universal one in early psychological thinking (Gibson, 1941); therefore, it was hardly surprising that many studies up to the 1960's used "set" as a central explanatory construct (McLaughlin, 1965). Incidental learning, as such, was characterized as learning in the absence of a set to learn, whereas intentional learning was characterized by an experimental set to learn.

Many early researchers attempted to investigate incidental learning by not instructing the subject to learn specific information, thereby assuming an absence of a set to learn. However, not instructing subjects to learn does not mean there is not a set to learn. Sets to learn were conceptualized to be a result of previous experience. Brown (1954) suggested that a set to learn may be evoked through stimulus generalization, the principle that when a person has been conditioned to make a response to a stimulus, similar stimuli will also evoke that response. Thus, it has been argued that although the experimenter has not induced an experimental set to learn, it is still possible that, through stimulus generalization, uncontrolled sets to learn are operating during an incidental learning paradigm (Postman & Senders, 1946).

It may appear that an understanding of incidental learning is dependent on understanding the functions of set during the learning of information. The problem is, however, that the concept of set has been used loosely and may connote different things (Gibson, 1941). To demonstrate the looseness of terminology in describing the variations in the meaning of set, Gibson noted that the varieties of set described in the literature included preparatory set, unconscious set, voluntary set, mental set, motor set, neural set, expectation, anticipation and directing tendency. Noting these varieties of set, the usefulness of the concept of set in describing the role of intentions in learning is unclear. For example, Tolman (1932) argued that learning is not dependent on intentions because of the phenomenon of latent learning. However, Tolman believed learning is dependent on the acquisition of expectations. Futhermore, some psychologists have argued that it is necessary to have a set to learn, but one may also learn a set. This makes the concept of set confusing and ambiguous in that, "if intentions are learned, how can learning be 'dependent on intentions'?" (Gibson, 1941, p. 789).

Operational Definition

Although Postman and Senders (1946) argued that set is an important determinant in the formation of associations necessary for learning, recent researchers in the study of incidental learning have abandoned the concept of set as an important part of an operational definition for incidental learning. The majority of researchers have differentiated between intentional and incidental learning on the basis of formal instructions to learn specific information. Incidental learning may be operationally defined as learning in the absence of formal instructions to learn (McLaughlin, 1965; Postman, 1964). Postman has also suggested that this operational definition should, in practice, be supplemented by a postexperimental inquiry to screen incidental learning subjects who anticipated a test of retention.

For the purpose of this thesis the distinction between intentional and incidental learning is based on the defining procedures of formal instructions. Learning will be called incidental when there are no formal instructions to learn specific material and intentional when there are formal instructions to learn. Furthermore, incidental learning subjects who in a post-test interview admit that they anticipated a recall test or deliberately rehearsed or systematically attempted to learn the information will be discarded and replaced.

It should be noted that the definition of incidental learning is, in a formal sense, logically dependent on the definition of intentional learning. It is assumed that incidental and intentional learning are mutually exclusive and exhaustive categories of learning. In other words, learning is either incidental or intentional.

Experimental Designs

Two basic experimental methods have evolved for investigating the principles or factors that govern incidental learning (Kausler & Trapp, 1960; McLaughlin, 1965; Postman, 1964). The first methodology, Type I, involves exposing a group of subjects to some specific material or information, but without explicit instructions to learn. A second comparison group, on the other hand, is presented the same material but is given explicit instructions to learn. It is crucial that the incidental group is directed to the material, usually by an orienting task, so that perception of the material takes place.

This "exposure" period is followed by an unexpected test of the material. Several types of tests have been used including recognition, free recall, serial recall, and transfer to a new task (Postman, 1964).

The second methodology employed in incidental learning investigations, known as Type II, involves having the subject learn a task with instructions to learn, while being exposed to additional "irrelevant" material (Kausler & Trapp, 1960). Subjects are asked to recall both the relevant material and irrelevant material.

Postman (1964) suggested that the Type II design may be divided into two classes on the basis of the relationship between relevant and irrelevant components of the learning environment. Certain attributes of the irrelevant (incidental) material may be directly or indirectly related to the material to be learned under intentional conditions. For example, if the materials which the subject has been instructed to learn appear in different colours, then the colours are the irrelevant attributes but are directly or intrinsically related to the task. On the other hand, the irrelevant component of the learning situation may be materials which bear no direct relation to the learning task. Such an extrinsic component would exist in the case when a subject is instructed to learn a list of words which have additional items such as geometric forms exposed along with the words. Thus, the two classes of Type II design are referred to as the "intrinsic" and "extrinsic" components of the learning situation.

The use of either experimental method in investigating incidental learning depends on several considerations. Although Type I and Type II designs both involve incidental learning situations, there are important differences between them. The most fundamental difference is that in the Type I design incidental learning subjects are not given instructions to learn, whereas instructions to learn are given in the Type II method. Postman (1964) argued that the Type II design is, in one sense, more favourable to incidental learning because responses which mediate correct performance may generalize to the irrelevant materials. However, in another sense, under limited exposure conditions (Mechanic, 1962) there is competition between relevant and irrelevant materials for the necessary responses to learn. Under these conditions Type II is less favourable than Type I. Futhermore, the choice of experimental designs depends on the theoretical questions at issue. Type I is usually preferred if one wishes to manipulate either the task, procedural or orienting variables to clarify the associative processes in incidental learning (Kausler & Trapp, 1960; Postman, 1964). On the other hand, investigations into the role of motivation and incentive have typically used the Type II design. This kind of research has usually attempted to determine how incentive, drive, and motivation affect competition of responses and learning response generalization (Kausler & Trapp, 1960, 1962).

Orienting Task

The experimental methods employed in incidental learning investigations are designed to "expose" subjects to particular information, but without explicit instructions to learn that information. This exposure condition is necessary so that the subject perceives the incidental material. Ensuring that the incidental material is perceived is accomplished through the use of an orienting task. Examples of orienting tasks include rating words on an affective scale (Eagle & Mulliken, 1974), estimating the number of letters in a word (Hyde & Jenkins, 1969), or making movement length estimations (Dickinson, 1977, 1978).

The use of orienting tasks, nevertheless, raises problems of interpretation in the analysis of incidental learning. In a Type I design, the incidental subjects perform an orienting task, whereas intentional subjects do not perform an orienting task but are instructed to learn. Theoretically it is difficult to determine the extent that intent to learn and freedom from interference produced by the orienting task contribute to the superiority of intentional learning conditions (Postman, 1964). It is necessary for both the incidental and intentional groups to perform the orienting task. Using this procedure both groups are subjected to orienting task interference. This eliminates the possibility that superior intentional performance is due to both intention to learn and freedom from activities interfering with generating appropriate "learning responses" (Postman, 1964) or "representational responses" (Deese, 1964).

There are also problems with the Type II design, in which subjects do not receive an explicit orienting task. The instructions to learn the relevant material impose an orienting task for the incidental information. It is assumed that subjects perceive the irrelevant material. This assumption, however, may not be valid when the incidental material bears no direct relation to the intentional material (extrinsic condition). Under high incentive conditions (Bahrick, 1954), subjects may selectively focus their perception on the relevant material, thereby not perceiving the incidental material. Thus, it appears that the choice of orienting tasks and experimental design must be taken into consideration in the interpretation of incidental learning results.

Incidental Learning and The Motor Domain

While considerable research has been directed towards determining the principles governing incidental learning in the verbal domain, there has been little empirical investigation in the psychomotor domain. Dickinson (1977, 1978) has provided some empirical evidence for incidental motor learning. He demonstrated that subjects may learn a simple motor task in the assumed absence of an intention to learn. Dickinson's studies indicated some interesting implications for the relationship between incidental and intentional learning with regard to learning responses and differential coding. However, there are reasons to treat his findings with some caution. Several methodological problems confound the theoretical interpretation of his results. These problems are discussed after a brief review of the basic procedure and findings reported by Dickinson (1977,1978).

Dickinson (1977), employing a Type I experimental design, had intentional and incidental learners experience four linear movements of different lengths. The intentional and incidental groups were composed of three sub-groups which received either 1, 5, or 10 trials. The incidental group made the four movements, but were asked to estimate the movement lengths. Following the practice trials, the incidental subjects were asked to recall the four movements. The intentional learners did not perform the orienting task of movement estimation. They were instructed to attempt to remember the movements for later recall. The results indicated that, initially, intentional learners performed significantly better than incidental learners; however, after 10 trials there was no difference between the two instructional groups.

