THE EFFECTS OF CONTEXTUAL INTERFERENCE AND VARIABILITY OF PRACTICE ON THE ACQUISITION OF A MOTOR TASK AND TRANSFER TO A NOVEL TASK

Submitted by

STEPHEN WRATHALL

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School of Exercise Science

Faculty of Health Sciences

Australian Catholic University

Research Services

Locked Bag 4115,

Fitzroy, Victoria 3065

Australia

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Signed:_____ Date: 04-12-2000

Name: Stephen Wrathall

ABSTRACT

AIM

The purpose of this experiment is to assess whether the advantages of variable practice are due to schema formation or to enhanced information processing (contextual interference) alone.

DESIGN

The design involved a 2 (mode; cognitive and motor) x 5 (practice schedule; blocked, random, constant distance one, constant distance two, and constant distance three) between subjects design resulting in ten groups. One hundred participants were randomly chosen from Human Movement students at Australian Catholic University and assigned to each of the ten groups (n=10).

The cognitive mode involved the participants having to recognise the appropriate target from three geometrical shapes (triangle, square or circle), the triangle being the target in every case. The motor mode involved the participants having to tap on the target among three boxes that was merely filled in. The experiment consisted of ninety (3 blocks of 30) acquisition trials followed by ten transfer trials to a novel movement.

MAIN HYPOTHESIS

It was hypothesised that if facilitated transfer to a novel target occurs through schema formation, then there would be no differences between the motor groups and their corresponding cognitive groups. However, if facilitated transfer to a novel target occurs through enhanced information processing, then there would be differences between the motor groups and their corresponding cognitive groups.

RESULTS

Statistical analysis revealed a contextual interference effect for participants involved in the cognitive mode, in that the cognitive blocked group outperformed the cognitive random group in acquisition, but the reverse was the case in transfer. In the motor mode, the motor blocked group outperformed the motor random group in acquisition, and repeated the performance in transfer.

CONCLUSION

The results appear to indicate that for simple motor tasks it is the amount of variability of practice that is important for transfer to a novel task, while for tasks with a cognitive component, the schedule of practice is critical.

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INTRODUCTION{ XE "INTRODUCTION" }

The study of motor skill learning has generally involved the attempt to understand the underlying processes that are at work when acquiring and performing skills, with an eye to the application for skill instruction situations. Theories have been advanced and their fortunes have waxed and waned as questions regarding their validity have been raised, but one of the more enduring has been schema theory (Schmidt, 1975, 1976). However, this theory of generalised motor programs and schemata has been recently challenged by proponents of action theory who reject any notion that movement kinematics are represented centrally, rather, movement kinematics arise naturally out of the complex interactions among many connected elements. In the same way that many complex systems in the natural world self-organise without any centralised control, so do many of the movements of humans. Any investigation into the action systems approach is beyond the scope of the present study, however it is important to note that schema theory is not a universally accepted theory and it may be that action theory will supplant schema theory as the leading explanation of human motor control. Indeed, research into an interesting learning phenomenon, the contextual interference effect, has cast some doubt on one of schema theory's basic tenets, variability of practice, and to date no clear decision has been reached.

Schema theory states that practicing variations of a movement (variable practice) will be of benefit when the movement must be later recalled (retention) or when producing a novel form of the movement (transfer). However, study concerning the cognitive

processes thought to occur in verbal learning (Battig, 1966, 1972, 1979) was applied to the area of motor control (Shea and Morgan, 1979). The improved retention and transfer occurred following practice in which the cognitive events, that are useful in information processing that takes place prior to a movement, were interfered with by changes in the context of the skill being practiced. Random practice, where trials of different skills, or variations of the same skill are presented in a random manner, is thought to produce high levels of interference. Blocked practice, where trials of different skills, or variations of the same skill are presented as a block of one skill form, followed by a block of the next skill form and so on, produces low levels of interference. Typically, blocked practice produces superior performance during practice (acquisition), but random practice facilitates retention of the skill and/or transfer. This phenomenon became known as the contextual interference effect. Explanations for the effect centre about the cognitive aspects of low versus high contextual interference. Variable practice produces results very similar to contextual interference, but schema theory explanations are not consistent with those of contextual interference. The need arises, therefore, to determine the causes of these practice effects and to resolve any ambiguity about one of the most important contributions to motor control understanding. This would appear to be of importance as we attempt to understand the underlying mechanisms of human control of movement, if only to avoid wasting unnecessary time and effort on unprofitable areas of research.

Before examining the empirical bases of the contextual interference effect and of variable practice, the underlying concepts of each theory will be examined to aid in the assessment of individual studies.

Schema Theory{ XE "Schema Theory" }

Schema theory arose more than two decades ago from a dissatisfaction with the prevailing notion of specific motor programs and its inability to explain how movements are satisfactorily performed for the first time (the novelty problem) and, if specific motor programs are required to perform a movement, how is the potentially infinite number of programs stored in the brain (the storage problem). Schmidt (1976) proposed that generalised motor programs for particular classes of movement could be stored so that when a movement is required a generalised motor program is retrieved from memory and additional information (parameters) supplied to allow the same motor program to be run off in a variety of ways. This additional information could concern the force supplied by the appropriate muscles or the overall duration of movement.

Correct parameter selection is necessary to produce desired movements. The theory states that when one makes a movement four kinds of information are briefly stored: the parameter of the movement (force, overall duration), the outcome of the movement (what happened in the environment), the sensory consequences of the movement (what the movement "felt" like) and the initial conditions of the movement (initial state of the body or the object that is to be moved - am I sitting or standing, is the object heavy or light?). Rules are constructed by abstracting relationships among these four pieces of information in order to handle similar situations in the future and the rules that are formed are called schemata.

Schmidt used the schema concept to describe the generalised motor program as a control mechanism responsible for controlling the general characteristics of classes of action, such as throwing or kicking, and the motor response schema as the mechanism responsible for providing the parameters for running the particular motor program in the manner necessary to produce the desired outcome.

Implicit in schema theory is the role that practice plays in forming and strengthening schemata. Specifically, schema theory states that variability of practice within a movement class facilitates rule learning and produces stronger schemata. Therefore, research in variability of practice that provides support for the existence and formation of schemata is an important cornerstone of schema theory.

Variable Practice

Variable practice refers to rehearsing many possible variations of a class of movements - those governed by a generalised motor program with certain invariant characteristics (for instance relative timing). Different sets of parameters must be chosen to produce different variations of the motor program in order to achieve the various desired outcomes.

The strength of the schema is a function of the range and richness of the feedback experienced, and it follows that the more varied the practice the more feedback is gained, and the stronger the rule. Rules developed under varied practice allow the performer to more accurately determine the response specifications or parameters needed to produce a novel version of the response class. The football player who

practices at 10, 20 and 40 metres during an acquisition session can easily transfer to kicking accurately at 30 metres in what is essentially a novel task.

Schema theory can account for the ability to satisfactorily produce movements that were never performed before, by the learner drawing upon existing schemata to produce a movement considered suitable to satisfy the initial conditions and desired outcome. Variable practice involves practicing many variations of a class of movements, resulting in stronger schemata formation for the particular generalised motor program used and therefore increased ability to generalise parameters to novel tasks using that motor program (that is, within the same class of movements).

The Contextual Interference Effect{ XE "The Contextual Interference Effect" }

Early research into verbal learning and rule learning (Battig, 1966, 1972, 1979) indicated that learning under conditions in which there is a great deal of within-task interference (that is, intratask interference) improved retention and facilitated transfer to a novel task. High intratask interference will occur, for instance, when several variations of a task must be learned during practice and these variations are presented randomly in the course of the practice. This intratask interference principle was shown to be able to be applied to motor skill learning (Shea & Morgan, 1979) and interest in the contextual interference effect has led to a large number of related studies. Typically the contextual interference effect has been demonstrated in research by manipulating characteristics of across-trials conditions when several variations of a skill must be learned. The method employed is often to contrast random practice (high contextual interference) and blocked practice (low contextual interference). Results

show that practice under levels of high contextual interference leads to depressed performance during acquisition of the task, but facilitates retention and transfer to a novel task when compared to low contextual interference practice conditions.

One explanation for the contextual interference effect, known as the elaboration benefit explanation (Shea & Morgan, 1979; Shea & Zimny, 1983), is that random practice encourages the learner to compare and contrast the methods and strategies used for performing the different tasks, developing richer representations and discovering a greater number of relationships and differences between movement patterns. Such deeper conceptual processing results in more elaborate and distinctive representations, resulting in the advantages seen later in retention.

Another explanation (the action plan reconstruction view) is that forgetting the action plan is the crucial aspect of the effect (Lee and Magill, 1983, 1985). Random practice requires the learner to develop a strategy or plan of action. However the nature of random practice requires a new plan to be constructed for each trial. By the time the previous plan needs to be used again it has been lost from memory and must be reconstructed. In contrast, in blocked practice the same plan is used over and over as the same movement is performed repeatedly. The consequence is that having to develop an action plan when necessary (under random practice) makes the learning more memorable and better suited for novel performance situations.

The elaboration benefit explanation and the action plan reconstruction view of the contextual interference effect both pose problems for Schmidt's schema theory. If variability by itself has less effect on transfer than the actual structure of variable

practice, then it seems more likely that contextual interference during practice rather than a more reliable schema is responsible for improved transfer (Horak, 1992). Both schema theory and contextual interference theory give rise to similar predictions regarding performance variability. Variability of practice, according to contextual interference theory, would require the participant to develop multiple strategies or actively reconstruct the solution on each trial. According to schema theory, variability of practice provides a stronger schema rule for the movement as a function of the greater variety in initial conditions and desired outcomes experienced during practice. Therefore, for both theories, variable practice would result in better retention and transfer. The major difference between the two theories is that schema theory makes no predictions regarding the effect of practice order. If the order of practice is not controlled for in studies of variability of practice, then improved performance in retention and transfer resulting from contextual interference may be attributed to variability of practice rather than the order of practice.

Findings demonstrating better retention and transfer to a novel task following variable practice than after constant practice have been one of the main supports of schema theory. The possibility of these results being due to the development of enhanced information processing capabilities through contextual interference may cast doubts on the validity of the variability of practice prediction of schema theory. The challenge remains to discover the nature of the contextual interference effect and its role vis a vis schema theory. This experiment aims to determine whether the variability of practice results are due to contextual interference.

Purpose of the Study{ XE "Purpose of the Study" }

The purpose of the experiment is, therefore, to assess whether the advantages of variable practice are due to schema formation or to enhanced information processing (caused by contextual interference) and the implications for schema theory will be discussed.

CHAPTER 2{ XE "CHAPTER 2" }

LITERATURE REVIEW{ XE "LITERATURE REVIEW" }

Introduction{ XE "Introduction" }

This chapter will evaluate the empirical bases of the contextual interference effect and the variability of practice hypothesis. The review of the contextual interference effect literature will examine the impact of a number of factors (for instance, age, variations in tasks) on the effect.

Variability of practice studies typically examine the differences in acquisition and in tests of learning (usually retention and/or transfer tests) between variable and constant practice. The review of the variability of practice hypothesis literature will centre about the nature of the variable practice used in the studies and the degree to which the variability of practice hypothesis has been supported. Studies that have attempted to investigate both the variability of practice hypothesis and the contextual interference effect will be paid special attention.

Landmark Studies in the Contextual Interference Effect{ XE "Landmark Studies in the Contextual Interference Effect" }

Battig's Influence

The interest in contextual interference can be traced directly to Battig's work in the area of verbal learning. Battig's initial contribution to the contextual interference effect was in his 1966 paper in which he summarised efforts to examine the effects of intratask interference (within-task interference) on learning lists of words (Battig, 1966). His proposal that 'intertask facilitation is produced by intratask interference' (Battig, 1966, p. 227) was in direct contradiction to the predominant methods of conceptualising the role of interference in learning and memory at that time (intertask facilitation refers to the improved capacity to transfer and perform well between different tasks).

Shea and Morgan (1979)

This study showed that the contextual interference effect, as observed by Battig (1966, 1972), was applicable to the area of motor skill learning and involved participants learning to move their arms as quickly as possible through three different three-segment patterns. In response to a stimulus light, the participant picked up a ball with the right hand, knocked over a series of freely moveable wooden barriers, and then brought the ball to a final resting position. The required movement patterns were illustrated on cards visible to the participant and located above a coloured light specific to that movement pattern. Total movement time was the time between the

illumination of the stimulus light and the placing of the ball in the final resting

position. A blocked practice schedule, representing low contextual interference, and a

random practice schedule, representing high contextual interference, were used to

incorporate contextual interference into the practice. In the blocked practice schedule

all the participants practiced Task A eighteen times before moving on to practice Task

B and then Task C eighteen times each. In the random practice schedule participants

practiced each task eighteen times as well, but the order of presentation was random

(e.g., ACBCAB).

Results showed that although participants who had practiced in a blocked practice

schedule performed better than participants who had practiced in a random practice

schedule in acquisition, the random group performed better in retention and transfer.

This result could have been because the random group received practice under the

same conditions in both acquisition and retention, giving them an advantage in the

retention test. To test this specificity hypothesis, half the participants performed a

retention test under blocked conditions and half under random conditions. Again, the

random practice group outperformed the blocked practice group, although the

difference between the groups was much more apparent when tested with random-

ordered trials. Shea and colleagues explained their findings by describing the random

condition as a high contextual interference condition, which led to more complex

processing, facilitating remembering of motor responses (Shea & Morgan, 1979; Shea

& Zimny, 1983).

The Role of Cognitive Effort{ XE "The Role of Cognitive Effort" }

The amount of cognitive effort required when practicing is thought to influence the learning process. Cognitive effort refers to the amount of mental work involved in making decisions (Lee, Swinnen, & Serrien, 1994) and learning appears to be facilitated when practice promotes decision making processes. The contextual interference effect is thought to be cognitive in nature (Blandin, Proteau & Alain, 1994; Del Rey, Liu, & Simpson, 1994; Shea & Wright, 1991; Wright, Li, & Whitacre, 1992) in that random practice encourages the formation of a richer set of retrieval cues to be available allowing greater contrast between the items to be learned (Shea & Morgan, 1979; Shea & Zimny, 1983) or that random practice encourages the reconstruction of a solution to a problem for each trial (Lee & Magill, 1985).

In their study in which participants practiced calculations with Boolean mathematical functions in an effort to elicit the contextual interference effect in purely cognitive procedures as opposed to the acquisition of motor skills, Carlson and Yaure (1990) found a striking similarity between the effects of practice schedules on the acquisition of motor skills and cognitive procedural skills. They concluded that skill acquisition in perceptual, cognitive, and motor domains share underlying mechanisms and that '[T]his consistency across domains fits well with the emphasis on cognitive factors in explaining contextual interference effects in the acquisition of motor skills' (Carlson & Yaure, 1990, p. 495).

It appears that the contextual interference effect could be a result of higher level thought processes due to the increased levels of cognitive effort that are elicited in

participants during practice (for instance, under conditions of random practice). The present study, then, will attempt to manipulate the amount of cognitive effort to determine its effect on learning, and it was decided to use set up conditions in which participants will practice at two levels of cognitive effort. Although any practice session will have a cognitive component to it, in this study participants will practice in either a high cognitive effort mode (cognitive mode) or low cognitive effort mode (motor mode).

Further Studies in Contextual Interference{ XE "Further Studies in Contextual Interference" }

A major review of the literature concerning the contextual interference effect by Magill and Hall (1990) cited over forty empirical investigations of the effect since the Shea and Morgan (1979) study. The most common feature of these studies was a comparison of blocked and random practice schedules during periods of practice (acquisition), retention, and transfer. Important differences among this research were the impact of various factors on the contextual interference effect (Chamberlin & Lee, 1993). These factors include variations in scheduling of practice, variations in scheduling retention and transfer, participant variations, and task variations.

Variations in Scheduling Practice

The basic practice schedules of blocked and random practice have generally been used in studies of the contextual interference effect, however, other practice schedules, such as serial practice and constant practice, have also been employed.

Lee and Magill (1983, experiment 2) approached blocked practice as a practice schedule in which the cognitive processes necessary for an upcoming movement are "just remembered" for each successive trial (Lee & Magill, 1983, p. 737). Random practice, on the other hand, requires the active reconstruction of the action plan for each trial. They postulated that the predicability of the upcoming event may be the reason why there was less information to be processed in blocked practice and added a third practice schedule (serial practice) to those of blocked and random practice. In their second experiment, participants practiced at three patterns in a knockdown barrier task. The blocked group practiced eighteen acquisition trials on a particular pattern consecutively, followed by eighteen trials of the next pattern and, finally, eighteen trials of the last pattern. The random group practiced their trials in random fashion, and the serial group practiced trials in blocked orders of triplets (ABCABCABC…). Therefore the serial group, like the blocked group, knew which pattern was next, but, like the random group, each successive pattern was different. Lee and Magill discovered that the respective movement times and reaction times for the random and serial groups were almost identical in acquisition and retention and that the serial and random groups performed with significantly lower reaction time and movement time than the blocked group in retention. It appeared that facilitated retention and transfer performance that occurred as a result of random or serial practice, compared to blocked practice, was due to the different cognitive processes that occurred because each successive trial was different. Although the general practice in contextual interference effect experiments has been to contrast random and blocked practice, serial practice has been shown to be as effective as random practice in other studies (e.g., Hebert, Landin & Solmon, 1996; Seyika, Magill & Anderson, 1996; but see Goode & Magill, 1986).

Lee, Magill and Weeks (1985) contrasted constant, blocked and random practice using a knock-down barrier apparatus in an effort to test schema theory predictions. All three groups' variable error scores were significantly different in acquisition. However, for constant error, the random group performed more poorly than both the constant and blocked groups, which were not different. In a transfer test, outside the range of parameters varied in acquisition, the random group outperformed the blocked and constant groups (which were not different) in variable error. For constant error, both random and blocked practice outperformed constant practice. Lee and his colleagues saw this as a result that could be argued to be favourable to either contextual interference theory or schema theory.

Gabriele, Hall and Buckolz (1987) were concerned with ensuring that the blocked and random groups should have attained the same level of performance by the end of the practice (acquisition) period, before retention tests were administered. They allowed the two groups to practice as long as it took to ensure that a set standard had been attained in a barrier-knockdown task. They then gave the same amount of practice that the random group had had to a third group (blocked-matched) but in a blocked practice schedule. They found that the random group had to practice longer than the blocked group to achieve the same standard but, when tested on immediate and delayed retention, this group outperformed both the blocked and blocked-matched groups.

Shea, Kohl and Indermill (1990) used a modified form of blocked practice in their study. Their goal was to assess the effects of differing numbers of acquisition trials on subsequent retention. The participants (seventy-two undergraduate students) were

required to elevate a trace dot on an oscilloscope screen to the current target line by hitting the padded arm of a force transducer. The participants practiced in either a blocked or random fashion and performed either fifty, two hundred or four hundred acquisition trials of five different forces. During practice, the random groups performed with greater error than the blocked groups, although the differences in error decreased with increasing trials. When retention was measured under blocked conditions the random groups performed similarly to the blocked groups except where the groups had practiced at a greater number of trials (400) and then the random group outperformed the blocked group. When retention was measured under random conditions the random group that had practiced fifty trials was inferior to the blocked group that had practiced the same amount of acquisition trials, but as the number of acquisition trials increased, the random groups outperformed the blocked groups. Shea and colleagues concluded that 'the benefits of blocked practice occur very early in practice with the response production strategy becoming increasingly more rigid and inflexible. On the other hand, the benefits of random practice surface after initial practice…' (Shea et al., 1990, p. 153).

The effects of different practice schedules on the amount of learning (as tested using a retention test and/or a transfer test) are the major concern of these studies. In an effort to allow the comparison of this study with previous studies, it was decided to compare a random practice schedule with a blocked practice schedule.

Variations in Scheduling Retention and Transfer

Studies that include retention tests typically involve an immediate retention test, a delayed retention test, or a combination of both. There has been some debate as to whether the retention test(s) should be performed under the same or different conditions as those practiced in acquisition.

Shea and Morgan (1979) found that the random retention advantage was larger under randomly ordered retention trials than under blocked retention trials. Although this finding has not always been observed, it is interesting to note that the advantage of random practice over blocked practice is apparent in retention tests in which the retention trials are presented in either a blocked (e.g., Gabriele et al., 1987; Gabriele, Hall & Lee, 1989; Immink & Wright, 1998; Jelsma & Van Merrienboer, 1989; Wright, Li & Whitacre, 1992; but see, Blandin, Proteau & Alain, 1994) or random order (e.g., Blandin, Alain & Dorion, 1994; Goode & Magill, 1986; Proteau Lee & Magill, 1983, experiments 1,2 & 3).

A transfer test is typically included to evaluate the participant's ability to apply any learning achieved in one task or setting to some other task. This other task is normally related to the movements practiced in acquisition. It can be termed inside-transfer (a transfer task that is within the range of motion(s) practiced in the acquisition task) or outside-transfer (a transfer task that is outside the range of motion(s) practiced in the acquisition task). Inclusion of transfer tests of these two basic types has produced mixed results.

Lee et al. (1985) found that there was no contextual interference effect when participants were tested on "inside" transfer but that there was a typical contextual interference effect when they were tested on "outside" transfer. Goode and Magill (1986) found a contextual interference effect in a transfer test when participants who had practiced different types of badminton serves were required to serve from the left side of the court. It is difficult to classify this type of test as either an "inside" or "outside" transfer test or even a real transfer test, as the participants merely had to repeat the same three practiced serves in a random presentation, albeit from the left side of the court. It is possible that the enhanced performance of the random group over the serial and blocked groups in transfer was due to the blocked and serial groups being at a disadvantage when confronted with a random presentation of retention tasks.

Wulf and Lee (1993) used identical immediate and delayed (one day later) transfer tests that had the same relative timing, but a longer overall duration, as the acquisition tasks, in their study designed to dissociate the effects of generalised motor program learning from parameter learning. The experimenters found a contextual interference effect in generalised motor program learning in the delayed transfer test only. There were no differences between the blocked and random acquisition groups in the immediate transfer test. Interestingly, the experimenters found that blocked practice, rather than random practice, facilitated transfer in both the immediate and delayed transfer tests for parameter learning.

Performing retention tests in either blocked or a random schedule appears to have little effect on the contextual interference effect, in that random practice still leads to

better learning than blocked practice. Ideally, a retention test would be of use in assessing the level of learning in the present study. However, due to the large number of groups involved in the study (10) leading to a large number of participants (100), a transfer test was chosen instead of a retention test as an indication of the level of learning produced. There was the possibility of a large number of participants dropping out between the practice and retention sessions leading to unacceptably low numbers in the groups. The transfer test allowed for immediate testing of the participant.

Variations in Participants

Most studies of contextual interference have involved university-aged participants (e.g., Goodwin & Meeuwsen, 1996; Inui, 1996; Lai & Shea,1998; Pollatou, Kioumourtzoglou, Agelousis & Mavromatis, 1997; Proteau et al., 1994; Sekiya et al., 1996; Smith, 1997), but some studies have attempted to determine the effect on the contextual interference effect of various participant factors, including age, sex, skill level and previous sport experience.

When children are used as participants a mixed pattern of results appears to emerge. Del Rey, Whitehurst, and Wood (1983) examined the effects of sports experience, gender and practice schedule (random versus blocked) in children aged six to ten years old. They found, when tested on a transfer test, that sports-experienced children outperformed non-sports-experienced children, boys generally outperformed girls, and that blocked practice facilitated transfer compared to random practice.

Pigott and Shapiro (1984) found no difference between constant, blocked and random practice groups of children in acquisition and transfer, but a combination of blocked and random practice outperformed all the other groups.

Wegman (1999) contrasted random, blocked and blocked-random practice (five trials of each skill, followed by random practice) using grade four girls learning ball-rolling, racquet-striking and ball-kicking. Wegman found a contextual interference effect in a three-week delayed retention test for the racquet-striking only, with the random group performing significantly better than the blocked group. There were no differences observed between the blocked and blocked-random groups, nor the random and blocked-random groups and no differences were found between groups for the two other skill retention tests.

In a study involving older adults who participated in different levels of physical activity, Del Rey (1982) found that the active participants group performed better in retention than the less active group, and that a typical contextual interference effect was demonstrated between the active-blocked and active-random groups only. Del Rey and colleagues also found a connection between levels of prior activity in open sport skills and practice in a constant, blocked or random manner in college-age females using a Bassin Anticipation Timer (Del Rey, Wughalter, & Whitehurst, 1982). Those participants who had prior experience in open sport skills and who practiced in a random schedule performed better in transfer than those who had experience in open sport skills and who practiced in a blocked schedule. There was no contextual interference effect between the participants who had no prior experience in open sport skills.

Jelsma and Pieters (1989) showed that cognitive style appears to interact with the contextual interference effect. In the study it was indicated that reflectivity-impulsivity aspects of the participants' learning styles (a reflective person will typically favour accuracy and an impulsive person will favour quickness in a speed-accuracy tradeoff situation) interacted with the practice schedule (blocked or random). They used a computerised tracking task with participants practicing in a blocked or random fashion to demonstrate that, when tested on retention and transfer tests, a typical contextual interference effect was shown for the reflectives but not for the impulsives. Jelsma and Van Merrienboer (1989) used a different computerised tracking task to obtain similar results.

The use of university students as participants in the present study allowed for a sufficiently large sample and was consistent with many other studies.

Variations in Tasks

The type of task performed by participants in studies concerning the contextual interference effect has varied considerably. The most popular tasks in laboratory-based experiments have been variations of the multi-segment movement task used by Shea and Morgan (1979). The barrier knockdown apparatus is designed to require arm movement through a specified multi-segment movement pattern. Two goals have characterised these tasks. One requires participants to move as fast as possible through the prescribed movement pattern. The other requires the whole movement, or each pattern segment, to be performed according to a set movement time. In general, support for the contextual interference effect has been found using these types of tasks

(e.g., Blandin et al., 1994; Carnahan, Van Eerd & Allard, 1990; Gabriele et al., 1987; Lee & Magill, 1983; Proteau et al., 1994; Shea & Wright, 1991; Shea & Zimny, 1988; Wright, 1991; Wulf & Lee, 1993; but see Carnahan & Lee, 1989).

The anticipation timing task, generally using the Bassin Anticipation Timer, has also been used to investigate the contextual interference effect. Contextual interference effects are found in some situations (e.g., Del Rey, 1982; Del Rey, 1989; Del Rey, Wughalter, & Carnes, 1987) but not in others (e.g., Del Rey, Wughalter, DuBois, & Carnes, 1982; Edwards, Elliott & Lee, 1986).

Jarus, Wughalter and Gianutsos (1997) contrasted random and blocked practice conditions in open and closed skills. Participants practicing in the open-skill condition tracked a moving cursor through movements of the head to one of three target areas, while participants practicing in the closed-skill condition had to move the cursor from the start area to one of three target areas and then keep the cursor in the target area through delicate movements of the head. The experimenters found some support for the contextual interference effect hypothesis in the open-skill participants only.

Sherwood (1996) attempted to discover if the advantage of random practice over blocked practice that results in better movement production in long-term retention would also result in better error detection. Participants were required to make rapid lever reversal movements so the reversal point was 20°, 40° or 60° and the goal time to reversal was 225 milliseconds. Participants were asked to guess their reversal point five seconds after each trial and were then told the actual reversal point. The experimenter found a typical contextual interference effect, in both movement

production and error detection, in that the blocked group performed better than the random group in acquisition, while the random group performed better in retention.

Experiments designed to replicate laboratory results in field studies have been performed using a number of skills. Bortoli, Robazza, Durigon, and Carra (1991) used three volleyball skills to investigate the contextual interference effect in high school students. A blocked group practiced one of three skills each practice session; a random group practiced one skill six times before moving to the next skill, which was chosen randomly; a serial group practiced one of the skills six times before moving to the next and the order of skills was always the volley, followed by the bump (dig) and then the serve; a very high serial group which practiced like the serial group, however the participants only practiced each skill twice before moving on to the next. There were no differences noted between the groups on a retention test, nor a transfer test where the participants had to perform each skill one meter closer to their targets. However, on a transfer test where the participants were one metre further from the target than at acquisition, the serial and random groups performed better than the blocked and the high serial groups.

Hall, Domingues, and Cavasos (1994) demonstrated the contextual interference effect in skilled baseball players by scheduling additional batting practice for two of three groups of batters (a blocked and random practice group), while a control group received no extra practice. The extra practice consisted of batting to three different types of pitching, and after six weeks of training transfer tests revealed that the random group performed better even when tested in a blocked or random fashion.

Hebert et al. (1996) contrasted high and low-skilled students practicing the forehand and backhand strokes of tennis in either a blocked or alternating schedule over a semester of tennis classes. Retention tests showed that blocked practice was superior to alternating practice for the low-skilled participants, while there were no differences between the two high-skilled groups. Although the high-skilled students tended to perform better on retention if they had practiced in an alternating schedule, the differences were not significant and this may have been due to the relatively small number of variations of the task as only backhand and forehand strokes were practiced. Although serial practice has tended to produce the same results as random practice, the students may not have had to participate in cognitive processing high enough to produce the benefits of random and serial practice.

Brady (1997) found no differences between blocked and random practice of golf shots when the two groups' learning was tested with an eighteen-hole round of golf. The participants learnt four different golf strokes and the experimenter surmised that practicing that many different skills may have produced too much interference, leading to the lack of difference between the groups.

Shewokis (1997) attempted to test the contextual interference effect in a non-laboratory setting using computer games (three events of the winter Olympics) as tasks. The experimenters found a contextual interference effect in that the random group performed better than the blocked group in a delayed transfer test, but not in delayed retention tests. However, the random and blocked group performed similarly in one of the acquisition tasks (the bobsled), the random group significantly better in another (speed-skating), but worse in the last (the luge). The experimenters noted that

the typical effects of contextual interference may not have been found in acquisition because of the increased cognitive effort and enhanced motivation that participants experience when practicing computer games.

Tsutsui, Lee and Hodges (1998) were concerned that the types of tasks typically used in contextual interference studies merely involved the rescaling of previously acquired coordination patterns – the participants were capable of performing that movement pattern prior to practice. The participants of their study were required to move two handles that moved in parallel along a track with both arms in one of three bimanual coordination patterns. The experimenters argued that, without practice, only two coordination patterns can be performed skilfully (0° and 180° relative phase, or in-phase and antiphase) and, therefore, practice at 45°, 90°, and 135° relative phase required the acquisition of three fundamentally new patterns of motor coordination.

The experimenters had two groups practice the three coordination patterns in a blocked or random manner over two days (experiment one) and found no statistically significant differences between the two groups in either acquisition nor retention tests at the end of each day of acquisition. The experimenters postulated that the lack of differences between the two groups may have been due to the blocked group practicing all three patterns on both days of acquisition and designed a second experiment in which the blocked group performed forty-five trials of one pattern on the first day, practiced a second pattern on the second day, and the remaining pattern on the last day. The random group performed fifteen trials of each pattern in a random order each day, similar to the first experiment. The experimenters now found a typical contextual interference effect in the one-week delayed retention test.