Dickinson (1978) also provided preliminary evidence that there may be qualitative differences in the retention of movements learned under incidental and intentional conditions. Using the same orienting task of movement estimation for incidental learners, eight subject groups received ten trials of four movements. The groups were asked to recall the movements either immediately, after 30 seconds, 60 seconds, or 600 seconds. During the retention intervals, subjects received a verbal questionnaire to prevent rehearsal. The results indicated that there was no differential effect between incidental and intentional learners for the 0, 30, and 60 second retention intervals. However, the intentional learners performed significantly better than the incidental learners after 600 seconds. Dickinson suggested that intention to learn may prompt appropriate coding for long-term storage of information.

Notwithstanding the fact that Dickinson's findings provide evidence of incidental motor learning, there are several problems in determining the relationship between incidental and intentional learning. First, the intentional subjects did not perform the orienting task. As a result, the initial superiority of the intentional subjects (Dickinson, 1977) may have been due to both intention to learn and freedom from orienting task interference. Second, the interaction between instructions to learn and practice trials may have been due to a ceiling effect for the intentional group. Since this group did not improve, at least significantly, over trials the task may have been too simple, thereby allowing optimal performance to be quickly attained. It is plausible, that given a more complex task, intentional learners would have continued to improve over trials. This argument receives indirect support from studies in the verbal domain (Fozanagi, 1958; Postman & Adams, 1958) which found that intentional learning increased as a function of practice, whereas incidental learning did not seem to be affected.

An extensive review revealed that the only other published study of incidental motor learning was conducted by Ho and Shea (1979). They investigated the orienting task specificity and suggested that incidental motor learning may be explained in terms of the levels-of-processing memory framework. The task employed by Ho and Shea (1979) involved having subjects experience a target movement and four non-target movements. Subjects were instructed to either: a) make a verbal estimate of the distance between the target positions (EST); b) discriminate between target and non-target positions by saying "yes" if the movements were the same, or "no" if not the same (YN); and c) make no verbal response at all (NR). Following the practice trial the subjects were asked to recall the target and non-target positions. The results indicated that the subjects required to make judgements were more accurate in recall of both target and non-target positions than subjects in the no judgement (NR) groups. Ho and Shea suggested that the differences may be attributed to the depth of coding. They argued that the EST and YN groups had to process more and different information, resulting in a more meaningful, deeper level of processing.

The interpretation of Ho and Shea's (1979) results in terms of the levels-of-processing framework is open to criticism. The major criticism focusses on the lack of an independent measure of depth in the levels-of-processing approach (Baddeley, 1978; Eysenck, 1978; Nelson, 1977). Nelson argued that it is only possible to define the measure of depth in terms of its alleged memorial consequences. That is, if findings indicate that a particular orienting task does not produce a stable memory trace, and thus better retention, one may argue that the information was not processed to a deep level. Thus, the measure of depth is circular and falsification of the framework is not possible. Futhermore, it would be extremely difficult to demonstrate empirically that verbal responses are deeper or more meaningful than non-verbal responses, especially since previous researchers have stated that verbal responses could be shallow or deep (i.e., Craik & Lockhart, 1972). Although, one may argue quite forcefully that Ho and Shea's (1979) post-hoc analysis relies on circularity, their findings do indicate that the orienting task is an important feature in incidental psychomotor learning.

III. GENERAL STATEMENT OF THE PROBLEM

The previous chapter has shown that while there has been extensive and intensive investigation of the factors that affect both incidental and intentional learning in the verbal domain, there has been little systematic research in the psychomotor area. Previously, it has been argued that the two psychomotor learning studies which focussed on the relationship between incidental and intentional learning (Dickinson, 1977, 1978), while providing some important initial findings for generating additional research, suffered from some methodological problems. It follows that any further investigation of some of the functional properties of the variables affecting intentional and incidental learning must attempt to correct or avoid these problems.

The major purpose of the experiments found herein was to investigate some of the factors that affect both incidental and intentional learning in the psychomotor domain. The first experiment was designed to determine if acquisition under incidental and intentional learning conditions is affected in similar ways when the amount of information to be learned is systematically varied. The second experiment was designed to investigate the effects of practice under incidental and intentional learning conditions. The third and final experiment was designed to determine if the difference between incidental and intentional learning can be partially explained by differences in the mediating strategies employed by the two types of learners. These studies should provide further knowledge about the factors that influence incidental and intentional psychomotor learning.

As Dickinson (1977) has noted, the major difficulty in the study of incidental learning lies in the selection of the orienting task. For the incidental learning condition it is necessary to expose the subjects to the central or experimentally relevant task, but without their being aware that a later recall will be required. It follows that another important feature of testing incidental learning is the selection of an appropriate central task.

For this thesis it was decided to use a movement sequence task as the central task. The employment of a movement sequence task was selected for several reasons. First, many "real life" skills are sequential in nature (Keele & Summers, 1976). Second, the movement sequence task is easily modified to test different experimental variables. Third, a movement sequence task with discrete movements allows the use of a reaction time-movement time task as an orienting task. Incidental subjects perform the movement task under the guise that the experimental task is to react and move as quickly as possible to different target keys. In fact, each of these movements comprise a component of a sequence.

IV. EXPERIMENT 1

Generally, studies of incidental learning in the verbal domain have presented subjects with an information load that is greater than the immediate memory span (Postman, 1964). The concept of memory span, which dates back to Ebbinghaus's (1885) serial learning work, is usually defined by the number of discrete units that can be reproduced fifty percent of the time in correct serial order following a single presentation; that is, there is an even chance of perfect recall (Watkins, 1977). The concept of a limited memory span was advanced by Miller (1956) who suggested that the capacity of the memory span is " seven plus or minus two items" of information. Thus, it follows that most studies of incidental learning have been concerned with the acquisition of information of greater than seven plus or minus two items.

One possible criticism of incidental motor learning studies is that the experimental information load has not exceeded the immediate memory span. For example, Dickinson (1977, 1978) asked subjects to recall only four linear movements. There is a problem, however, in determining the information load of a simple linear movement. Nevertheless, since the intentional learning group (Dickinson, 1977) did not show any appreciable improvement over ten trials, it may be argued that the four movements did not exceed the immediate memory span. One may question, however, the need to use supra-span material, that is material that exceeds the limit of the immediate memory span, for incidental learning experiments. One possible reason to use supra-span information load is that learning might be affected by qualitatively different processes under supra-span and sub-span conditions (see Watkins, 1977 for a review). However, it is probably not possible to test the construct of the memory span under incidental learning conditions. Immediate memory span is measured by a recall test immediately following presentation. Incidental learners can only be informed of the recall test after the presentation. Therefore, immediate recall is not possible.

By varying the size of the movement sequence to be learned it is possible to determine if the amount of the material to be acquired is an important factor in incidental psychomotor learning. Psychomotor learning research indicates that movement error is a monotonically increasing function of the number of movements (Wilberg & Salmela, 1973). This is similar to verbal learning findings which indicate that as the list length increases, the percentage of total recall decreases. It has been hypothesised that this decrease is due to increased interitem interference. In contrast, incidental verbal learning studies have found that increases in the list length has a less pronounced effect on incidental than intentional learners (Postman & Adams, 1957, 1958). No evidence exists in the psychomotor learning literature.

Therefore, the purpose of Experiment 1 was to investigate the effects of the number of movements on the acquisition of a movement sequence under incidental and intentional learning conditions. For intentional learners it was expected that as the size of the movement sequence was increased the percentage of movements recalled would decrease. Furthermore, if the findings from Postman and Adams (1958) are valid for the psychomotor domain then increases in the number of movements should not have any differential effect on acquisition under incidental learning conditions.