In the present study, an attempt was made to contrast levels of cognitive effort used during practice with different practice schedules. The difficulty was in finding a movement that could have different levels of cognitive effort when practicing without changing the movement. A computer based skill was decided upon but the skill had to be unexciting enough to allow a clear delineation between a low level cognitive effort mode and high level cognitive effort mode. This was to avoid raising the level of cognitive effort used in the low cognitive effort mode merely by the use of a computer task as may have been the case in the Shewokis (1997) study.

Dependent Measures{ XE "Dependent Measures" }

In their review, Magill and Hall (1990) proposed that the contextual interference effect would not be exhibited if the tasks learnt in blocked and random practice were from the same generalised motor program. A generalised motor program is assumed to govern a class of movements that have certain invariant characteristics, such as relative timing or relative force, but which differ with regard to the movement parameters, such as absolute time, absolute force, and the muscle groups involved. Many studies have attempted to investigate the hypothesis (e.g., Goodwin & Meeuwsen, 1996; Lee, Wulf, & Schmidt, 1992; Seyika et al., 1996; Seyika, Magill, Sidaway, & Anderson, 1994; Wulf & Lee, 1993). However, studies that found support for Magill and Hall's (1990) hypothesis (e.g., Lee et al., 1992; Wulf, 1992) used global error measures, such as root-mean-square error (RMSE) and absolute error (AE), that confound errors in generalised motor program and parameter learning, or used an experimental model that did not allow the differentiation between parameter and motor program learning (e.g., Pigott & Shapiro, 1984; Turnbull & Dickinson,

1986; Whitehurst & Del Rey, 1983; Wood & Ging, 1991). Absolute error is 'a composite score of varying (and usually unknown) portions of constant error (C) and variable error (V^2)' (Schutz, 1974, p. 299). Using only absolute error as the dependent measure can lead to problems in interpreting interactions for absolute error as the 'AE scores represent a varying mixture of CE (constant error) and VE (variable error), rather than a single dependent variable', (Schutz & Roy, 1973, p. 150). RMSE is a measure that includes errors both in relative timing/amplitude and in absolute timing/amplitude. Therefore if performance is enhanced in one timing/amplitude and degraded in the other, the dependent variable effectively cancels out, indicating no change (Wulf and Lee, 1993).

Wulf and Lee (1993) argue that measuring changes in overall segment duration reflects parameter learning, while measuring changes in the relative proportion of segment duration reflects generalised motor program learning. Only recently have studies measured dependent variables that allow the dissociation of generalised motor program and parameter learning. Wulf and Lee (1993) used constant error to measure parameter learning and absolute error (proportional) to measure generalised motor program learning and reported that random practice was more effective than blocked practice for generalised motor program learning, not parameter learning, on a transfer task. However, Sekiya et al. (1994), using measurements of relative timing performance, E(RT), to assess the proportional accuracy of the generalised motor program and overall duration performance, E(OD), to assess accuracy of parameter modifications, showed that, on a retention test, serial practice was more effective than blocked practice for learning parameters, not generalised motor program learning. Sekiya and colleagues (1996) extended and replicated the findings by Sekiya et al.

(1994) and found that parameter learning, not generalised motor program learning, was enhanced by high contextual interference practice on a retention test when overall force parameters were modified.

There is the possibility that the dependent variable(s) used in previous studies may have led to the masking of a contextual interference effect. Magill and Hall (1990) propose that a contextual interference effect will not be exhibited if the tasks learnt in blocked and random practice are from the same generalised motor program. However, if learning is depressed in tasks from the same generalised motor program learnt in both blocked and random practice, the possibility arises that this may occur because the amount of cognitive effort is low even when practiced in a random practice schedule. Further, the use of different dependent variables that allow the dissociation of generalised motor program and parameter learning have led to inconclusive findings. In the present study, it was decided to avoid the uncertainty by choosing movement time (MT) as a dependent measure with the assumption that as learning progressed, movement times would decrease.

Studies Investigating Variability of Practice{ XE "Studies Investigating Variability of Practice" }

The variability of practice hypothesis has generally received strong empirical support. However, when the structure of the practice schedule is examined in the studies a pattern begins to emerge. In their study investigating the influence of random and blocked practice against constant practice, Lee, Magill and Weeks (1985) noted that studies which manipulated variable practice in a blocked fashion found little or no

support for the variability of practice hypothesis, while studies that manipulated practice in a random order generally found strong support for schema predictions. The possibility arises that studies that have contrasted random practice with constant practice and have supported the variability of practice hypothesis may have, in fact, tested the contextual interference effect. Therefore, the different effects of blocked versus constant practice and random versus constant practice are examined to illustrate any confounding practice schedule effects that may be present in the studies.

Studies involving blocked and constant practice

In an experiment using a rapid linear timing apparatus with adults, Newell and Shapiro (1976, experiment one) compared groups that practiced in a blocked variable fashion and a constant fashion at two targets. A transfer test revealed no differences between the variable and constant practice groups. The experimenters then performed an additional experiment and increased the intra-group variability by adding a group that practiced at three targets and two other groups that practiced at two targets in either a random fashion or serial fashion. Once again, there were no differences between the groups in a transfer test to a novel target. The experimenters were surprised at the lack of training effect, but noted that, upon perusal of the raw data, 'very variable performance by a few participants in all groups accounted for this' (Newell & Shapiro, 1976, p. 240).

Husak and Reeve (1979) investigated the effects of differing amounts of practice on constant and blocked practice. They found that constant practice of six, eighteen or thirty-six trials produced no differences between the constant groups when tested on a

novel response. However, the blocked practice groups that had greater amounts of practice (18 and 36 trials) had less error than the blocked group with less practice (6 trials) on transfer. The results also showed that the blocked practice/six trials group performed worst on transfer, with no differences between the other five groups.

Margolis and Christina (1981) contrasted blocked and constant practice and different levels of visual displacement information. All of the participants wore prism glasses and could see the target but could not see their responding limb, nor how close their response came to the target. However, half of the participants (those receiving displacement information) were allowed to lift the glasses three times before acquisition to examine the amount of shift from the target the prism glasses provided. The experimenters found that transfer to a novel target was unaffected by the amount of visual displacement information, but that a main effect for practice type existed. This indicated that variable practice facilitated transfer when compared to constant practice.

Bird and Rikli (1983) contrasted blocked and constant practice for observers who only listened to the knowledge of results of models practicing in either a blocked or random practice schedule, and participants who physically practiced in the two practice schedules. The four groups were tested using a transfer test and, although the only statistically significant differences were the physical practice groups demonstrating less error than both of the modelling groups, the direction of the means indicated that variable practice facilitated transfer to a novel task.

Pease and Rupnow (1983) tested the variability of practice prediction, with blindfolded children aged nine and eleven years of age, by manipulating the over-all force required to move a car on a linear slide apparatus. They contrasted blocked and constant practice and found that constant practice facilitated transfer to a novel target (the constant group performed better on the first trial, with no differences observed on the subsequent nine trials), and that the older participants performed better than the younger on the transfer test.

Wrisberg, Winter and Kuhlman (1987) investigated practicing variations in movement distance and/or movement time during training of one hundred and eighty trials. The participants were required to move their right hand in a ballistic motion and knock down a target. Four constant practice groups practiced at a set movement distance and movement time, while three variable groups (set distance/varying movement time, set movement time/varying distance, and varying movement times/varying distances) practiced in a blocked fashion of five unchanging trials before changing to the next variation for a further five trials. Following the practice trials the participants were tested on a transfer test at which one of the constant groups had practiced. The experimenters found that the constant group that had practiced at the transfer task performed best at transfer, followed by the variable groups and, finally the other three constant groups. The experimenters concluded that there was some support for the variability of practice hypothesis, while noting that the results also supported contextual interference theory.

The inconclusiveness of the studies may be due to there being little difference between blocked and constant practice in the levels of cognitive effort engaged during

practice. The attempt to manipulate cognitive effort in these practice schedules is an effort to further investigate these findings.

Studies Involving Random and Constant Practice

McCracken and Stelmach (1977) used a barrier knockdown task in which participants had to move different distances to a barrier in a set time (200 milliseconds). A constant group performed the three hundred trials at one distance, while the variable group practiced at four different distances in a random practice schedule. On an immediate transfer test to a novel distance the variable practice group outperformed the constant group, however, after two days there was no difference between the two groups on the same transfer test.

In their experiment concerning the development of motor recognition, Zelaznik, Shapiro and Newell (1978, experiment one) gave their participants auditory information of movements on a linear tracking apparatus in either a constant fashion or one of two random conditions. The constant group listened to the sound of the apparatus moving at the transfer criterion speed, while the random groups listened to movements that had either a relatively narrow range of variability about the criterion movement speed or a relatively wide range of variability. In addition, the experimenters manipulated the amount of auditory practice the participants received (six trials or sixty). The participants then had to perform the criterion movement speed, without knowledge of results, for twenty trials. The experimenters only found differences in the low (six trials) practice condition and noted an advantage of the narrow and wide range forms of variable practice over the constant practice for the

first three attempts of the participants to reproduce the criterion movement speed. There was no difference between the groups until the thirteenth trial, where the constant group increased its errors, continuing to do so to the end of the trials. The variable groups maintained their level of performance across the trials.

Carson and Wiegand (1979), using a bean bag tossing task with children, contrasted random variable practice with two constant practice groups. One constant practice group practiced using a bean bag weight that was different to the criterion transfer test weight, and the other practiced using a bean bag weight that was the same as the criterion transfer test weight. It was found that the variable group performed the transfer test as well as the criterion weight constant group and better than the other constant group, and, when tested on a transfer test that was novel to all groups, the variable group performed better than the other groups.

Using a Bassin Anticipation Timer, Wrisberg and Ragsdale (1979) contrasted random practice and constant practice at four different light speeds. When the participants transferred to a novel light speed that was within the range of speeds practiced in acquisition, the random group outperformed the constant group.

Johnson and McCabe (1982) contrasted random practice with a constant practice group that practiced at the criterion transfer target and two constant groups that practiced above and below the criterion target respectively. Each group practiced a total of fifty trials, the random group practicing at six different targets, none of which were the criterion transfer target. The results only showed an advantage for the random group in a difference between the random and the constant group that had

practiced below the criterion target. The constant group that had practiced at the criterion target performed the best at transfer in absolute error. These results could be due to the random group having not enough trials and/or too many targets to acquire to effectively develop cognitive strategies that would enable the participants to transfer well to a novel target.

Catalano and Kleiner (1984) examined the effects of practice in either a constant or random fashion using a Bassin Anticipation Timer. They found that random practice facilitated transfer to a novel task, compared to constant practice, and that, when the transfer task was increasingly outside the range of that practiced in acquisition, performance deteriorated for both practice schedules but less for the random schedule.

Clifton (1985) hypothesised that practicing overarm throwing in different degrees of variable practice would facilitate transfer to a striking task using kindergarten and first-grade children as participants. The participants practiced in a random schedule in one of three conditions. The weight of the ball was unchanged while the target distance was changed, or the distance was held constant while the weight of the ball changed, or the participants practiced combinations of changing weight and distance. The experimenter found that the maximally variable practice (changing weights and distances) was most beneficial for the kindergarten boys on the striking test, while varying the distances was most beneficial for the older first-grade boys. The author speculated that the differences were due to the older boys having stronger schemata and therefore benefited less from variable practice.

In an attempt to investigate the effects of variability of practice and learning in the hierarchical organisation of movement variations, Wulf (1991) contrasted random, blocked, constant and organised (hierarchical) practice in children (mean age of 11.3 years). The participants had to throw miniature rice bags of two different weights (40grams and 80 grams) at three different targets (3, 4, and 6 metres distance from the participant). The random practice group had twenty trials of each of the six variations, presented in a random manner, the organised group practiced the smallest weight and smallest distance first for twenty trials, increasing their weights and distances until they reached the largest weight/largest distance variation. The blocked group practiced in the same manner as the organised group, but switched to the next variation after every four trials and the constant group practiced all trials using the eighty grams, four metre rice weight/distance combination. A control group that received no practice was included for the transfer test and the results showed that the random group performed significantly better in transfer (120 grams/5 metres) than the constant group and that there were no differences between the organised, blocked and constant practice groups.

In a more recent study, Wulf and Schmidt (1997, experiment one) examined the practice effects of constant practice and variable (in this experiment, serial) practice on participants' ability to implicitly learn a pursuit tracking task. Implicit learning refers to learning that occurs in a passive, automatic fashion (Wulf & Schmidt, 1997), with apparently unconscious acquisition of complex procedural knowledge (Lewicki, Czyzewska & Hoffman, 1988). The experiment involved the participants learning a pursuit tracking task that was comprised of three segments. Different variations of segments one and three were randomly chosen by the computer program, while

segment two was the same for each of the three constant subgroups or varied in a serial fashion for the variable group. Wulf and Schmidt found that the variable group outperformed the constant group in acquisition, retention and transfer.

Two major reviews of the empirical base of support for the variability of practice hypothesis have been undertaken since Schmidt proposed his schema in 1975 (Schmidt, 1975). The first was undertaken approximately six years after Schmidt's 1975 paper and attempted to examine how well schema theory predictions had held up to direct experimental testing (Shapiro and Schmidt,1982). Although the authors noted some concerns for schema theory (for instance, in 1977 Zelaznik found that constant practice facilitated retention and transfer compared to variable practice), they concluded that 'the support for the predictions of schema theory is generally quite good' (Shapiro & Schmidt, 1982, p. 143). However, the authors made no distinction between the types of variable practice that were used in the reviewed studies (e.g., random, blocked, serial) but merely that, in general, variable practice outperformed constant practice.

In another effort to review the empirical base of the variability of practice hypothesis (Van Rossum, 1990), seventy-three experiments were evaluated. Van Rossum concluded that about half were not addressing the variability prediction, particularly because no learning was evident during practice, and only limited support favouring the prediction could be obtained from the other experiments.

Van Rossum discounted any experiments in which learning was not evaluated and stated that '[s]tudies aimed at empirically testing the variability of practice hypothesis

must ensure that learning has taken place during the practice period' (Van Rossum, 1990 p. 393). He also questioned the validity of experiments on methodological grounds and discarded any studies that showed a proximity effect (Van Rossum, 1990 p. 402). Out of an original 73 experiments, 38 remained after the learning-during-practice threshold and eight more were discarded for violating the proximity threshold. The 'actual' findings demonstrated clear supportive evidence for the variability of practice hypothesis in six experiments and limited support in nine experiments. Six experiments were clearly not supportive of the variability of practice hypothesis. Van Rossum concluded that the empirical base of the variability prediction is not as solid as has been claimed.

Van Rossum's review raised some doubts as to the veracity of Shapiro and Schmidt's (1982) conclusions, however, his method of article selection is open to criticism. The wholesale elimination of articles that did not show learning to occur in acquisition does not take into account the possibility that some variable (the most likely being the amount of variable practice) may have a temporary depressing effect upon performance during acquisition but would not hinder the learning process (Chamberlin & Lee, 1993). Although the participants' performance in acquisition did not improve, this does not necessarily mean that learning did not occur. Schmidt defines learning as 'a set of processes associated with practice or experience leading to relatively permanent changes in the capability for skilled performance' (Schmidt, 1991. p.153), and it would seem that the purpose of the retention and/or transfer tests is to measure these changes to assess if learning has occurred during acquisition.