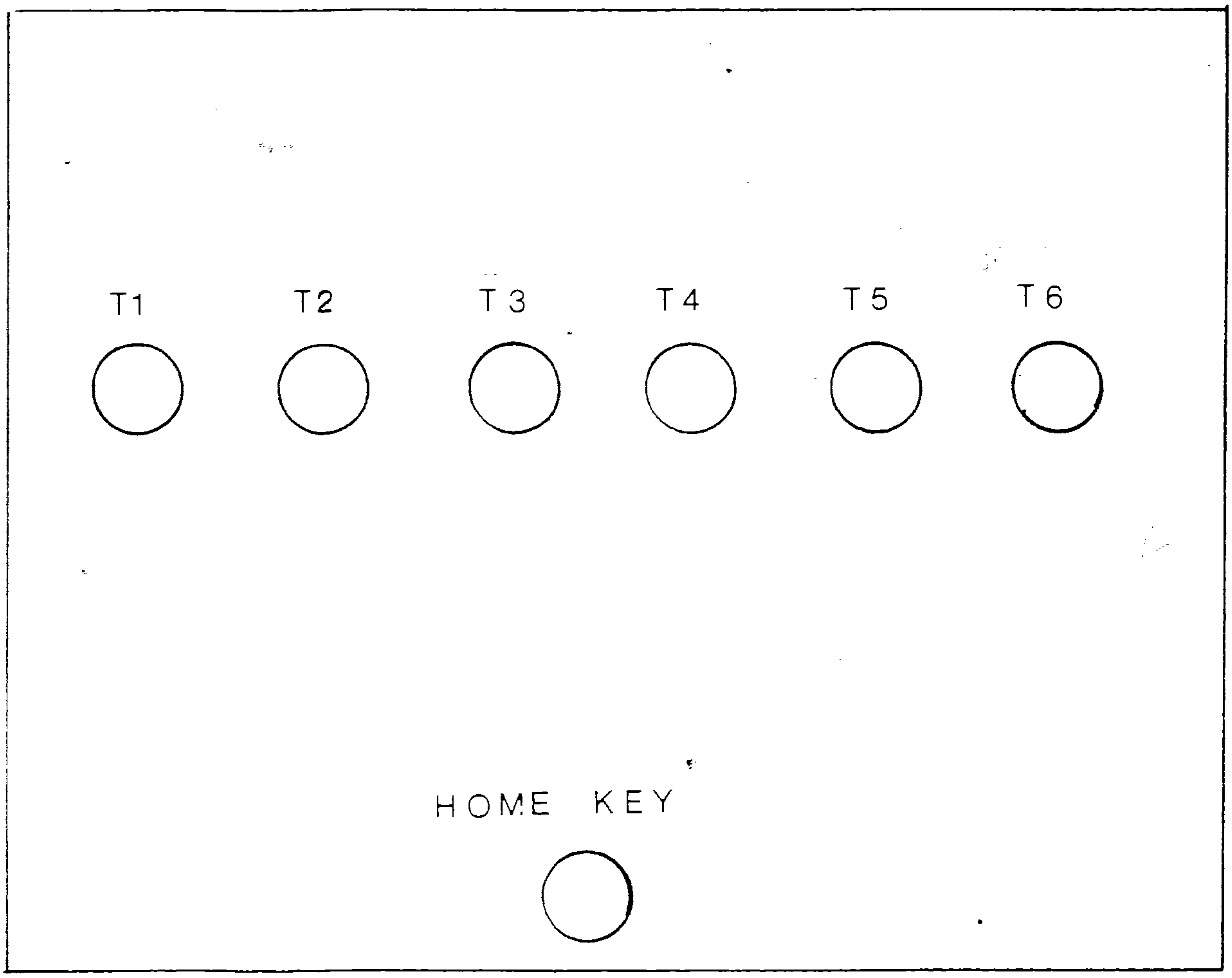
Method

Subjects. Sixty (n=60) task naive students from Simon Fraser University served as subjects.

Apparatus. The apparatus consisted of a response panel (60 x 42 cm) interfaced to an AppleII microcomputer through an input/output parallel interface card. Seven switches (telegraph keys) were mounted on the panel as indicated in Figure 1. Six telegragh keys were designated target keys (T1, T2,...T6). The seventh key served as a home key. Six red LED's were mounted on a black background 8 cm over each target key.

Procedure. The subjects were randomly assigned to each cell of a 2 X 3 factorial design in which the factors were the types of learning (intentional verus incidental) and movement sequence size (4, 7, or 11 movements).

Figure 1. Schematic diagram of the response panel.


T1
T2
T3
T4
T5
T6
HOME KEY

For all subjects the experimental task consisted of learning a series of discrete movements, which together composed a movement sequence. Each movement was defined as moving the right hand from the home-key to a target key, and back to the home-key. The order of the movements which made up the sequence was controlled by an orienting task, in this case a reaction-time task. Each subject was instructed to move from the home-key to a target key as quickly as possible, always returning back to the home-key. Each target key was designated by an illuminated LED, which was terminated when the appropriate target key was depressed. The interval between the onset of each LED was three seconds.

The subject was seated directly in front of the apparatus and received instructions about the nature of the experiment. Each subject was told that the experiment was a choice reaction-time task. Each subject was asked to turn-off the stimulus lights as quickly as possible. The intentional learners were additionally instructed to remember the order of the movements in the sequence and that there would be a recall test.

The subject started the presentation of the orienting task by depressing the home-key. Each subject received a sequence of either 4, 7, or 11 movements. The order of the target keys was 3,5,2,6,; 3,5,2,6,4,5,1,; 3,5,2,6,4,5,1,2,4,1,6, respectively. Since the experiment was concerned with learning under minimal trial conditions each subject received only two trials of the complete sequence. Following the completion of each trial an auditory signal ("Beep") sounded, informing the subject to stop. There was a 10 second interval between each trial. Ten seconds following the completion of the second trial all subjects received written instructions asking for the correct serial recall of each movement in the sequence. The onset of this recall test was 45 seconds after the completion of the second practice trial.

The incidental subjects received a post-test inquiry following the completion of the experiment. They were asked if they had expected a recall test or had systematically tried to learn the movement sequence during the orienting period. Any subject who answered affirmatively to either question was discarded and replaced.

Analysis of data.

During the recall test all keys that were depressed by the subject were recorded. Two dependent measures, position scores and event-to-event scores, were analyzed. For the position measure, a correct movement was defined as depressing a target key in the proper sequential position. For example, if target key (T6) was the fourth key depressed during the practice trial, it was required to be the fourth key depressed during the recall test to be scored correct. If a different key was depressed an error was registered. From this data the percentage of correct movements was calculated. An additional measure, that is, event-to-event associations was also calculated. This measure is based on the possiblity that the movements of the sequence are associated with each other, not neccesarily with the position in the sequence (Keele & Summers, 1976). Each time a subject recalled two movements in their proper order, regardless of the serial position, the subject received a correct score. An example will serve to illustrate the use of this measure. In the seven movement sequence the correct order was 3,5,2,6,4,5,1. Suppose a subject recalled the movements in the order 1,5,3,2,6,4,5. Using the position measure the subject would receive a score of 1 because only movement T5 is correct. Using the event-to-event measure, however, the subject would receive a score of 3. This is because the order 2,6,4,5 is a correct sequence of movements, producing 3 associations. Suppose another subject recalled the sequence 3,5,6,4,3,5,1. The event-to-event score would be 3 because the movements 3-5, 6-4, 5-1 were correctly associated together. The subject would receive only a score of 1 for the 3-5 association, even though the association was produced twice.

Results and Discussion

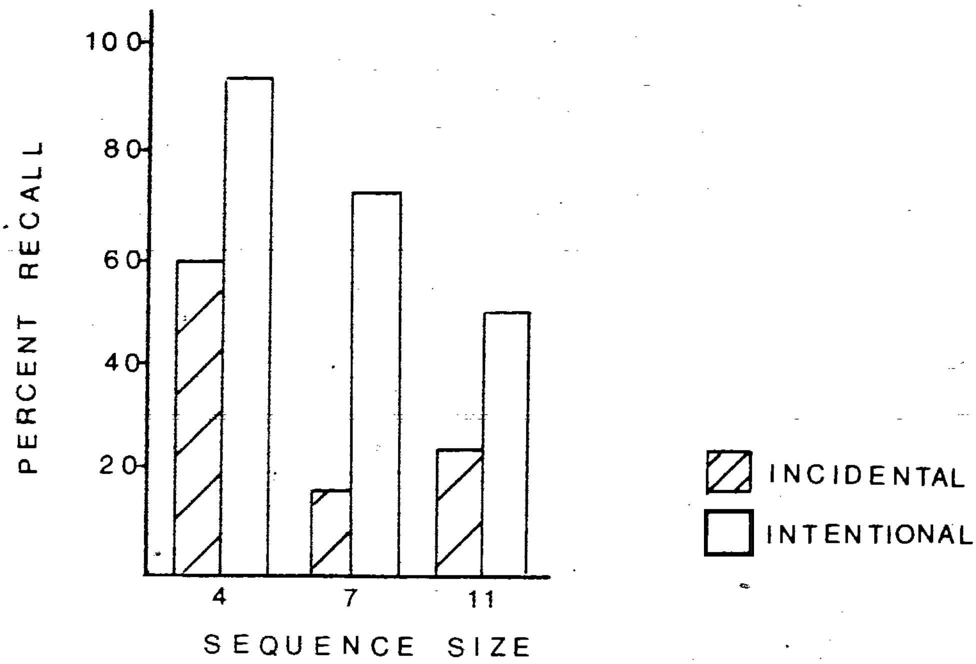
One incidental learning subject who reported that she had anticipated the recall test was discarded and replaced. The data for each dependent measure were analyzed by an ANOVA. The analysis of the position measure was discussed first, followed by the analysis of the event-to-event measure. The general findings were then discussed. For the purpose of the analysis, all values in the ANOVA and post-hoc comparison were considered statistically significant at $p<.05$.

Position analysis. The overall analysis revealed that both the main effects of types of learning and sequence size were significant, $F(1,54) = 55.06$ and $F(2,54) = 23.84$, respectively. The findings summarized in Figure 2 indicate that the intentional learners recalled a greater number of movements from the sequence than incidental learners. Furthermore, as the sequence size increased, the percentage of movements recalled decreased.

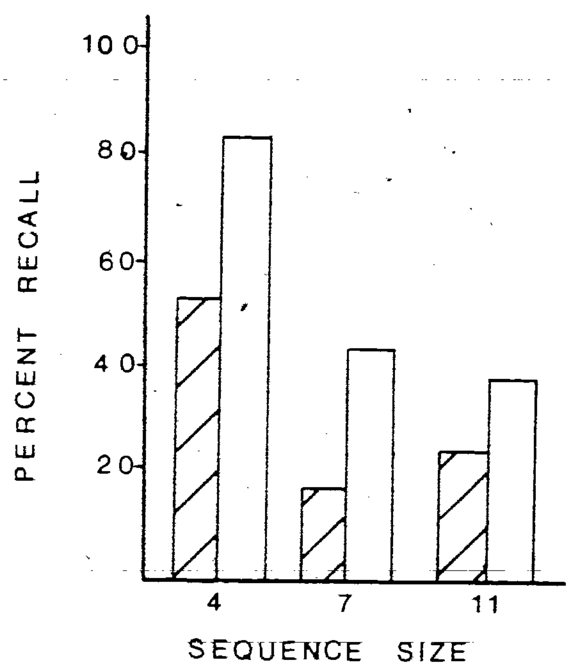
The instruction by sequence size interaction was also significant, $F(2,54)=3.24$. Due to this interaction the effects of the number of movements in the sequence was analyzed separately for intentional and incidental groups. For intentional learners, the recall of movements decreased monotonically as the number of movements increased (95%, 72.4%, 48.1%). Post hoc analysis, using Tukey's HSD test, revealed that each intentional group was significantly different from each other. For incidental learners, the percentage of movements recalled decreased from 60% for 4 movements to approximately chance levels (16.6%) for 7 and 11 movements (15.8% and 23.4%, respectively). Post hoc analysis, using Tukey's HSD, revealed that the recall of four movements was significantly better than either seven or eleven movements. There was, however, no significant difference between the percentage recalled by the seven or eleven movement groups. This interaction was most

Figure 2a. Percent recall of positions under incidental and intentional learning conditions as a function of movement sequence size.

Figure 2b. Adjusted percent recall for events under incidental and intentional learning learning conditions as a function of movement sequence size.


100
80
60
40
20
PERCENT RECALL
4
7
11
SEQUENCE SIZE
INCIDENTAL
INTENTIONAL

A)


100
80
60
40
20
PERCENT RECALL
4
7
11
SEQUENCE SIZE

B)

likely produced because of a floor effect in the incidental learning conditions for seven and eleven movements. That is, the recall for the seven and eleven movement conditions was not significantly difference than chance. The group means are represented graphically in Figure 2.

In general, the position measure demonstated that intentional learning is superior to incidental learning under all three sequence size conditions. The results also indicated that incidental and intentional learning are affected in a similar manner by the amount of information. Increasing the information load resulted in a decrease in the percentage of movements recalled. It should be noted , nevertheless, that position recall dropped to a chance level for seven and eleven movements.

Event-to-Event analysis. The overall analysis revealed that the main effects of types of learning and sequence size were significant, $F(1,54) = 13.15$ and $F(2,54) = 16.01$, respectively. Intentional learners had larger event-to-event scores (associations) than incidental learners. A post hoc analysis of the sequence size conditions revealed that the four movements condition was significantly larger than either seven or eleven movements conditions. There was no difference between the seven and eleven movements conditions. Generally, as with position recall, intentional learning groups demonstrated greater recall than incidental learners (see Figure 2). Furthermore, the results of the event scores are fairly consistent with the findings found for the position measure.

Some of the findings demonstrated in this experiment are consistent with previous findings in verbal and psychomotor research. Both dependent variables employed in this study provided evidence that intentional learning is superior to incidental learning. This general finding is consistent with previous research in both the psychomotor (Dickinson, 1977) and verbal (Postman & Adams, 1957, 1958) literature. The finding that intentional learning varied inversely with the amount of information to be acquired is also consisitent with the psychomotor (Magill & Dowell, 1977; Wilberg & Salmela, 1973) and verbal (Calhoun, 1934; Postman & Adams, 1958) literature. There were some results, though, that are not consistent with previous research. Earlier studies in the verbal learning domain demonstrated that for incidental learning, the percentage of recall did not decrease as a function of the amount of information (Postman & Adams, 1958). The present findings, on the other hand, showed that the percentage of recall dropped significantly after the movement sequence size was increased from four to seven movements. This finding may be open to two different interpretations. First, though probably a weak interpretation, it might be argued that psychomotor and verbal incidental learning are not governed by a common process; that is, qualitatively different processes govern the acquisition and retention of psychomotor and verbal information. This interpretation is difficult to advance on the basis of a single experiment. Also, it is highly difficult to seperate the verbal components from the motor components in the present task. A second, and probably a better interpretation, is that the differences between the present incidental learning findings and previous work may be explained by methodological differences. Whereas the present study employed 4, 7, or 11 movements, Postman and Adams (1958) presented subjects with lists of 24, 36, or 48 nonsense syllables or adjectives. It is very likely that the information load in the Postman and Adams study would be considered supra-span. In the present study, incidental learning dropped when the information load increased from four to seven movements. It is most probable that four movements represented a "sub-span" information load. It may be argued that a sequence size of seven movements was beyond the immediate memory span. This contention is supported by the finding that none of the ten intentional learners were able to recall all seven movements in correct serial order. Thus, it might be that incidental learning is adversely affected as the the number of movements exceeds the capacity of the memory span. As this capacity is exceeded information is lost or forgotten unless recycled or organized by appropriate cognitive control processes, such as rehearsal.

Another important feature of the incidental learning findings appears to be linked to the notion of a limited memory span. Under the task conditions employed in this study, the position measure findings imply that incidental learning does not seem to occur when the information load exceeds the limited span capacity. This conclusion is inferred from the finding that the recall for seven and eleven movements was not greater than that of chance. However, the event-to-event findings indicated that subjects were acquiring some aspects of the task. This finding suggests that the event measure may be more sensitive to changes in behaviour.

Serial Position Effect

A reliable phenomenon found in the study of verbal serial learning is the bowed serial position curve. This curve involves the relationship of errors to the serial position of the item in the list. In general, for serial recall errors are greatest in the middle, followed by the end position (recency effect), with the fewest errors occurring at the beginning (primacy effect). Psychomotor studies, however, have had difficulty demonstrating this phenomenon. Zaichkowsky (1974), in a study involving the acquisition of eight serial movements, found that learning occurred in the same order as the movements were presented. On the other hand, Magill and Dowell (1977) found a bowed serial position curve for serial recall in motor memory.