Those studies that involved random practice versus constant practice typically show that random practice facilitates learning. This has been seen to be evidence supporting the variability of practice theory but could as easily be seen to support contextual interference theory. An important part of the present study is to contrast constant, blocked and random practice while also manipulating the levels of cognitive effort.

It would appear that contextual interference theory could be used as an alternative explanation in those variability of practice studies where differences have been found between variable practice and constant practice. Contextual interference theory suggests that randomly ordering practice where any variability of practice exists facilitates retention of the skill and transfer to a novel task. The following section examines efforts that have been made to manipulate contextual interference and variability of practice in the same study.

Studies Involving Both Contextual Interference and Variability of Practice{ XE "Studies Involving Both Contextual Interference and Variability of Practice" }

In a study by Turnbull and Dickinson (1986) the experimenters attempted to contrast variability of practice and contextual interference by designing an experiment in which participants made horizontal arm positioning movements with their preferred hand, while blindfolded. The experiment was devised to provide maximal practice variability on a linear slide apparatus in an effort to take the variability of practice hypothesis to its logical extreme. Seventy participants were assigned to six groups that ranged from maximally variable to low variable and a control group that received no practice. Participants were asked to move the slide a specified distance and were

given verbal knowledge of results advising them of the error (e.g., "You were 2.8 cm short"). The maximally variable group participants (15 distances x 1 trial) attempted a different movement on every practice trial; two traditionally variable groups performed multiple repetitions of three distances but one practiced serially variable (3 distances x 5 trials) and the other blocked variable (3 distances x 5 trials) to safeguard against order effects and to see if the contextual interference effect could be elicited on a linear slide apparatus. A medium variability, low repetition group (3 distances x 1 trial) was included to assess the interaction between variability and repetition; two constant practice groups performed one distance either five or fifteen times (1 x 5 and 1 x 15); and a control group was included and did not receive any practice prior to testing. After the practice sessions the groups performed five trials of a movement not experienced previously, without knowledge of results and this same distance was tested one week later, when five trials without knowledge of results were performed.

Turnbull and Dickinson reported some support for schema theory's variability of practice hypothesis in that the maximally variable group (15 x 1) outperformed all other groups on transfer and retention. No support for contextual interference theory was found as there was no significant difference between the serial (3 x 5S) and the blocked (3 x 5B) groups. The failure of the low repetition variable group (3 x 1) to perform well was thought to indicate that there may be a minimum number of trials required to develop a given schema to a useful level.

The reason the Turnbull and Dickinson study did not demonstrate a contextual interference effect between the serial (3 x 5S) and the blocked (3 x 5B) groups may be due to the nature of the task participants were required to perform. The participants

had very limited external information with which to base their analyses of movement distance. The starting point was not the same from trial to trial and, being blindfolded, participants had to rely on the proprioceptive and exteroceptive consequences of movement production to update recall and recognition schemata, which were then used for subsequent movements. Since the thrust of the present study is that the contextual interference effect is cognitive in nature, it can be argued that the participants may not have had enough information with which to develop strategies that could have been used in concert with proprioceptive information and knowledge of results to generate movements. Although Turnbull and Dickinson attempted to differentiate between variability of practice and contextual interference effects, the nature of the task may have favoured the development of schemata, but not the development of cognitive strategies necessary to evoke the contextual interference effect.

Another attempt at investigating variability of practice and contextual interference effects in the same study was made by Wulf and Schmidt (1988) using a sequential timing task. The purpose of the study was to assess whether the advantages of variable practice within a class of movements was due to schema formation or enhanced information processing (caused by higher contextual interference) alone. Participants were required to hit four buttons in an unchanging prescribed sequence with respect to goal segment movement times for the three segments (1-2, 2-3, 3-4) that were presented to the participant by means of cards mounted in front of them. Forty-eight participants were assigned to two treatment groups and these were each divided into three subgroups. In the three schema subgroups, the relative timing of the segments (e.g., a ratio of 4:3:2) remained the same but the absolute overall timing differed (e.g.,

300-225-150 ms or 400-300-200 ms), while in the three context subgroups, both the relative timing (e.g., a ratio of 4:3:2 or 2:4:3 or 3:2:4) and overall absolute timing differed.

After the first acquisition phase, consisting of 126 practice trials with knowledge of results provided after each trial, participants performed eighteen retention trials of a previously practiced task version without knowledge of results. The second acquisition phase consisted of twelve blocks of six practice trials after which the participants transferred to one of two transfer tasks with longer absolute goal movement times. One transfer task had the same relative timing pattern that had been experienced by all groups before, while the other had a different timing pattern than had been practiced by any of the groups.

Wulf and Schmidt (1998) hypothesised that if variability of practice leads to schema formation, then the schema group should outperform the context group on the retention tests and the transfer tests that required the same relative timing as experienced in acquisition. According to contextual interference theory, the context group should perform better on the transfer test that required different relative timing. While the results supported the authors' hypotheses, the design of the study is open to question in that the context group did not experience a random presentation of tasks, rather each participant practiced six trials of one task variation, followed by six trials of a second task variation, and so forth. Even though the context group did not practice in a random fashion, it was still able to better transfer to a novel task requiring different relative timing when compared to the schema group.

In a more recent attempt to investigate the relationship between the contextual interference effect and variability of practice, Hall and Magill (1995) sought to extend and replicate Wulf and Schmidt's (1988) study. Hall and Magill noted that the results of Wulf and Schmidt's study provided support for a hypothesis proposed by Magill and Hall (1990) concerning the contextual interference effect. This hypothesis stated that practicing task variations controlled by different generalised motor programs would more readily illicit the contextual interference effect than practicing task variations of the same generalised motor program. Furthermore, they proposed that schema enhancement that results from variability of practice, as defined by schema theory, will occur when the task variations are parameter variations of the same generalised motor program. Hall and Magill proposed that rather than investigating the either-or question addressed by Wulf and Schmidt, it would be more appropriate to consider '[W]hat are the practice or skill variations characteristics that differentially influence the variability of practice and contextual interference effects?' (Hall & Magill, 1995, p.300).

Experiment one of Hall and Magill's study sought to replicate Wulf and Schmidt's (1988) study by assigning participants to one of four groups: same relative timing, blocked practice (same blocked group); different relative timing, blocked practice (different blocked group); same relative timing, random practice (same random group); different relative timing, random practice (different random group). The same relative timing groups corresponded to the Wulf and Schmidt's (1988) study's schema group, who practiced three speed variations that had the same relative timing ratio, while the different relative timing groups corresponded to Wulf and Schmidt's context group, which practiced a fast variation of one relative timing ratio, a medium variation

of another relative timing ratio, and a slow variation from a third relative timing ratio. However, for the random practice schedule conditions (same random and different random), the three task variations were presented randomly throughout the practice trials (in an effort to address the problem of there being no random presentation of practice trials in Wulf and Schmidt's study). Day one consisted of practice (acquisition one -126 trials) and a retention test of eighteen trials in which the participants performed the medium speed trial practiced in acquisition. Day two began with seventy-two more practice trials (acquisition two) followed by two transfer tests, one involving participants performing eighteen trials of a task with the same relative timing as practiced in acquisition but with a (novel) longer overall duration, and another involving different relative timing and longer overall duration from that practiced in acquisition. Three retention tests were performed after a ten minute rest period involving same relative timing, blocked retention; same relative timing, random retention; and different relative timing, random retention, respectively.

Hall and Magill reported that performances were better for tasks that required the same relative timing characteristics than those that required different relative timing characteristics in acquisition and when retention tests involved the same relative timing characteristics as those practices on acquisition. This supports Wulf and Schmidt's (1988) conclusion that learning benefits are caused more by schema enhancement than by contextual factors, when the tasks variations are within the same movement class. The results also support Magill and Hall's (1990) hypothesis that contextual factors influence learning when the task variations belong to a different movement class. A typical contextual interference effect was noted as the two blocked groups performed with less error than the two random groups in acquisition and, in

retention tests involving different relative timing characteristics, the random groups outperformed the blocked groups. The novel transfer tests did not show any significant practice effects, even when different relative timing tasks were involved, as predicted by contextual interference theory. Hall and Magill proposed that the acquisition tasks and the transfer tests may not have been sufficiently distinctive (the criterion times differed by only 100 milliseconds). Experiment two attempted to consider these limitations by replicating the first experiment in acquisition but introducing different transfer tests, and also a control group was added to assess levels of learning in acquisition.

The results of experiment two replicated those of experiment one with an important variation. The new transfer tests demonstrated a contextual interference effect in that the random group outperformed the blocked group when the transfer test involved different relative timing tasks. The control group received no practice but took part in the retention and transfer tests and consistently performed with the most error. Hall and Magill concluded that the contextual interference effect and the practice variability hypothesis of schema theory are specific to different situations. Contextual factors influence the learning of skill variations only when the task variations are controlled by different generalised motor programs. Practice schedule context has little, if any, influence when the task variations are parameter modifications of the same generalised motor program.

Hall and Magill's study analysed data in a fashion similar to the way in which the data of the Wulf and Schmidt (1988) experiment had been analysed. Both used absolute error (AE), and dependent measures of errors in relative timing a measure that

indicates how well a participant learns the timing ratio (e.g., 3:2:4 perhaps equalling a movement time of 375-250-500 ms). In Wulf and Schmidt's study average absolute error in relative timing was used and in Hall and Magill's study proportional error (PE) was used to measure learning of the timing ratio. As discussed earlier, the use of absolute error without reporting variable error and constant error can lead to misleading conclusions. Dissociating parameter learning (by measuring constant error) from generalised motor program learning (by measuring variable error) (e.g., Seyika et al., 1994; Wulf & Lee, 1993) may have shown a contextual interference effect even though the task variations were controlled by the same generalised motor program

It can be seen that although these three experiments attempt to investigate some of the debate surrounding the variability of practice theory and the contextual interference theory, problems with experimental design have led to inconclusive results. It would appear that it is important to include the three practice schedules (random, blocked and constant) in an experiment to discover what differences occur in participants learning under each of the schedules. It

Conclusions{ XE "Conclusions" }

The contextual interference effect is a typically robust effect that can be elicited (in adults) using a number of laboratory apparatus and real-life situations and is generally seen in both retention and transfer tests of learning. The effect can be found to influence generalised motor program learning and parameter learning when these factors are investigated by dissociating the appropriate dependent measures. It appears

to be a cognitive effect, related to the degree of effortful processing required in practice.

The variability of practice prediction has received strong empirical support in studies that have contrasted random and constant practice, but equivocal support in studies that have contrasted blocked and constant practice. It would appear that the variability of practice empirical base is built upon studies that could confound practice order effects.

Those studies that have attempted to manipulate both the contextual interference effect and variability of practice have had methodological problems that have not allowed a true comparison. Variability of practice studies have contrasted constant and variable practice and neither Wulf and Schmidt (1988) nor Hall and Magill (1995) included constant practice in their studies and it would appear to be important to be able to compare practice schedules that are at different points along the variability of practice continuum. These studies have not attempted to manipulate the cognitive aspects of practice, but have been more concerned with manipulating an aspect concerned with the schema, namely relative timing. An alternative approach may be to hold the schema aspect constant, but manipulate the cognitive aspect, the level of contextual interference.

Conceptualising the Problem{ XE "Conceptualising the Problem" }

That the contextual interference effect appears to be cognitive in nature raises the possibility that manipulating the cognitive effort required to practice in constant, blocked and random practice schedules could help to identify the processes that facilitate transfer. Specifically, if two comparisons of constant, blocked and random practice are made of the same movements, and in one of the comparisons the participants have the ability to develop a cognitive strategy, while in the other the participants practice in a purely motor fashion, then contextual interference theory predicts that the conditions of cognitive strategy and no cognitive strategy should produce different results.

If contextual interference is responsible for enhanced transfer, then random, blocked and constant practice groups that perform a motor task while employing a cognitive strategy (a cognitive mode) should perform better in transfer than practice groups that perform the motor task without a cognitive strategy (a motor mode). If, on the other hand, variability of practice is responsible for enhanced transfer, then using a cognitive strategy should make no difference to the abstracting of relationships between the parameters of the movement, the outcome of the movement, the sensory consequences of the movement, and the initial conditions of the movement, resulting in no differences between the cognitive strategy groups and the corresponding motor groups (cognitive random versus motor random and so on).

It should be noted that the advantages of variable practice over constant practice should be apparent regardless of the ability to develop a cognitive strategy. That is,

the constant groups should perform better than the corresponding blocked groups, who, in turn, should perform better than the corresponding random groups in acquisition. However, in transfer, the random groups should perform better than the constant and blocked groups. Due to the apparent lack of evidence in the literature supporting the variability of practice hypothesis when constant practice is contrasted with blocked practice, there should be no differences between the constant and blocked groups in transfer.

Experimental Hypotheses{ XE "Experimental Hypotheses" }

The following are the established hypotheses relating to the outcome of the study.

Movement Time

Hypothesis 1. In acquisition both variability of practice and contextual interference theory would indicate that, within each mode (motor and cognitive), blocked practice would lead to decreased movement times when compared to random practice.

Hypothesis 2. In acquisition, between each mode, there will be no differences between the random groups and the blocked groups.

Hypothesis 3. In transfer contextual interference theory would indicate that, within each mode (motor and cognitive), the random groups will outperform both the constant and blocked groups. Furthermore, the literature indicates that there will be no difference between the constant and blocked groups.

Hypothesis 4. In transfer, the increased cognitive effort induced in each of the cognitive modes will allow each of the cognitive mode groups to outperform its corresponding motor mode group.

Reaction Time

Hypothesis 5. In acquisition, within each mode, the random groups will have greater reaction times than the blocked groups as they search for the correct target.

Hypothesis 6. In acquisition, between each mode, there will be differences between the groups. This amount of pre-processing time should be greater for the cognitive groups and exhibited as greater reaction times.

Hypothesis 7. In transfer, both variability of practice and contextual interference theory would indicate that, within each mode, the random groups will have smaller reaction times than both the constant and blocked groups. Furthermore, the literature indicates that there will be no differences between the constant and blocked groups.

Hypothesis 8. In transfer, the increased cognitive effort induced in each of the cognitive modes will allow each of the cognitive mode groups to outperform its corresponding motor mode group

Significance of the Study{ XE "Significance of the Study" }

The basis for the empirical research in this study lies in the review of contextual interference and variability of practice literature. Unproductive training practices are still being used when the evidence would seem to state that improvements during practice following blocked practice will not be retained or aid in transfer to a novel

task. For those interested in maximising motor skill acquisition, retention and transfer, clarifying whether or not variability of practice effects are a result of contextual interference is an important issue. If contextual interference effects are cognitive in nature and different from variability of practice, then this has implications for the teaching of motor skills. The complexity and cognitive requirements of the skill will dictate the structure of the practice session. Once it has been determined if variability of practice effects are different to contextual interference effects, the laboratory-based findings can be applied to real-world settings to facilitate the learning and enjoyment of motor skills.

Assumptions{ XE "Assumptions" }

For the purpose of this study, a number of assumptions have been made:

1. it is assumed that the movement is novel enough that the participants have not developed a strong schema that would diminish a recognisable amount of learning to be inferred,

2. the participants are attempting to improve their movement and reaction times, as exhorted by the experimenter.

CHAPTER 3{ XE "CHAPTER 3" }

METHOD OF THE STUDY{ XE "METHOD OF THE STUDY" }

This chapter explains the procedures used to conduct the experiment and will address the issues of (a) sampling procedure, (b) instrumentation, (c) data collection, (d) statistical analysis, and (e) delimitations.