The present findings also demonstrated the phenomenon of a bowed serial position curve. But this effect was only found for intentional learners (see appendix B-1). Furthermore, like the Magill and Dowell study, the bowing seemed to be a function of the number of movements. The seven and eleven movement sequences both demonstrated evidence of primacy and recency effects. In both cases, the primacy effect was much stronger than the recency effect.

Several attempts have been made to account for the serial position curve (cf. Jung, 1968). One of the most recent efforts by Crowder (1976) proposed that the bowed serial curve was produced by two processes. Primacy results from active strategies such as rehearsal. Items, in the present case movements, in the beginning of the list have more rehearsal opportunity. The recency effect is produced by a second process, temporal distinctiveness of the end items. Crowder's proposal gives a good account of the primacy differences between incidental and intentional conditions. In the post-test inquiry, none of the incidental subjects reported engaging in rehearsal. Therefore, the incidental group should not, and did not, demonstrate any primacy effect. However, if the recency effect is due to temporal distinctiveness, both incidental and intentional groups should have produced recency effects. The incidental learners did not show any evidence of recency. Thus, it appears that the recency portion of the serial position curve is not completely understood.

It may be the case that the low level of incidental learning with larger information demands may not be attributed to differential memory span processes. Rather, with more information to be acquired, a greater number of trials is required to build up the associative links necessary for successful serial recall of the discrete movements. Therefore, Experiment 2 was designed to test the effects of practice on the acquisition of a movement sequence under incidental and intentional learning conditions.

V. EXPERIMENT 2

In the field of learning there has been considerable research effort directed towards determining the effects of practice on learning. In fact, the concept of practice has been incorporated into many definitions of learning. For example, in the psychomotor area Magill (1980) stated that learning occurs as a function of practice. Also, a classic finding in the motor memory field is that retention of movement information increases with practice (i.e., Adams & Dijkstra, 1966).

Since the study of incidental learning is concerned with the initial disposition of the learner (Postman, 1964), it is not surprising that the effects of practice on incidental learning have been of interest. One psychomotor learning study that has investigated the effects of practice on incidental learning was conducted by Dickinson (1977). He found that the initial differences between incidental and intentional groups disappeared after ten trials. These findings conflict with verbal findings which demonstrated that intentional learning increased as a function of practice, while incidental learning did not seem to be affected (i.e., Postman & Adams, 1958).

Dickinson's (1977) study appeared to have significant theoretical and practical implications. One such implication was that if subjects were directed to information by an appropriate orienting task, learning would occur over time at a level equivalent to that acheived under intentional learning conditions, regardless of an 'intent to learn'. Unfortunately, as discussed in Chapter 2, there were problems with Dickinson's (1977) study. One problem was the apparent ceiling effect in the intentional learning condition. This problem could be rectified by having subjects attempt to acquire a demanding task. In the present study, by using the same central task as employed in Experiment 1, it was possible to increase number of movements by increasing the size of the movement sequence.

Dickinson's (1977) results imply that if subjects are directed to the experimental task, incidental learning will occur over trials. Thus, the purpose of Experiment 2 was to investigate the effects of practice on incidental and intentional learning. If mere exposure to the central task will produce learning, it follows that incidental learning should increase as a function of the number of trials.

Method

Subjects. The subjects were 40 (n=40) task naive students, 20 females and 20 males, from Simon Fraser University.

Apparatus. The apparatus was the same as used in Experiment 1.

Procedure. The subjects were randomly assigned to each cell of a 2 X 2 factorial design in which the factors are types of learning (intentional verus incidental) and the amount of practice (two or ten trials). The orienting task used in Experiment 1 was also used in this experiment. It was necessary to determine a movement sequence size that would not result in a ceiling effect under intentional learning conditions. Pilot work indicated that perfect serial recall occured after only a few trials (4-6) using the two sequence sizes (7 & 11) that showed little incidental learning in Experiment 1. Subsequent pilot work determined that intentional learners were unable to perfectly recall a sequence size of 15 movements after 10 trials. Therefore, it was decided to use 15 movements in the sequence. The order of the target keys was 5,4,6,4,3,5,1,6,2,1,3,4,2,5,3.

The subject was seated directly in front of the apparatus. After being briefed on the purpose of the experiment, dependent on the instructional condition, the subject started the experiment by depressing the home key. This started the presentation of the stimuli lights which defined the movements of the sequence. The interval between the onset of each successive stimulus was three seconds. The subjects performed the movement sequence either two or ten times. The completion of each sequence was signalled by an auditory signal ("Beep"). The interval between trials was ten seconds. After the completion of all practice trials, subjects received another auditory signal, informing them to stop. Ten seconds following the end of the last practice trial, all subjects, regardless of condition, received written instructions asking for the recall of each movement in the sequence in correct serial order. The recall test started forty-five seconds after the completion of the final practice trial.

As in Experiment 1, all incidental subjects received a post-trial inquiry.

Analysis of Data. Since the number of movements in the sequence was the same for all conditions, the number of correct movements was recorded. As in Experiment 1, both position and event-to-event scores were calculated. An ANOVA was performed to determine any significant treatment effects.

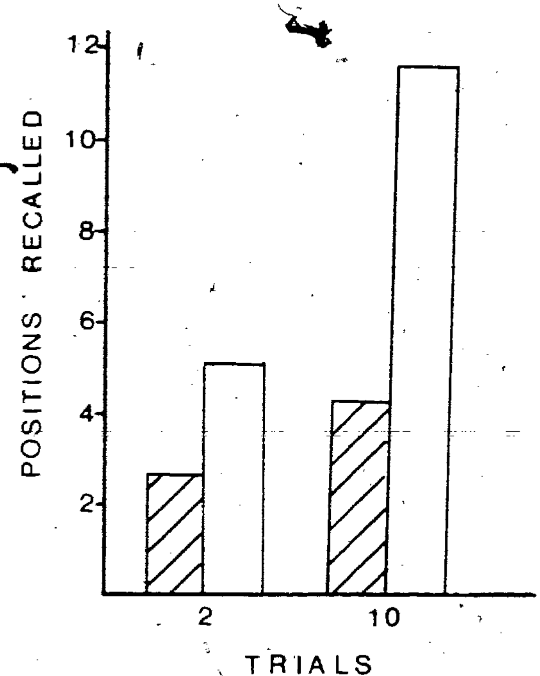
Results and Discussion

No incidental subjects reported in the post-experimental inquiry that they had previous knowledge of the recall test. The data for each dependent measure were analyzed by an ANOVA. The analysis of the position measure was discussed first, followed by the analysis of the event-to-event measure. The general findings are then discussed. For the purpose of the analysis, all values of the ANOVA and post-hoc comparison were considered statistically significant at $p<.05$.

Position analysis. An analysis of variance showed that the main effects of types of learning and amount of practice were significant, $F(1,36)=42.04$ and $F(1,36)=24.64$. There was also a significant types of learning by amount of practice interaction, $F(1,36)=8.41$. It is apparent from Figure 3 that intentional learning was superior to incidental learning. Post-hoc analysis,

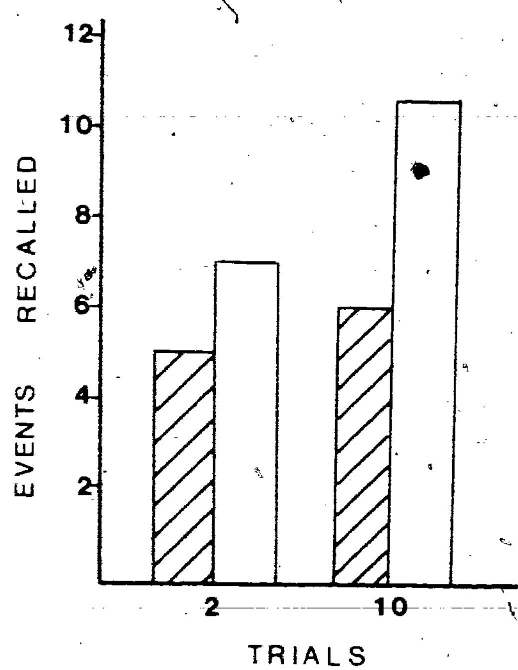
Figure 3a. Correct number of positions recalled under incidental and intentional learning conditions as a function of practice.

Figure 3b. Correct number of events recalled under incidental and intentional learning conditions as a function of practice.