Sampling Procedure{ XE "Sampling Procedure" }

Participants

In this study 100 right-handed males and females (ages ranging from 17 - 40 years, average age was 20.97 years) were a sample of convenience from a group (N=300) of university students. Participants were randomly assigned to one of ten groups (n=10). This was achieved by writing the one hundred different code numbers onto individual cards, producing two piles, one each for male and female participants. The two piles were shuffled twenty times, turned face-down and, when a participant entered the testing venue, the top card of the appropriate pile was selected depending on the participant's gender. Cards of participants who had undergone the procedure were discarded.

Sample Selection

The following factors were considered when selecting the sample for the study:

- right-handed participants only were chosen as, due to the measuring method of the study, left-handed participants would be performing a different movement from right-handed participants and so were subsequently excluded from the study;

- to guard against any gender effects, each group had an equal number of male and female participants;

- university students only were chosen as the university provided large, easily accessible samples of convenience.

The Australian Catholic University Research Office approved the study prior to the data collection stage.

Sample Adequacy

The selective nature of this sample limited the extrapolation of its results to a more general population. However, this selective nature is mirrored in many studies in this area of interest and it was felt that results using this sample could be compared easily to these other studies. Indeed, due to the large number of earlier, related, studies, a sample taken from outside of the university may have introduced the extra factor of sampling a specific and special population.

Instrumentation{ XE "Instrumentation" }

Software Development

The principal stages of the software development involved (a) variable selection, (b) software design, (c) piloting the software, and (d) software review.

Variable Selection

The review of literature identified those variables with the potential to influence schema formation (variability of practice) and the contextual interference effect. The aim, therefore, of this stage of the research design was to create a method of measuring those variables. The variables of random, blocked and constant practice and those of practicing with or without a cognitive strategy (motor and cognitive) had been investigated separately , but the aim was to develop a method of measuring the combined effects.

Software Design

The design of the software stage was done with the close aid of the software programmer and an early version of the experiment was discarded as taking too long to complete and substantially increasing the time before data collection could commence. A simplified version was designed that utilised dependent measures commonly used in motor control experiments (reaction time and movement time) that would identify if learning had occurred during the experiment.

<u>Piloting the Software</u>

Following the delivery of the software, the experiment was run through in all its stages by the experimenter. Minor problems were immediately noticed, relating to the program not opening easily to the transfer stage at the end of the acquisition phase, and the software was returned to the programmer and revised.

Following the return of the software, ten third-year students and tutors were asked to pilot the study at the end of the school year, in the knowledge that they would not be available the next year for data collection. Each was placed in one of the ten groups and the experiment was run with emphasis being placed on noting the effect of instructions to participants, the correct running of the program, the correct functioning of the graphics tablet and graphics pen, and that data collected was of a form that could be analysed readily. Each participant's data was placed by the program into a separate Notepad file on the computer's desktop with the four-digit I.D. code assigned to the participant at the beginning of the experiment. The data files were then imported separately to an Excel spreadsheet for further manipulation before being imported into a Statistical Package for the Social Sciences (SPSS) sheet.

<u>Software Review</u>

As there were no problems with the experiment software, nor with the stages the data followed before data analysis could begin, it was felt that there were no reasons why data collection could not begin. Following the review, pilot data was deleted from the records.

Data Collection{ XE "Data Collection" }

The stages of this section will include (a) the research timetable, (b) the setting, (c) experimental design, (d) apparatus (e) administrative procedures, and (f) the task.

Research Timetable

Testing took place over a two year period from May 1998 to May 2000. The extended period of testing was due to circumstances beyond the control of the experimenter.

Setting

The venue for acquisition and transfer testing was a tutorial laboratory of the Australian Catholic University. The rooms were booked for the time needed for acquisition and transfer testing and only the participants were allowed in the rooms to reduce distraction from the task.

Experimental Design

A factorial model of 2 (mode: cognitive and motor) x 5 (practice schedule: random, blocked, constant distance 1, constant distance 2, and constant distance 3) produced ten groups. The ten groups practiced acquisition of the task in 3 blocks of 30 trials with a two minute rest period between each block of trials.
Following a five minute rest period, the ten groups performed a transfer test of a novel distance.

Apparatus

The equipment used in this experiment was the custom-made software, a graphics tablet (Wacom ArtZII 12x18 graphics tablet, Wacom Co Ltd), a personal computer (Hewlett-Packard Vectra 5/75, Series 3), and a table and computer chair.

The graphics tablet and computer screen were placed on the table and the computer placed on the floor. The participants were seated in a standard computer chair that was easily adjusted for height.

Administrative Procedures

Participants were actively recruited through numerous requests for participants at lectures and through notices placed about the university grounds advertising the study, with the incentive of field placement credit. Participants who reported to the venue were asked to read a "Letter to Participants" form (see Appendix A) and, after being asked by the experimenter if they had any questions regarding the study, they were asked to fill in two copies of the "Informed Consent" form (see Appendix B), which the experimenter also signed. The ten groups had been assigned identification codes (see Appendix C) and participants were then randomly assigned to one of the ten groups. Participants were asked to sit directly in front of the graphics tablet and to adjust the chair so they were sitting comfortably, with the table edge at navel height. They were asked to hold the graphics pen as they would a normal pen in their right hand and move it over the graphics tablet, observing the movement of the arrow on the computer screen.

The graphics tablet used its own software to display an arrow that corresponded to the graphics pen's position on the tablet and any movement of the graphics pen was shown as movement of the arrow on the computer screen. The graphics pen displayed movement on the computer screen if it was contacting the graphics tablet or lifted until four centimetres from the surface. After lifting of the graphics pen above this height the computer screen did not display any movement of the graphics pen until the pen was brought back to within four centimetres of the surface and the graphics pen arrow on the computer screen would then jump to its new position. The tablet was configured to the computer screen so that, although the graphics tablet was physically larger than the computer screen, any point on the graphics tablet was scaled to that of the computer screen.

The number of trials per block was adjusted at the beginning of the testing session by a setup button displayed on the computer screen (see Figure 3.01), and was set at thirty trials for the constant target and ten for the variable target ('constant' referring to the constant distances one, two and three under motor and cognitive conditions; 'variable' referring to the blocked and random groups under motor and cognitive conditions).
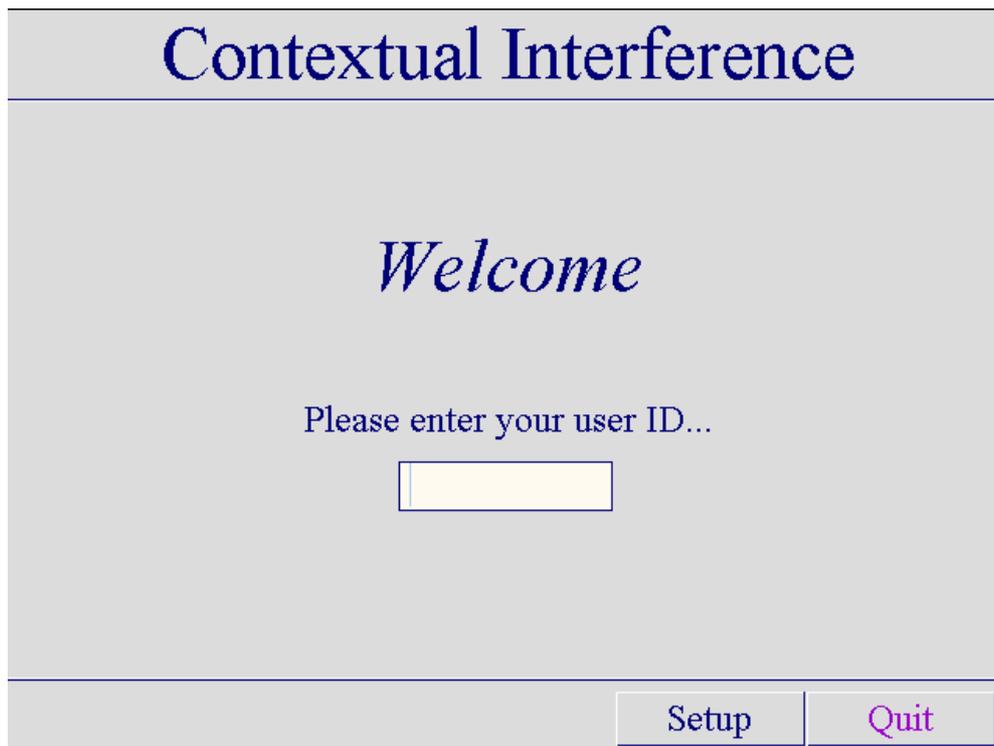
Figure 3.01. Number of trials set-up screen.

Each participant was allowed thirty seconds of 'play' with the graphics pen, after which the participants were required to type in their four-digit identification number (see Figure 3.02), proceed to the next screen, tap on the graphics tablet with the graphics pen to answer questions of age and gender (see Figure 3.03) and then to tap on "O.K.".

Figure 3.02. Participant identification screen.
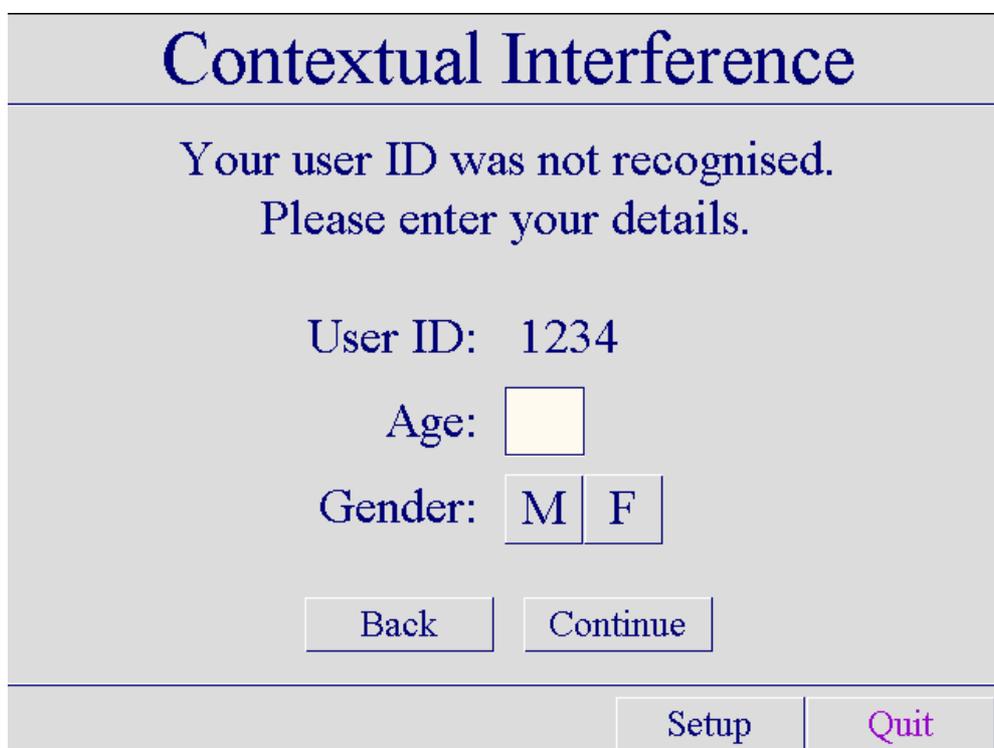
Figure 3.03. Participant age and gender details screen.

At this stage the experimenter would state; "at the next screen a start box and three target boxes will appear, (the experimenter would point to the approximate positions of the start box and three target boxes on the computer screen) corresponding to the start box on the graphics tablet, (the experimenter would tap on the start box on the graphics tablet with the graphics pen) and to three target boxes on the graphics tablet (the experimenter would tap on the approximate positions of the three target boxes on the graphics tablet with the graphics pen). Your task is to wait until one of the three target boxes changes and then to lift from the start box and tap on that target box as quickly as possible (the experimenter then moved the graphics pen from the start box and tapped on the graphics tablet at the approximate positions of the three target boxes in sequence from nearest to the start box, to that furthest away from the start box)." The experimenter would then state, "you will now commence with the first trial".

At this point the experimenter selected which of the experimental conditions the participant was allocated (see Figure 3.04).

Figure 3.04. Experimental conditions screen.

The experimenter would watch the first trials and prompt if the participant did not appear to know which target box to tap. As soon as the participant seemed sure of the procedure, the experimenter would state, " Remember, your task is to tap on the target box as quickly as possible" and retire until the participant had completed the first block of trials. Following the first block of trials the participant would be informed that they had a rest period, and after an unfilled two minutes had elapsed, the experimenter would initiate another block of trials. At the conclusion of this set the participant had another two minute rest period, followed by the last acquisition block of trials. The participant then spent an unfilled five-minute rest period, before the experimenter initiated the transfer task. At the end of the transfer task, the experimenter informed the participant that the experiment was finished, filled out the "Application for Course Credit" form (see Appendix D), and thanked the participant for taking part in the study.

The Task

Acquisition trials commenced after an experimental condition had been selected by the experimenter and the next screen appeared automatically. As the acquisition screen appeared, the experimenter stated, "your target box will always be the one that is filled in blue", for those participants practicing in the motor mode, or "your target box will always be the triangle", for those practicing in the cognitive mode. The target box (a box coloured in blue for the motor-only conditions, and a box with a blue triangle with an inner border of green for the cognitive conditions) would flash for five seconds displaying the acquisition conditions for the group the participant had been assigned. For instance, in the case of the motor constant distance one group, the first target box would flash rapidly for five seconds (see Figure 3.05) to signify it was the target box for the next set of trials.
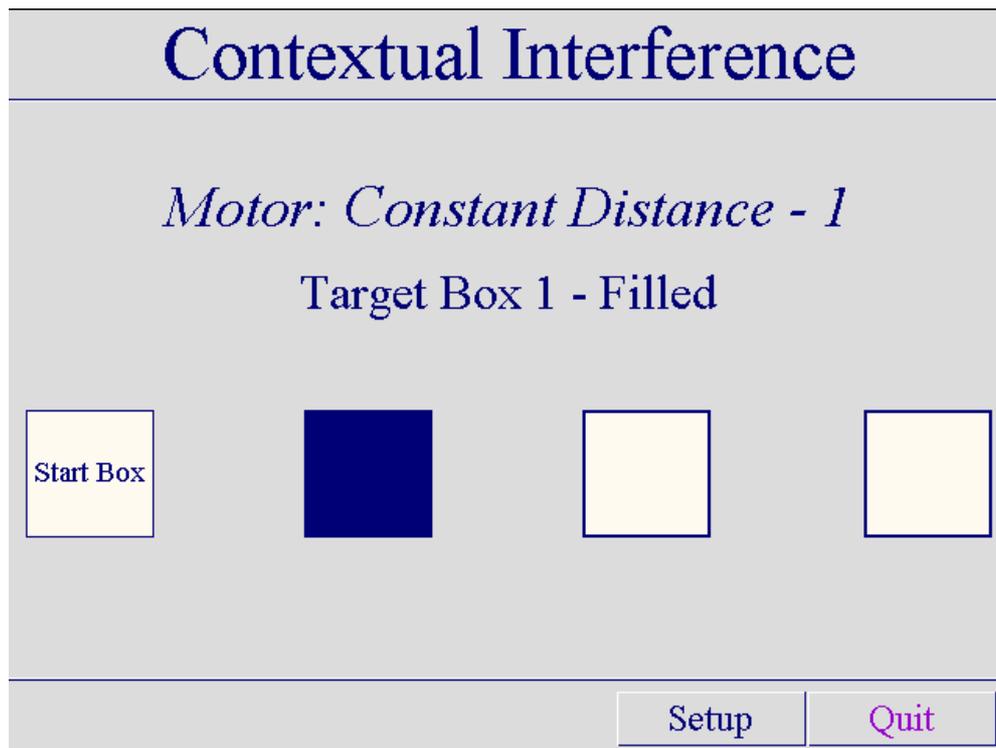
Figure 3.05. Screen showing target box 1 flashing for motor mode.