POSITIONS RECALLED
12
10
8
6
4
2
2
10
TRIALS

A)



EVENTS RECALLED
12
10
8
6
4
2
2
10
TRIALS

B)

using Tukey's HSD, for simple pairwise differences indicated that in both the intentional and incidental instructional conditions there was a significant increase in recall over trials. However, there was a significant gain for the intentional learners over the incidental learners as a function of practice.

Event-to-event analysis. An analysis of variance revealed that the main effects of types of learning and amount of practice were significant, $F(1,36)=24.75$ and $F(1,36)=12.36$. The type of learning by amount of practice interaction was not significant, $F(1,36)=3.89$. The results, shown in Figure 3, indicate that the event-to-event measure, as with the position measure, provide strong evidence that intentional learning was superior to incidental learning. This finding is consistent with the ordinal interaction found for the position scores. Both measures, position and event scores, indicate that both incidental and intentional learning increases with practice.

The present findings support the hypothesis that repeated exposure to the movement sequence produces increased incidental learning. These findings are inconsistent with the findings demonstrated in previous psychomotor research (Dickinson, 1977, 1978). Dickinson's (1977) results showed that after ten trials there was no difference between incidental and intentional groups. In contrast, the present findings, as may be seen from Figure 3, show that the initial superiority of intentional learners increased over trials. The discrepencies between the present findings and those published by Dickinson (1977) are more than likely due to differences in task demands. The task used by Dickinson involved the acquisition of four linear movements. It is probably the case that this task was too simple, allowing optimal performance to be quickly attained. The task used in the present experiment was more demanding, as reflected by the intentional learners sub-optimal performance.

The findings from the verbal domain are inconsistent. For example, Postman and Adams (1958) and Koyanasgi (1958) found that learning under intentional instructional conditions increased as the number of presentations increased. However, both these studies demonstrated that the incidental subjects did not show any significant trend towards increased learning as a function of practice. On the other hand, Gleitman and Gillett (1957) demonstrated that incidental and intentional learning increased with practice. The present findings are consistent with those of Gleitman and Gillett.

Finally, referring to the position measure as one indicator of learning, the present study demonstrated that under minimal practice conditions (two trials), the recall for incidental learners was no greater than that which could be acheived by chance. This finding is consistent with the results of Experiment 1. Furthermore, the position score for the intentional learners is consistent with the trend of decreasing recall efficiency as the amount of information is increased found in Experiment 1.

Thus, it appears that practice results in a significant increase in acquisition of a movement sequence under incidental learning conditions. A question that does arise is what accounts for the differences between incidental and intentional learning. One possibility is that there is a difference in the cognitive activities used by the two types of learners. Therefore, the purpose of Experiment 3 was to investigate the influence of mediating activity on the acquisition of a movment sequence under incidental and intentional learning conditions.

VI. EXPERIMENT 3

Postman (1964) argued that intention to learn is not an important determinant of the amount of learning by subjects. He contended that the superiority of intentional learners over incidental learners is only due to the extent that instructions to learn trigger responses that are more favourable to learning. It has been been suggested that instructions to learn encourage subjects to engage in rehearsal (Postman & Kruesi, 1977). This type of mediating activity might allow for the build-up or formation of associative links between items that may be necessary for correct serial recall of the relevant material.

The results of Experiment 1 indicated that incidental learning of a movement sequence occurred during minimal exposure conditions in "sub-span" information load conditions (four movement components). Under the same conditions, the intentional learning group still recalled significantly more movement components. From the previous arguments one may assume that these differences are produced because intentional learners are using mediating activities that produce superior recall. If instructions to learn encouraged the use of mediating activities such as rehearsal, it follows that preventing such mediating activity should eliminate any differences in recall between incidental and intentional learning conditions.

The purpose of Experiment 3 was to determine if mediating activity was responsible for the superiority of intentional learners over incidental learners. It was hypothesised that when the mediating activity was blocked by distractor tasks, the differences between instructional groups would disappear.

Method

Subjects. Twenty-eight (n=28) task naive students, twelve females and sixteen males, from Simon Fraser University served as subjects.

Apparatus. The apparatus was the same as used in Experiments 1 and 2.

Procedure. The subjects were randomly assigned to each cell of a 2 X 2 factorial design in which the factors were types of learning (intentional versus incidental) and rehearsal type (unfilled or filled).

For all subjects the experimental task consisted of learning a series of four discrete movements, which together compose a movement sequence. Each movement is defined as moving the right hand from the home-key to a target key, and back to the home-key. The order of the movements which made up the sequence was specified by an orienting task, in this case a reaction-time task. Each subject was instructed to move from the home-key to a target key and back to the home-key as quickly as possible. Each target key was designated by an illuminated LED, which was terminated when the appropriate target key was depressed. The interval between the onset of each LED was three seconds. Subjects in the rehearsal blocking condition were required to read aloud a series of four two-to-three place random digits that appeared on a video screen during the interval following the depression of the homekey and the onset of the next LED.

The subject was seated directly in front of the apparatus and received instructions about the nature of the experiment. Each subject was told that the experiment was a choice reaction-time task. Each subject was asked to turn-off the stimulus lights as quickly as possible. The intentional learners were additionally instructed to remember the order of the movements in the sequence and that there would be a recall test.

Each subject received one pre-experimental trial. This trial was used to familiarize the subject with the task demands. The movement sequence used in this pre-experimental trial was different from the sequence used during the experimental trials.

The subject started the presentation of the orienting task by depressing the home-key. The subject was presented with a sequence of four movements. Since the experiment was concerned with learning under minimal trial conditions each subject received only two trials of the complete sequence. Following the completion of each practice trial an auditory signal ("Beep-Beep") sounded, informing the subject to stop. There was a 10 second interval between each trial. During this interval subjects in the rehearsal blocking condition were instructed to answer an arithmetic problem that appeared on the video screen. Immediately following the completion of the second trial subjects in the rehearsal blocking condition were instructed to solve another arithmetic problem for ten seconds. All subjects then received written instructions asking for the correct serial recall of each movement in the sequence. The onset of this recall test occurred 45 seconds after the completion of the second practice trial.

The incidental subjects received a post-test inquiry following the completion of the experiment. They were asked if they had expected a recall test or had systematically tried to learn the movement sequence during the orienting period. Any subject who answered affirmatively to this question was discarded and replaced. Furthermore, intentional subjects in the rehearsal blocking condition also received a post-test inquiry. They were asked if they had not attempted to perform the distractor tasks. It was decided that any subject who answered affirmatively would be discarded and replaced.

Analysis of data. Since the number of movements was the same for each condition, the number of correct movements was recorded. As in both previous experiments both position and event-to-event scores were calculated and analyzed.

Results and Discussion

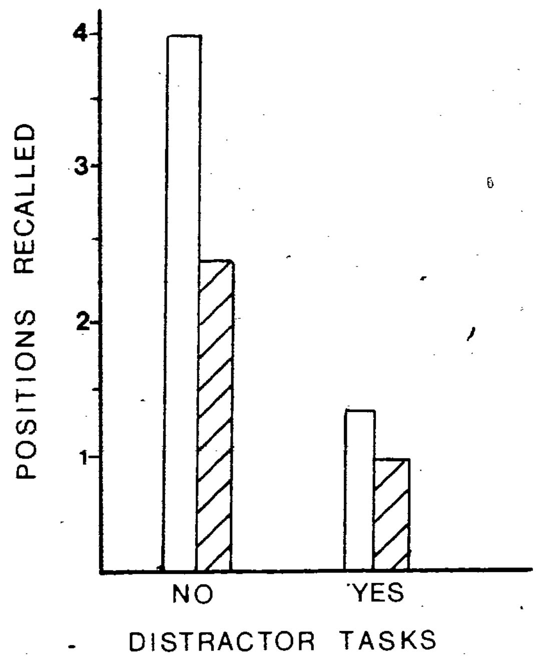
One intentional learning subject who could not successfully perform the distractor task was discarded and replaced. The data for each dependent measure were analyzed by an ANOVA. The analysis of the position measure is discussed first, followed by the analysis of the event-to-event measure. For the purpose of the analysis, all values in the ANOVA and post-hoc comparison were considered statistically significant at $p<.05$.