In the case of the cognitive constant distance one group, the first target box would flash (see Figure 3.06), showing a blue triangle with an inner border of green, the second target showed a blue circle, and the third target box, a blue 'x'.
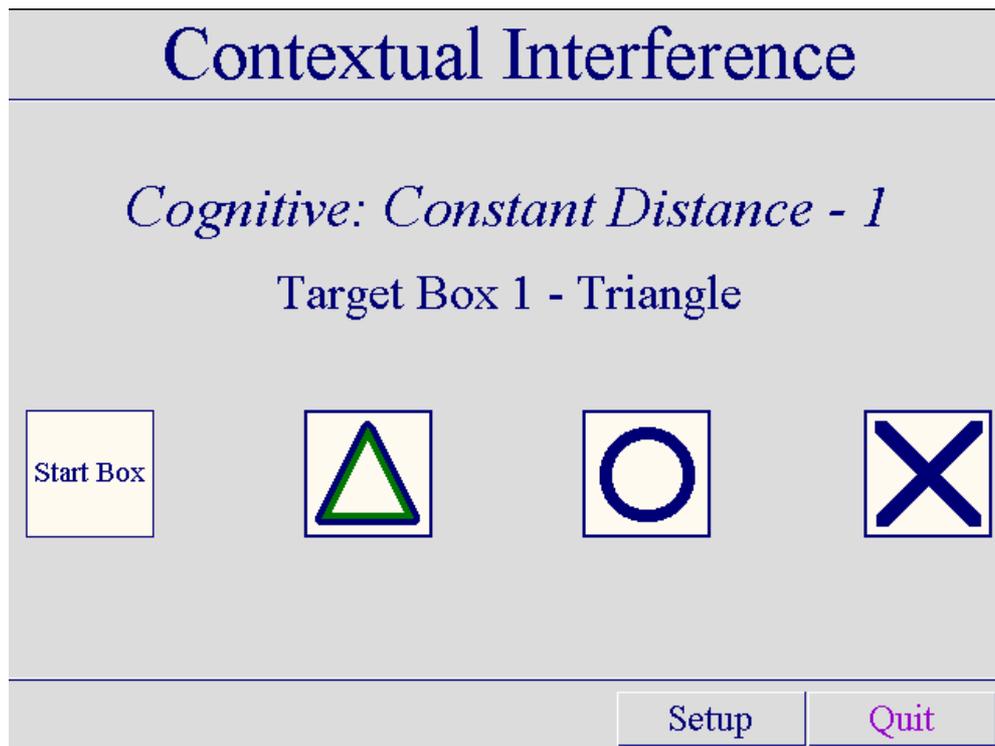
Figure 3.06. Screen showing target box 1 flashing for cognitive mode.

The program required the participants to hold the graphics pen in the start box marked on the graphics tablet and this corresponded to a start box displayed on the left side of the computer screen. When the graphics pen contacted the surface of the graphics tablet in the start box, the start box displayed the word "wait" until the target boxes changed.

For the five groups practicing under the motor mode, the target box would change from an outline of a square box to a filled-in blue box while the other two target boxes remained unchanged outlines of boxes. For the five groups practicing under the cognitive mode, the target box would change from an outline of a square box to a box with a blue triangle with an inner border of green, and the two other boxes would change to a box with a blue circle inside it, and a box with a blue 'x' in it, respectively.

Once the target boxes had changed the participant moved the graphics pen as quickly as possible to tap on the target box. Once the graphics pen touched the target box a feedback screen would be presented (see Figure 3.07) and this would remain on the screen until the participant tapped the graphics pen on "Continue" and another trial screen would appear.
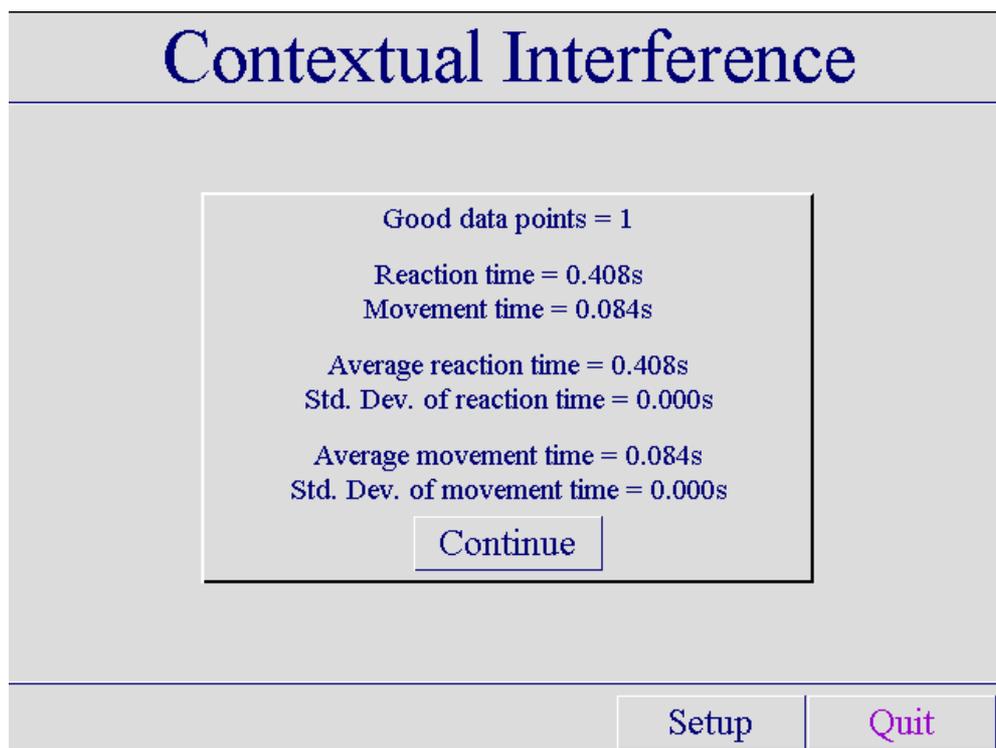
Figure 3.07. Trial feedback screen.

Therefore the participant received feedback immediately following each trial. This would continue until the required number of trials were attained and a screen would appear acknowledging the end of the trial set. At this point the participant tapped "Continue" and a screen appeared requesting user ID in anticipation of the next set of trials and the experimenter re-entered the participants identification number at the end of the rest period.

After the user ID was re-entered the screen displayed a message inquiring which trials to perform next. Pressing on "Yes" repeated the last trial, "No" returned the participant to the list of motor and cognitive trials available, and pressing on transfer brought about the transfer section of the experiment.

Acquisition

All participants performed acquisition in three blocks of thirty trials. The six constant distance groups (motor mode: constant distances one, two and three; cognitive mode: constant distances one, two and three) had the same target for every trial, dependant upon the constant distance group they belonged to. For instance, motor constant distance one would experience motor cues and always have the first target box as a target, while cognitive constant distance two would experience cognitive cues and always have the second target box as a target.

The two blocked groups practiced acquisition either experiencing motor cues or cognitive cues. In order to guard against practice order effects, a latin-square design was utilised for the blocked groups in acquisition. Whatever the order the participant performed their three sets of ten trials, each block of thirty trials consisted of tapping on target box one a total of ten times, target box two a total of ten times, and target box three a total of ten times.

The two random groups also practiced acquisition either experiencing motor cues or cognitive cues. Their three blocks of thirty trials involved tapping on whichever target box was presented. The target boxes were selected randomly by the computer and

within the thirty trials in one block each of the target boxes had been selected ten
times.

Therefore, the blocked and random groups practiced moving the graphics pen as
quickly as possible to each target box the same number of times (thirty in a total of
ninety trials), while the six constant distance groups practiced at the same target
ninety times in total.

Transfer

The transfer screen displayed the start box and four other boxes and the participant
performed transfer in the same mode (motor or cognitive) as they had for acquisition.
The transfer screen was an acquisition screen with a new target box placed between
the second and third acquisition targets. The required target box for the motor mode
appeared as a solid blue box (see Figure 3.08) while the required target for the
cognitive mode appeared as a box enclosing a blue triangle with an inner border of
green (see Figure 3.09). For motor transfer and for cognitive transfer the target box
flashed for five seconds before the first trial.
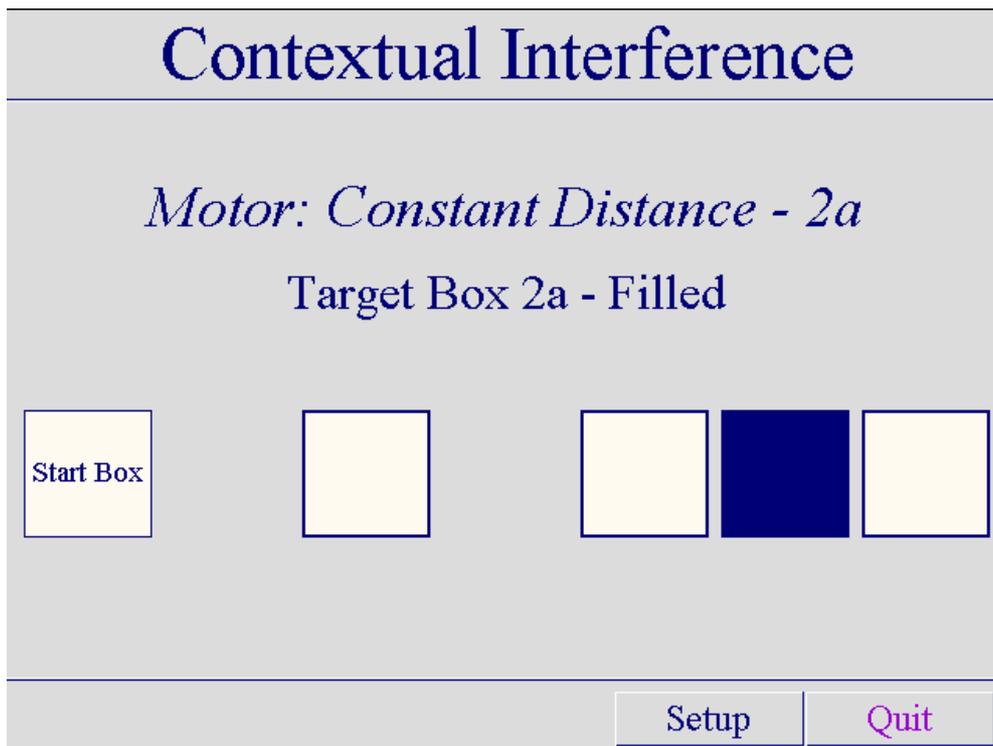
Figure 3.08. Transfer target screen for motor mode.
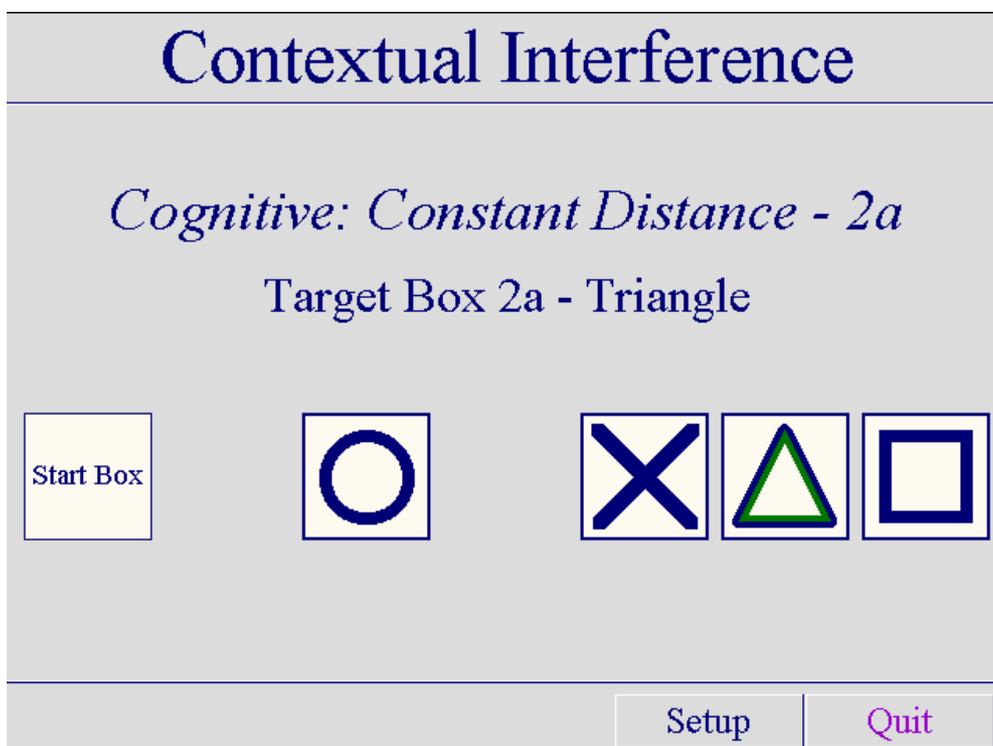
Figure 3.09. Transfer target screen for cognitive mode.

Transfer involved the participants to move from the start box to tap on a target box that was a different distance from any of those in acquisition. The transfer target box did not change during trials and transfer was tested with one block of ten trials with no rest.

Data Analysis{ XE "Data Analysis" }

Dependent measures

The computer program measured;

- Reaction time. This is the time taken from presentation of the target box changing to release of the graphics pen from the start box. Reaction time was measured as an indication of pre-processing time and it was expected that the reaction times of the cognitive groups would be greater than that of the motor groups as the tasks performed by the cognitive groups represent choice-reaction, while those of the motor groups represent simple-reaction.

- Movement time. The time taken from release of the graphics pen from the starting box to contact of the graphics pen on the target box.

Statistical Analysis

Separate statistical analyses were conducted to assess acquisition and transfer performance. For the acquisition data, split plot analyses of variance (SPANOVA) were performed for both dependent measures (movement time and reaction time). The constant distance groups were not included in the acquisition analysis due to the

groups practicing at different target distances (Del Rey et al, 1982). This resulted in each dependent measure being submitted to a 2 (Practice Mode; Motor and Cognitive) x 2 (Practice Schedule; Blocked and Random) x 3 (Block; Block One, Block Two and Block Three) analysis of variance with repeated measures on the last factor.

For the transfer tests all groups were included in the analysis as the transfer target was the same for all participants. Therefore, each variable was submitted to a 2 (Practice Mode; Motor and Cognitive) x 5 (Practice Schedule; Blocked, Constant Distance One, Constant Distance Two, Constant Distance 3 and Random) x 10 (trials) SPANOVA with repeated measures on the last factor.

Assumptions

Assumptions in SPANOVA are:

1. The scores are independent of each other.
2. Parametric data is used.
3. The population from which the samples are drawn is normally distributed.
4. Homogeneity of intercorrelations exists.
5. Homogeneity of variance exists in the groups.
6. Sphericity exists.

The first two assumptions were a matter of experimental design. The assumption of normality was assessed by the Kolmogorov-Smirnov statistic with a Lilliefors significance level and by examining the skewness and kurtosis for each group. Homogeneity of intercorrelations was tested using Box's test of equality of covariance

matrices with the alpha level set at .001. Levene's test of homogeneity of variance was used to test assumption five and Mauchly's test of sphericity was used to test assumption six. The alpha level for the two latter tests was set at .05.