Position analysis. An analysis of variance revealed that the main effects of type of learning and rehearsal type were significant, $F(1,24)=8.47$ and $F(1,24)=52.94$. The type of learning by rehearsal type interaction was also significant, $F(1,24)=5.88$. A post hoc analysis of the intentional learning condition, using Tukey's HSD, revealed that there was a significant difference between recall conditions. A similar effect was found for the incidental learning group. It is apparent from the findings as displayed in Figure 4 that intentional learning was superior to incidental learning when mediating activity was not disrupted. However, post hoc analysis revealed that there was no difference between instructional groups when such mediating activity is blocked (1.14 and 1.0 for intentional and incidental groups, respectively). The data also clearly indicated that both incidental and intentional learning were adversely affected by the distractor tasks.

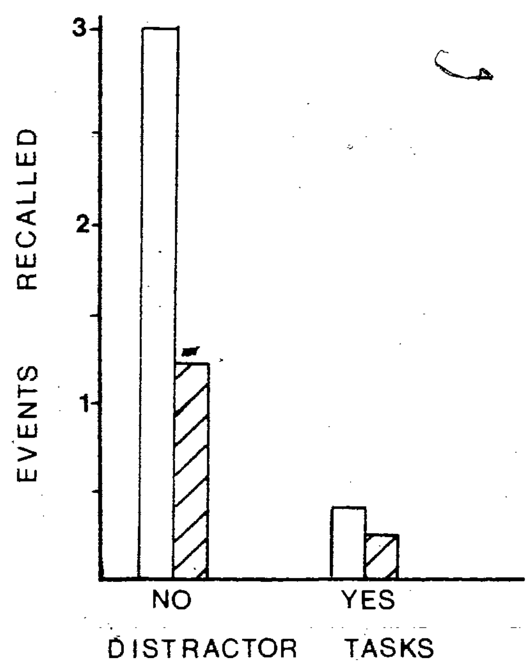
Event-to-event analysis. An analysis of variance revealed that both main effects of types of learning and rehearsal type

Figure 4a. Correct number of positions recalled under incidental and intentional learning conditions as a function of rehearsal blocking activity.

Figure 4b. Correct number of events recalled under incidental and intentional learning conditions as a function of rehearsal blocking activity.


4
3
2
1
POSITIONS RECALLED
NO
YES
DISTRACTOR TASKS

A)


3
2
1
EVENTS RECALLED
NO
YES
DISTRACTOR TASKS

B)

were significant, $F(1,24)=11.52$ and $F(1,24)=42.61$. The type of learning by rehearsal type interaction was also significant, $F(1,24)=8.25$. A post hoc analysis of the incidental learning condition revealed that there was a significant difference between rehearsal conditions. A similar effect was found for the intentional learners. The findings as seen in Figure 4 imply that intentional learning was significantly better than incidental learning when mediating activity was not disrupted. However, post hoc analysis revealed that when appropriate mediating activity was prevented by distractor tasks, the level of incidental and intentional learning was almost equivalent. These findings are consistent with those found for the position measure.

The findings from the present experiment supported the hypothesis that preventing mediating activity, such as rehearsal, eliminate the difference in recall under incidental and intentional learning conditions. This conclusion is inferred from the finding that intentional subjects allowed to engage in mediating activity performed far better than incidental learning subjects. This superior performance was eliminated under conditions of interference with mediating activity.

The findings also indicated that when rehearsal was prevented, incidental learning was disrupted. Postman and Kruesi (1977) suggested that the differences between incidental and intentional learners were produced by the intentional learners spontaneously engaging in rehearsal. The present findings provide support for their claim. The question arises, however, that if rehearsal results in superior intentional learning, why would the distractor tasks produce poorer incidental learning. The post-experimental inquiry revealed that none of the incidental learners engaged in rehearsal or other consciously controlled learning strategies. There are two possible explanations of this finding: 1) the prevention of automatic or "unconscious" processing, and 2) processing capacity interference. It might be the case that learning occurs through two processing modes: controlled and automatic. This notion of a two process theory of human information processing was advanced by Schneider and Shiffrin (1977). Although the explanation advanced for the incidental learning findings of the present study is much more simplistic than the elaborate theory proposed by Schneider and Shiffrin, the general idea is similar. According to this line of thought, both automatic and controlled processes are activated when a subject is exposed to the experimental task. A controlled process, such as rehearsal, is consciously controlled by the subject. An automatic process is activated without conscious control. This process may be conceived as operating through previous associations in long-term memory. Forcing subjects to engage in a task which prevents mediating activity simultaneously prevents these automatic processes from becoming fully activated. It might also be the case that these distractor tasks produced activation of automatic processes, resulting in interference.

The second explanation for the incidental learning finding is based on the explanatory construct of limited processing capacity (Broadbent, 1958). It has been generally recognized that humans have a limited capacity to process information. It was previously argued that the four movements of the sequence were within this limited capacity. This argument was based on the finding that intentional subjects were able to recall all four movements, a finding replicated in the present study. However, when the target movements of the sequence were combined with the distractor tasks, it is possible that this capacity is exceeded. This may have resulted in information being lost, producing poorer recall.

The results from the present study, as in Experiment 1, demonstrated that incidental learning occurred under "subspan" information load. The present findings, using a different movement sequence, were also identical with those of Experiment 1. If the position measure scores for both intentional and incidental conditions are transformed to percentage scores the similarities become readily apparent. For incidental learners the mean scores were 60% and 60.5% for Experiments 1 and 3, respectively. Under intentional learning conditions, the mean scores were 95% and 100% for Experiments 1 and 3, respectively. The event scores, however, are not as consistent between experiments. The transformed mean scores were 60% and 42.7% for Experiments 1 and 3, respectively. Nevertheless, these findings do provide evidence that incidental learning under these task

conditions is fairly robust.

VII. GENERAL DISCUSSION

The purpose of the experiments described was to investigate how number of movements, practice, and rehearsal influence the acquisition of psychomotor behaviour under incidental and intentional learning conditions. In this section the general findings of the three experiments are reviewed, with comparison to previous research and possible theoretical explanations. Furthermore, arguments are advanced concerning the significance of 'intention to learn' and the role of instructions to learn in psychomotor learning.

In general, subjects given instructions to learn recall more movements of a sequence than subjects who are merely exposed to the movement sequence by means of an orienting task. This finding is consistent with many earlier verbal studies (Murray & Ure, 1974; Postman & Adams, 1957, 1958; Postman, Adams, & Bohm, 1956; Shellows, 1923). This superiority for intentional learning was even more pronounced as the number of trials increased, a finding contary to that previously demonstrated by Dickinson (1977).

Analysis of the effects found in the present studies indicated that all the independent variables had a similar functional effect on incidental learning and intentional learning. Although the size of the effect did vary, the direction of the effect was always in the same direction. There was no evidence of any independent variable producing effects in the opposite directions under incidental and intentional learning conditions.

The observation that the independent variables produced effects in the same directions seems to be consistent with Postman's (1964) conclusion that incidental and intentional learning are functionally and conceptually equivalent. This conclusion implies that any differences between incidental and intentional learning are quantitative, not qualitative in nature (McLauglin, 1965). It follows that there is no justification for arguing that incidental and intentional learning represent two qualitatively different types of learning. One might argue, based on the findings of Experiment 3, that the intentional subjects simply engage in mediating activity that is effective for "higher" levels of learning. These mediating activities, such as rehearsal and mnemonic strategies like labelling, are important for the subsequent serial recall of the movement sequence. Nevertheless, the implication that incidental and intentional learning represent only one type of learning may be hasty. Murray and Ure (1974) have presented evidence that is inconsistent with Postman's claim. They found that both incidental and intentional paired associate verbal learning are affected in opposite ways as a function of inter-stimulus interval. The conclusion as to whether incidental and intentional learning involves different underlying mechanisms awaits further investigation.

Based on the findings of numerous investigations, Postman (1964) argued that intent per se has no significant effect on learning. He suggested that instructions to learn trigger responses to the experimental information which are favourable to learning. Arguing from this associationistic school of thought, Postman proposed that the most adequate theoretical explanation of results from incidental learning studies was the differential cue-producing hypothesis. This hypothesis holds that the amount and charateristics of learning depends on the responses - including categorizing responses such as naming and labelling, other responses elicited by stimulus generalization, and other responses serving as associative links among members of a series- which occur during exposure to the experimental material (cf. McLaughlin, 1965). These responses are seen as acting as essential cues mediating recall on a retention test. According to this hypothesis, intentional learners are expected to give more frequent and higher intensity differential responses to the experimental material, and are more likely to rehearse these differential responses. Most of the present findings are not consistent with the differential cue-producing hypothesis. These consistencies and inconsistencies will be discussed in the next few paragraphs.

The general finding that intentional learning is superior to incidental learning supports the notion that these learners are generating more frequent and intense differential responses. Further evidence for the differential cue-producing hypothesis is provided by Experiment 3. Blocking mediating activity, thus preventing the generation of differential reponses, resulted in the differences between the two instructional groups disappearing. However, not only did the differences disappear, both instructional groups exhibited a decrease in the number of correct movements recalled. This finding suggests that when the differential responses generated by the orienting task under incidental learning conditions are blocked, learning is adversely affected.

Unfortunately, the differential cue-producing hypothesis is open to criticism. Many authors have argued that any research finding may be explained on an adhoc basis as correlates of the pattern of responding generated by differences in instructions to learn (McLauglin, 1965; Saltzman & Carterette, 1959). However, even if the cue-producing hypothesis did not have these problems, some of the present findings are difficult to explain in terms of the differential cue-producing hypothesis. For example, early formulations of the hypothesis suggested that incidental learning should be limited to a few items and thus result in less intralist generalizations (Postman & Adams, 1957; Postman, Adams, & Philips, 1955). It follows that increases in the amount of information should have a less adverse effect on incidental learning than intentional learning (Postman & Adams, 1958). However, it is apparent from the results of Experiment 1 that increases in the size of the movement sequence had an adverse effect on both incidental and intentional learning.

Furthermore, the findings of Experiment 2 are inconsistent with this hypothesis. Postman, Adams, and Philips (1955) argued that, for incidental learners, differential responses are likely to occur during initial exposure to the experimental information. Therefore, it follows that further exposure should be of little benefit to the incidental learners. In Experiment 2, repeated exposure to the movement sequence resulted in a statistically significant gain in the recall. Thus, there appears to be some doubt that Postman's theoretical hypothesis is adequate to explain all the present incidental psychomotor learning results.

It may be argued, on the basis of the present experimentation and previous research, that there is sufficient evidence to indicate that intent per se has no significant effect on learning. It appears that intention to learn operates in an indirect manner. The instructions to learn operate to orient the subject to the appropriate information and encourage subjects to engage in cognitive processes which produce learning. When the appropriate learning operations or processes are blocked, as in Experiment 3, the differences between instructional conditions are eliminated.

In line with the previous argument, incidental learning only occurs as a by-product of the responses or operations that are activated from performing the orienting task. Postman (1964) suggested that the orienting task might produce responses which maximally facilitate associative learning, thus achieving the same results as instructions to learn. This idea was extended by

Eagle and Mulliken (1974). They argued that the orienting task may be viewed as a specific type of learning operation. They asserted that by selecting an appropriate orienting task one should be able to obtain incidental learning that is superior to "ordinary" intentional learning. Eagle and Mulliken found that having subjects rate words on an affective scale (pleasant / unpleasant) resulted in subsequent superior incidental recall compared to intentional subjects instructed merely to memorize the words. These findings provide additional evidence that intention is not a necessary condition for learning.

Although the effects of the orienting task on the relationship between incidental and intentional learning have not been investigated, Ho and Shea (1979) did show that manipulating the orienting task results in varying levels of incidental learning. Their results imply that activities which cause the subject to engage in effective learning operations are important determinants in learning. In the present study, it may be the case that the orienting task employed to expose subjects to the movement sequence did not activate the effective learning operations. This argument implies that the differences between experimental findings may be a factor of how the orienting task, experimental material, and the independent variable interact to activate processes that are necessary for learning.

In summary, the present experimentation found that instructions to learn are an important part of the conditions which should be identified in investigations of learning. In general, subjects given instructions to learn are superior in recall to subjects merely exposed to the experimental task by means of an orienting task. Since there was no evidence that independent variables produce effects in opposite directions, it might be argued that incidental and intentional psychomotor learning are governed by the same underlying processes. Finally, with regard to the findings of Experiment 3, there appears to be evidence to substantiate Postman's (1964) assertion that intent per se is not a significant factor in learning. It is apparent that instructions to learn encourage subjects to engage in cognitive activity that is appropriate for effective learning , and that when such activity is blocked, learning deterioriates.

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APPENDICES

APPENDIX A-1

Position Analysis of Variance Table: Experiment 1

Source of Variance	Sum of Squares	DF	Mean Squares	F
MEAN	165060.1	1	165060.1	403.22
I	22542.82	1	22542.82	55.06**
M	19522.29	2	9761.14	23.84**
IM	2650.42	2	1325.21	3.23*
S(IM)	22105.09	54	409.35	

S= Subjects, I= Instructions, M= Movements

** $p < 01$
* $p < 05$

APPENDIX A-2

Event Analysis of Variance Table: Experiment 1

Source of Variance	Sum of Squares	DF	Mean Squares	F
Mean	113013.6	1	113013.6	195.27
I	7616.26	1	7616.26	13.15 **
M	18529.89	2	9264.94	16.00 **
IM	665.62	2	332.81	0.57
S(IM)	31252.47	54	578.75	

S= Subjects, I= Instructions, M= Movements

** $p < .01$

APPENDIX A-3

Position Analysis of Variance Table: Experiment 2

Source of Variance	Sum of Squares	DF	Mean Squares	F
MEAN	1500.62	1	1500.62	249.52
I	255.02	1	255.02	42.40**
T	148.22	1	148.22	24.62**
IT	50.62	1	50.62	8.41**
S(IT)	216.49	36	6.01	

S= Subjects, I=Instructions, T=Trials

** $p < .01$

Appendix A-4

Event Analysis of Variance Table: Experiment 2

Source of Variance	Sum of Squares	DF	Mean Squares	F
MEAN	2059.22	1	2059.22	513.73
I	99.22	1	99.22	24.75 **
T	50.62	1	50.62	12.63 **
IT	15.62	1	15.62	3.89
s(IT)	144.29	36	4.00	

S=Subjects, I=Instructions, T=Trials

** $p<.01$

APPENDIX A-5

Position Analysis of Variance Table: Experiment 3

Source of Variance	Sum of Squares	DF	Mean Squares	F
MEAN	128.57	1	128.57	211.76
I	5.14	1	5.14	8.47 **
D	32.14	1	32.14	52.94 **
ID	3.57	1	3.57	5.88 *
S(ID)	14.57	24	.60	

S= Subjects, I= Instructions, D= Distractor Tasks

** $p < .01$
* $p < .05$

APPENDIX A-6

Event Analysis of Variance Table: Experiment 3

Source of Variance	Sum of Squares	DF	Mean Squares	F
MEAN	43.75	1	43.75	83.52
I	6.03	1	6.03	11.52**
D	22.32	1	22.32	42.61**
ID	4.32	1	4.32	8.25**
S(ID)	12.57	24	.52	

S=Subjects, I=Instructions, D=Distractor Tasks

** $p < .01$

Appendix B-1

Number of errors for each serial position in each movement sequence size condition in Experiment 1

	Position										
Group	1	2	3	4	5	6	7	8	9	10	11
Incidental											
4 movements	5	1	3	3	-	-	-	-	-	-	-
7 movements	8	8	6	10	9	7	6	-	-	-	-
11 movements	7	9	7	8	8	7	8	7	9	5	9
Intentional											
4 movements	1	0	1	0	-	-	-	-	-	-	-
7 movements	0	0	2	3	8	4	2	-	-	-	-
11 movements	1	1	2	2	4	8	8	9	9	6	6

Note Maximum error= 10

Appendix B-2

Number of errors for each serial position

in each trial condition in Experiment 2

Group	Position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Incidental															
2 trials	5	8	7	8	8	10	9	10	9	9	6	9	8	10	6
10 trials	4	6	7	7	8	8	9	7	7	7	8	6	8	7	6
Intentional															
2 trials	2	1	2	4	7	8	8	7	6	9	8	8	7	8	8
10 trials	0	0	0	3	4	4	3	3	2	4	3	4	1	2	0

Note maximum error= 10

Appendix B-3

Number of errors for each serial position when mediating activity was blocked in Experiment 3

Group	Position 1	2	3	4
Incidental				
unblocked	3	2	4	2
blocked	5	3	7	6
Intentional				
unblocked	0	0	0	0
blocked	5	3	6	6

Note maximum error= 7