Post hoc investigations were performed using simple main effects analyses (Keppel, 1973, p. 222), and where multiple comparisons were made of pairwise comparisons, the Bonferroni method (Winer, Brown & Michels, 1991, p.158) of adjusting the alpha level was used to guard against an inflation of the likelihood of a type one error.

Delimitations{ XE "Delimitations" }

The following delimitations were applied to this study:

- One university was sampled.

- Human movement males and females were sampled.

- Right handed participants were sampled.

- There were one hundred participants.

CHAPTER 4{ XE "CHAPTER 4" }

RESULTS{ XE "RESULTS" }

Separate analyses of variance were carried out for the two dependent variables, movement time (MT) and reaction time (RT). When testing the assumptions for SPANOVA with regard to the reaction time data, it was found that the assumptions of homogeneity of intercorrelations and homogeneity of variance had been violated and a natural logarithmic transformation of the data was performed (Winer, Brown & Michels, 1991, p.357). The resulting analysis of the transformed variables returned the same results as the untransformed variables, therefore the original results are reported. The assumption of sphericity was violated, as tested using Mauchly's test of sphericity (Winer, Brown & Michels, 1991, p.259), on three occasions and statistical significance was assessed using the Greenhouse-Geisser degrees-of-freedom adjustment (Greenhouse-Geisser, 1959). Where necessary the adjusted degrees of freedom are reported.

Movement Times in Acquisition{ XE "Movement Times in Acquisition" }

The analysis of variance indicated a main effect for practice schedule, $F(1,36)=10.59$, $p<.05$(ES=.227) and a main effect for block, $F(2,72)=24.50$, $p<.05$ (ES=.405). The main effect for mode was not significant, $p>.05$ and there were no significant interactions.

Main Effects

Schedule Main Effect

The schedule main effect was further analysed by pairwise comparisons at $p<.05$, with adjustments for multiple comparisons made using the Bonferroni method. They revealed that movement times in the random schedule were significantly longer than the blocked schedule. These differences are summarised in Table 4.01.

Table 4.01. Mean Movement Times for the Main Effect of Schedule in Acquisition.

Schedule	M	SD
Random	.585	.163
Blocked	.454	.137

Note. The means are significantly different.

Block Main Effect

The block main effect was also further analysed by pairwise comparisons at $p<.05$, with adjustments for multiple comparisons made using the Bonferroni method. They revealed that movement times in block one were significantly slower than movement times in block two and block three, but that block two movement times were not significantly slower than movement times in block three. These differences are summarised in Table 4.02.

Table 4.02. Mean Movement Times for the Main Effect of Block in Acquisition.

Blocks	M	SD
Block One	.590	.168
Block Two	.503	.156
Block Three	.466	.151

Note. The three means are significantly different, except blocks two and three.

Analysis of the Main Effects at Each Level of the Mode Factor

In order to locate the sources of the effects it was felt to be appropriate to investigate the main effects at the different levels of the factor mode, in the absence of any interactions, therefore, the main effects for schedule and block were further analysed using simple main effects analyses.

Simple Main Effects for Schedule

The analysis revealed simple main effects for schedule in the motor mode only, $F(1,36)=13.69$, $p<.05$ (ES=.275). The significant simple main effects of schedule were further analysed by pairwise comparisons at $p<.05$.

The comparisons revealed that, in the motor mode, the random group performed with significantly greater movement times than the blocked group. The lack of simple main effects in the cognitive mode showed that there was no significant difference between the random and blocked groups. The comparisons for schedule at the motor mode level are summarised in Table 4.03. The comparisons for schedule at the cognitive mode level, in which there were no significant differences, is summarised in Table E1 in Appendix E.

Table 4.03. Mean Motor Mode Movement Times for the Simple Main Effect of Schedule in Acquisition.

Schedule	M	SD
Random	.619	.350
Blocked	.408	.337

Note. The two means are significantly different.

Simple Main Effects for Block

The block main effect was further investigated in each mode at each level of schedule. This was in order to verify that improvement over acquisition had occurred for each group. The analysis revealed simple main effects for each of the three blocks in the motor mode only; $F(1,36)=9.63$, $p<.05$ (ES=.211), $F(1,36)=12.50$, $p<.05$ (ES=.258), $F(1,36)=10.75$, $p<.05$ (ES=.230) for Blocks One, Two and Three respectively.

The significant simple main effects of block were also further analysed by pairwise comparisons at $p<.05$.

The block effect within the motor mode is illustrated in Figure 4.01. The pairwise comparisons revealed that the random group performed with significantly greater movement times than the blocked group in each of the three blocks of trials.
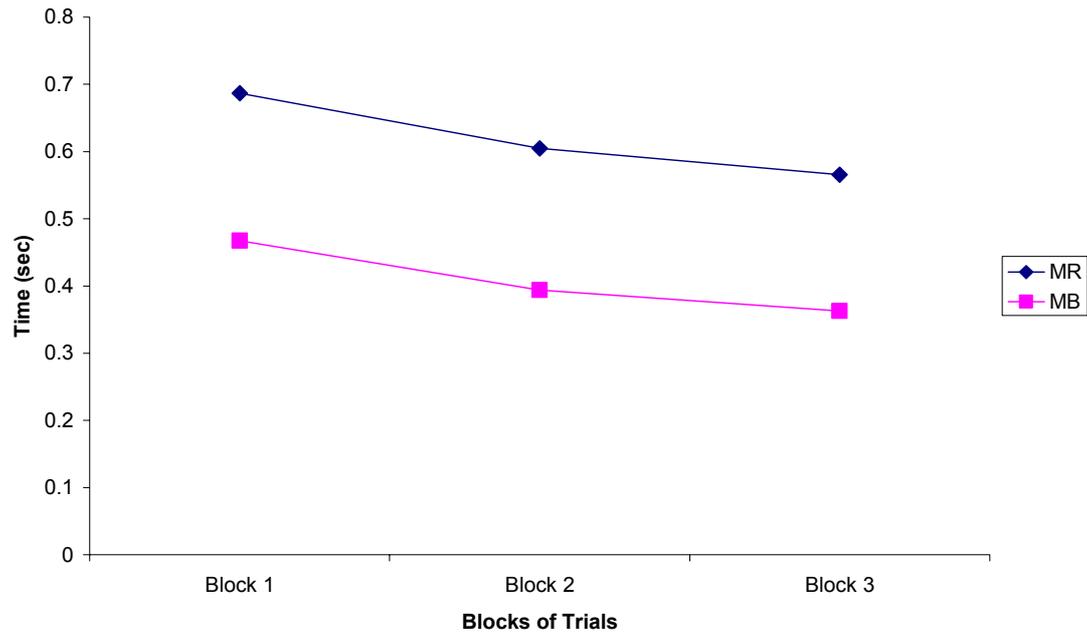
Figure 4.01. Mean Motor Mode Movement Times for Each Block of Trials in

Acquisition.

Note. MR=motor random, MB=motor blocked.

The block effect within the cognitive mode is illustrated in Figure 4.02. The pairwise comparisons revealed that in each block of trials there was no significant difference between the random and blocked groups.
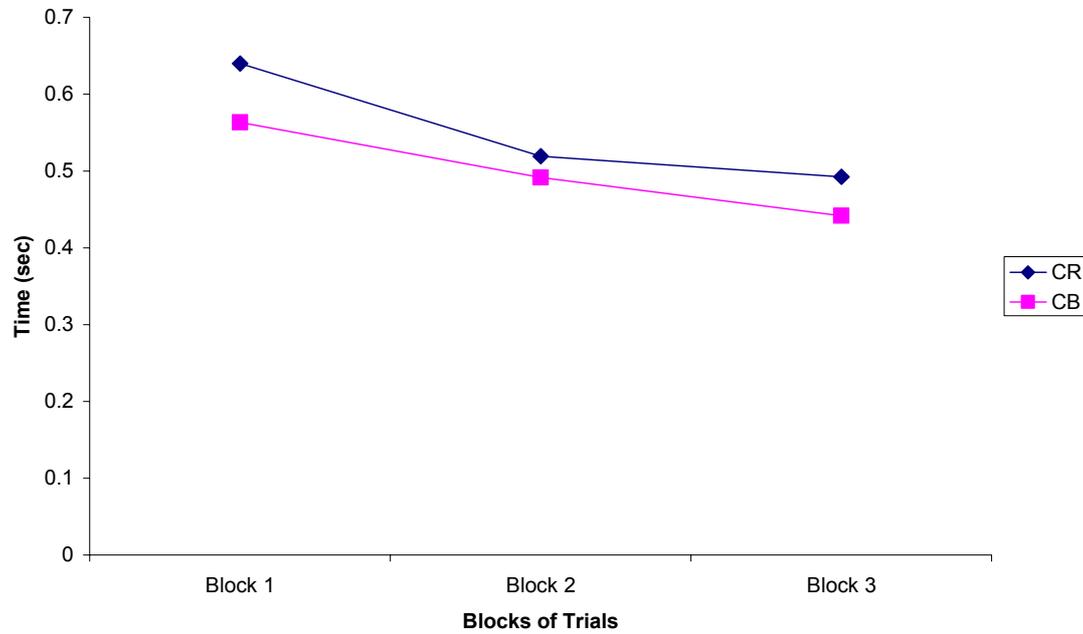
Figure 4.02. Mean Cognitive Mode Movement Times for Each Block of Trials in Acquisition.

Note. CR=cognitive random, CB=cognitive blocked.

Movement Times in Transfer{ XE "Movement Times in Transfer" }

The analysis of variance for movement time showed main effects for schedule, $F(4,90)=3.63$, $p<.05$ (ES=.139) and trials, $F(7.62, 685.82)=12.19$, $p<.05$ (ES=.119) and an interaction between schedule and mode, $F(4,90)=4.27$, $p<.05$ (ES=.159).

Main Effects

Schedule Main Effects

The schedule main effect was further analysed by pairwise comparisons at $p<.05$. They revealed that movement times in the constant distance two schedule were significantly less than the blocked and constant distance one schedules. These differences are summarised in Table 4.04.

Table 4.04. Mean Movement Times for the Main Effect of Schedule in Transfer.

Schedule	M	SD
Random	.430	.206
Blocked	.489[a]	.218
Constant Distance One	.500[a]	.257
Constant Distance Two	.373	.239
Constant Distance Three	.412	.244

[a] Denotes schedules that are significantly different from the constant distance two schedule.

Trial Main Effects

The trial main effect was further analysed by pairwise comparisons at $p<.05$. They revealed that, overall, movement times in trial one were significantly greater than all other trials and that trials two to ten showed no significant differences. These differences are summarised in Table 4.05.

Table 4.05. Mean Movement Times for the Main Effect of Trial in Transfer.

Trial	M	SD
1	.618	.234
2	.461[a]	.210
3	.466[a]	.236
4	.398[a]	.238
5	.451[a]	.248
6	.404[a]	.241
7	.403[a]	.222
8	.399[a]	.207
9	.404[a]	.241
10	.405[a]	.221

[a] Denotes trials that are significantly different to trial one.

Analysis of the Schedule by Mode Interaction

The schedule by mode interaction was analysed using simple main effects analyses by examining both the simple main effects of schedule within each level of mode, and the simple main effects of mode within each level of schedule. The first analysis revealed simple main effects for schedule in the motor mode, $F(4,90)=3.13$, $p<.05$ (ES=.122) and the cognitive mode, $F(4,90)=4.76$, $p<.05$ (ES=.175). Further analysis,

by pairwise comparisons at $p<.05$, of the simple main effects for the motor mode revealed that the only significant difference between the groups was that the constant distance two group had faster movement times than the random group. The pairwise analysis of the simple main effects for the cognitive mode revealed that the random group had significantly faster movement times than both the constant distance one group and the blocked group. The comparisons for schedule in the motor and cognitive modes are summarised in Table 4.06 and Table 4.07 respectively.

Table 4.06. Mean Motor Mode Movement Times for each Schedule in Transfer.

Schedule	M	SD
Random	.532	.195
Blocked	.438	.222
Constant Distance One	.494	.250
Constant Distance Two	.354[a]	.232
Constant Distance Three	.409	.238

[a] Denotes group with significant differences from the random schedule.

Table 4.07. Mean Cognitive Mode Movement Times for each Schedule in Transfer.

Schedule	M	SD
Random	.328	.158
Blocked	.540[a]	.203
Constant Distance One	.506[a]	.266
Constant Distance Two	.392	.245
Constant Distance Three	.416	.250

[a] Denotes groups with significant differences from the random schedule.

The second analysis revealed simple main effects for mode in the random schedule only, $F(1,90)=13.30$, $p<.05$ (ES=.129). Further analysis, by pairwise comparisons at $p<.05$ of the simple main effects, indicated that the two random groups differed

significantly. Specifically, the motor random group (M=.532, SD=.195) had slower

movement times in transfer than the cognitive random group (M=.328, SD=.158).

Reaction Times in Acquisition{ XE "Reaction Times in Acquisition" }

The analysis of variance for reaction time showed a main effect for mode, $F(1,36)=12.50$, $p<.05$ (ES=.258) and a main effect for block, $F(1.23, 44.20)=27.43$, $p<.05$ (ES=.432). An interaction between schedule and mode, $F(1,36)=10.25$, $p<.05$ (ES=.222) and an interaction between block and mode, $F(1.23,44.20)=9.03$, $p<.05$ (ES=.200) were also observed.

Main Effects

Mode Main Effects

The mode main effect was further analysed by pairwise comparisons at $p<.05$. They revealed that the motor mode had significantly smaller reaction times than the cognitive mode. These differences are summarised in Table 4.08.

Table 4.08. Mean Reaction Times for the Main Effect of Mode in Acquisition.

Mode	M	SD
Motor	.344	.120
Cognitive	.422	.246

Note. The means are significantly different.

<u>Block Main Effect</u>

The block main effect was also further analysed by pairwise comparisons at $p<.05$. They revealed that in block one there were significantly greater reaction times than in block two and block three. There were no significant differences between blocks two and three. These differences are summarised in Table 4.09.

<u>Table 4.09.</u> Mean Reaction Times for the Main Effect of Block in Acquisition.

Blocks	<u>M</u>	<u>SD</u>
Block One	.432	.283
Block Two	.362[a]	.131
Block Three	.355[a]	.125

[a] Denotes blocks with significant differences from Block 1.

Analysis of the Schedule by Mode Interaction

The schedule by mode interaction was analysed using simple main effects analyses by examining both the simple main effects of schedule within each level of mode, and the simple main effects of mode within each level of schedule. The first analysis revealed simple main effects for schedule in the cognitive mode only, $F(1,36)=10.85$, $p<.05$ (ES=.232), and the significant simple main effects were further analysed by pairwise comparisons at $p<.05$. The pairwise comparisons revealed that the cognitive random group had significantly greater reaction times than the cognitive blocked group. The comparisons for schedule at the cognitive mode level are summarised in Table 4.10. The comparisons for schedule at the motor mode level, in which there were no significant differences, is summarised in Table E2 in Appendix E.

Table 4.10. Mean Cognitive Mode Reaction Times for each Schedule in Acquisition.

Schedule	M	SD
Random	.474	.246
Blocked	.371	.234

Note. The means are significantly different.

The second analysis revealed simple main effects for mode in the random schedule only, $F(1,36)=22.69$, $p<.05$ (ES=.387), indicating that the motor random group (M=.325, SD=.088) had significantly smaller reaction times than the cognitive random group (M=.474, SD=.246).

Analysis of the Block by Mode Interaction

The block by mode interaction was analysed using simple main effects analyses by examining both the simple main effects of block within each level of mode, and the simple main effects of mode within each level of block. The first analysis revealed simple main effects for block in the cognitive mode only, Pillai's Trace, $F(2,35)=18.75$, $p<.05$ (ES=.517) and the simple main effects were further analysed by pairwise comparisons at $p<.05$. They revealed that, for the cognitive mode, there were significantly greater reaction times in block one than in blocks two and three. There were no significant differences between blocks two and three. These differences are summarised in Table 4.11.

Table 4.11. Mean Cognitive Mode Reaction Times for each Block in Acquisition.

Blocks	M	SD
Block One	.500	.357
Block Two	.388[a]	.155
Block Three	.379[a]	.144

[a] Denotes blocks that are significantly different to block one.

The comparisons for block at the motor mode level, in which there were no significant differences, is summarised in Table E3 in Appendix E.

The second analysis revealed simple main effects for mode in each of the three blocks; $F(1,36)=18.28$, $p<.05$ (ES=.337), $F(1,36)=5.23$, $p<.05$ (ES=.127), $F(1,36)=4.69$, $p<.05$ (ES=.115) for Blocks One, Two and Three respectively. The significant simple main effects were further analysed by pairwise comparisons at $p<.05$ and revealed that the motor mode had significantly smaller reaction times than the cognitive mode in each of the three blocks of trials. These differences are summarised in Table 4.12.

Table 4.12. Mean Block Reaction Times for each Mode in Acquisition.

Blocks	Mode	M	SD
Block One	Motor	.365	.154
	Cognitive	.500	.357
Block Two	Motor	.336	.096
	Cognitive	.388	.155
Block Three	Motor	.331	.097
	Cognitive	.379	.144

Note. The means in each block are significantly different.

Further Analysis of the Block Main Effect

The block main effect was further investigated in each mode at each level of schedule. As in the movement time data analysis, this was in order to verify that improvement over acquisition had occurred for each group. The analysis revealed simple main effects for the second and third blocks in the cognitive mode only; $F(1,36)=13.94$, $p<.05$ (ES=.279), $F(1,36)=12.29$, $p<.05$ (ES=.255), respectively. Figure 4.03 illustrates the significant differences between the two cognitive mode schedules.
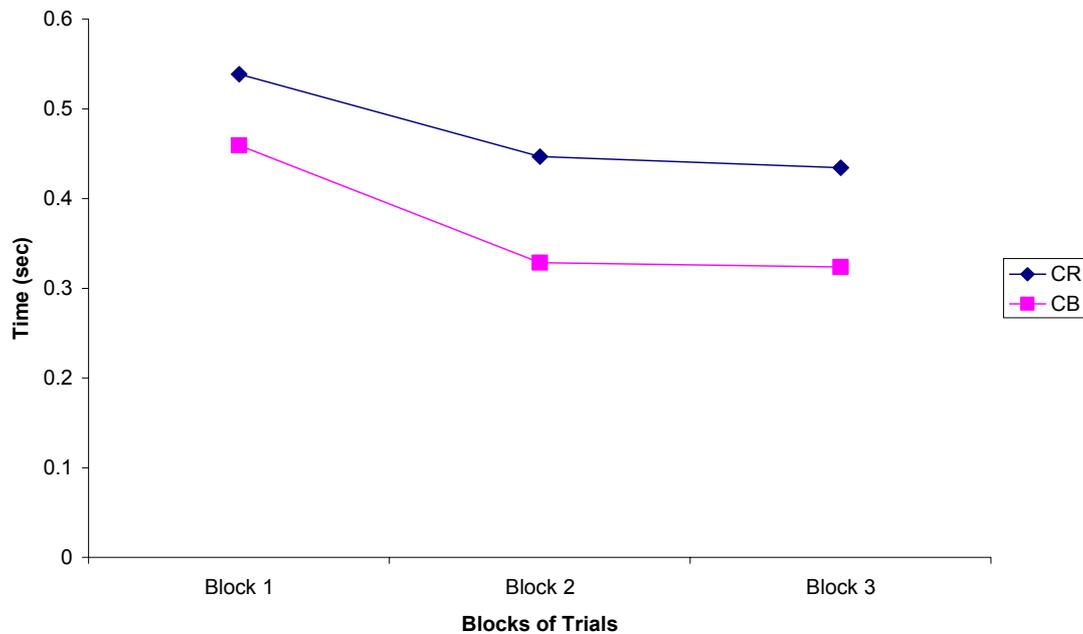
Figure 4.03. Mean Reaction Times for Each Block of Trials for the Cognitive Mode.

The comparisons for **t**he block effect within the motor mode for each level of schedule is illustrated in Figure 4.04. There were no significant differences between practice schedules in any of the blocks.
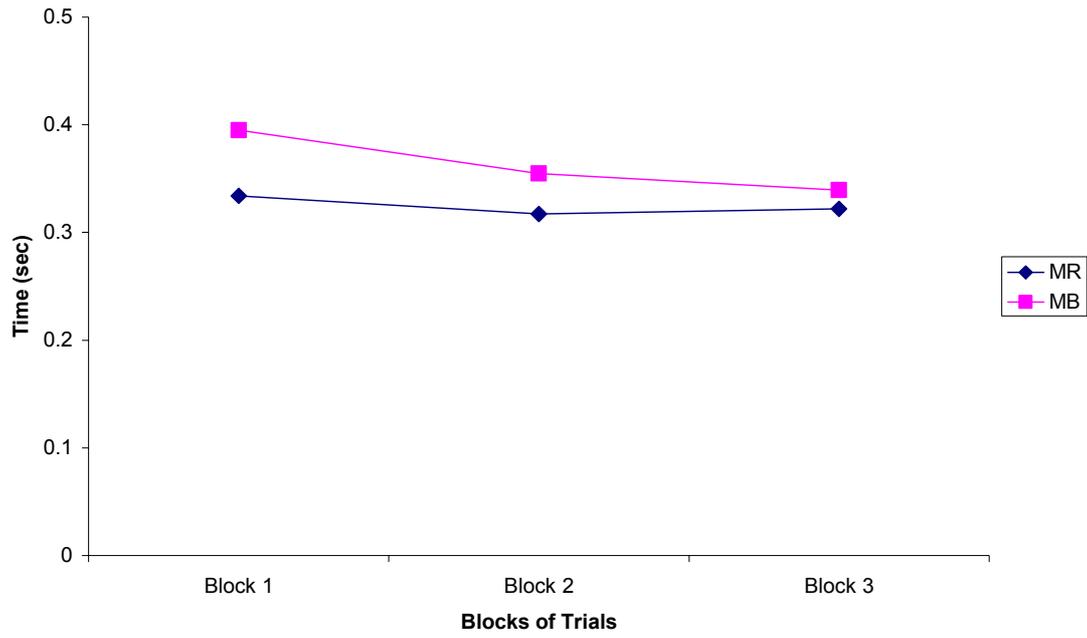
Figure 4.04. Mean Reaction Times for Each Block of Trials for the Motor Mode.

Reaction Times in Transfer{ XE "Reaction Times in Transfer" }

The analysis of variance for reaction time showed main effects for schedule, $F(4,90)=3.73$, $p<.05$ (ES=.142) and trials, $F(7.22, 650.07)=6.82$, $p<.05$ (ES=.07) and an interaction between schedule and mode, $F(4,90)=4.87$, $p<.05$ (ES=.178).

Main Effects

Main Effects for Schedule

The schedule main effect was further analysed by pairwise comparisons at $p<.05$ and revealed that, with the exception of the constant distance one schedule, the blocked schedule had significantly smaller reaction times than the other schedules. These differences are summarised in Table 4.13.

Table 4.13. Mean Reaction Times for the Main Effect of Schedule in Transfer.

Schedule	M	SD
Random	.374[a]	.144
Blocked	.281	.134
Constant Distance One	.340	.127
Constant Distance Two	.381[a]	.154
Constant Distance Three	.375[a]	.152

[a] Denotes schedules that are significantly different from the blocked schedule.

Main Effects for Trial

The trial main effect was further analysed by pairwise comparisons at $p<.05$ and revealed that, overall, mean reaction times in trial one were significantly greater than all but trials two and four. Trial two mean reaction times were greater than trials three, five and ten. There were no other differences between the trials. These differences are summarised in Table 4.14.

Table 4.14. Mean Reaction Times for the Main Effect of Trial in Transfer.

Trial	M	SD
1	.405	.172
2	.392	.159
3	.335[ab]	.135
4	.353	.150
5	.326[ab]	.128
6	.340[a]	.135
7	.336[a]	.134
8	.341[a]	.150
9	.344[a]	.153
10	.328[ab]	.136

[a] Denotes trials that are significantly different to trial one.
[b] Denotes trials that are significantly different to trial two.

Analysis of the Schedule by Mode Interaction

The schedule by mode interaction was analysed using simple main effects analyses by looking at the simple main effects of schedule within each level of mode and by looking at the simple main effects of mode within each level of schedule.

The first analysis revealed simple main effects for schedule in the cognitive mode only, $F(4,90)=7.19$, $p<.05$ (ES=.242). The comparisons for schedule in the cognitive mode are summarised in Table 4.15, and indicate that the blocked group had significantly smaller reaction times than all the groups, and that the random group had significantly larger reaction times than the blocked and constant distance one groups only. The comparisons for schedule in the motor mode, in which there are no significant differences, are summarised in Table E4 in Appendix E.

Table 4.15. Mean Cognitive Mode Reaction Times for each Schedule in Transfer.

Schedule	M	SD
Random	.446[ab]	.147
Blocked	.219[b]	.128
Constant Distance One	.329[a]	.108
Constant Distance Two	.375[a]	.133
Constant Distance Three	.357[a]	.135

[a] Denotes the groups that were significantly different from the blocked group.
[b] Denotes the groups that were significantly different from the constant distance one group.

The second analysis revealed simple main effects for mode in the random and blocked schedules only, $F(1,90)=10.85$, $p<.05$ (ES=.108), and $F(1,90)=7.91$, $p<.05$ (ES=.081) respectively, indicating that the two random groups and the two blocked groups differed significantly. Specifically, the cognitive random group (M=.446, SD=.147) had greater reaction times in transfer than the motor random group (M=.302, SD=.097), while the motor blocked group (M=.342, SD=.110) had greater reaction times in transfer than the cognitive blocked group (M=.219, SD=.128).

CHAPTER 5{ XE "CHAPTER 5" }

DISCUSSION{ XE "DISCUSSION" }

Introduction{ XE "Introduction" }

The purpose of this study was to assess whether the advantages of variable practice, as compared to constant practice, with respect to a transfer test, are best accounted for by the formation of schema or by contextual interference experienced under variable and constant practice conditions. An important need for this experiment was due to the debate surrounding the empirical basis of the variability of practice prediction and the possibility that results assumed to provide support for variability of practice, and therefore schema formation, may be due to the contextual interference effect.

To address this issue, the experiment was designed to differentiate between the contrasts of constant and variable practice under two conditions. The first (motor mode) compared constant and variable practice while practicing in a purely motor condition, while the second (cognitive mode) compared constant and variable practice under a condition in which the participants could develop a cognitive strategy. The expectation was that variable practice would facilitate transfer compared to constant practice in both conditions, as predicted under both variability of practice and contextual interference theories, and the main interest of the experiment lay in any differences exhibited between the corresponding motor mode and cognitive mode groups in acquisition and transfer.

Hypotheses Testing{ XE "Hypotheses Testing" }

Movement Times

The experiment found that, in acquisition in the motor mode, the random group performed with greater movement times than the blocked group. In the cognitive mode, there was no significant difference between the random and blocked groups. This did not support **hypothesis one** in which it was stated that differences between the two groups should be seen in both modes.

Supporting **hypothesis two,** when comparing movement times between the modes, there were no significant differences found between the schedules (motor random and cognitive random, motor blocked and cognitive blocked) indicating that the respective schedules in the different modes had similar patterns of acquisition.

In transfer, **hypothesis three** was partially supported in that, in the cognitive mode, the random group outperformed the other groups (statistically significant differences occurred only between the random group and the blocked and constant distance one groups), while the blocked group and the three constant distance groups were not significantly different. However, in the motor mode, the random group performed the worst of the groups, followed by the constant distance one group, the blocked group, the constant distance three and two groups respectively, and the only significant difference was between the constant distance two group and the random group.

Hypothesis four was also partially confirmed in that the cognitive random group performed significantly better than the motor random group, however, there were no other significant differences between the schedules (the pairwise comparison between the blocked groups did approach significance, $p=.071$, the motor blocked performed better than the cognitive blocked). It appears that the task requirements of blocked and constant practice were such that the participants in these schedules did not benefit from the ability to develop a cognitive strategy. The participants practicing in either a blocked or constant manner knew which target they had to move to and, although the participants in the cognitive mode had to pick out the correct geometrical shape, they could ignore the shape and merely move to the relevant target. On the other hand, the random group did not know which target was next and the cognitive random group's ability to develop a cognitive strategy in acquisition appears to have given that group a significant advantage over the motor random group when required to transfer to a novel target.

Reaction Times

Hypothesis five was partially supported in that there were differences in the reaction times of the random and blocked groups in the cognitive mode. These occurred in blocks two and three only, with the random group having significantly increased reaction times. It was expected that, in both modes, the random group would have greater reaction times.

Between the modes, in relation to **hypothesis six**, the cognitive random group did have greater reaction times than the motor random group. However, these differences

were not exhibited between the cognitive blocked and motor blocked groups. It was expected that the cognitive groups would have greater reaction times as they engaged in pre-motor response decision making that was more extensive than the motor mode. The cognitive task requirements of blocked practice did not appear to significantly differ across the modes in terms of reaction time.

With regard to **hypothesis seven**, there was no support as, in the motor mode there were no significant differences between the groups, and in the cognitive mode, the random group had the greatest reaction times and the blocked group the least.

Between the modes, there were significant differences between the random groups, and between the blocked groups. **Hypothesis eight** stated that the cognitive groups would have smaller reaction times than the motor groups, however only the cognitive blocked group outperformed its corresponding motor group. Indeed, the cognitive random group had greater reaction times than the motor random group and there were no significant differences between the constant groups.

Overall Discussion{ XE "Overall Discussion" }

The review of the literature produced the expectation that random practice would produce depressed performance in acquisition compared to blocked practice, but facilitate transfer to a novel target. With respect to movement times, the results were as expected in transfer in the cognitive mode, however, there were no significant differences in acquisition. In the motor mode the blocked group performed better than the random group in acquisition, but there were no differences between the groups in transfer.

The lack of differences between the random and blocked groups in the cognitive mode in acquisition could be due to the nature of the task. The use of a computer and the task involving a search for the correct target in the cognitive mode, could have led to heightened interest and enhanced motivation with participants (particularly those practicing in a random schedule) treating the task as a game, in the same manner as Shewokis (1997) noted in a study involving computer games. This was not the case in the motor mode as there was no shaped target with the result that the motor blocked group performing better than the motor random in acquisition as expected.

In transfer, there was support for contextual interference theory in the cognitive mode, as the random group's performance was better than the blocked and constant distance groups (see Figure 5.01)**.**

Figure 5.01. Mean Movement Times for Each Block of Trials for Acquisition and

Transfer for the Cognitive Mode.

Note. The constant distance groups are included in the graph in the acquisition phase

to indicate their performance over the three blocks.

In the motor mode, the random group performed the worst in transfer. However, an

inspection of the graph of acquisition and transfer movement times for the motor

mode (see Figure 5.02) indicates that the random group continued to improve its

performance into transfer which was not the case for the blocked group, whose

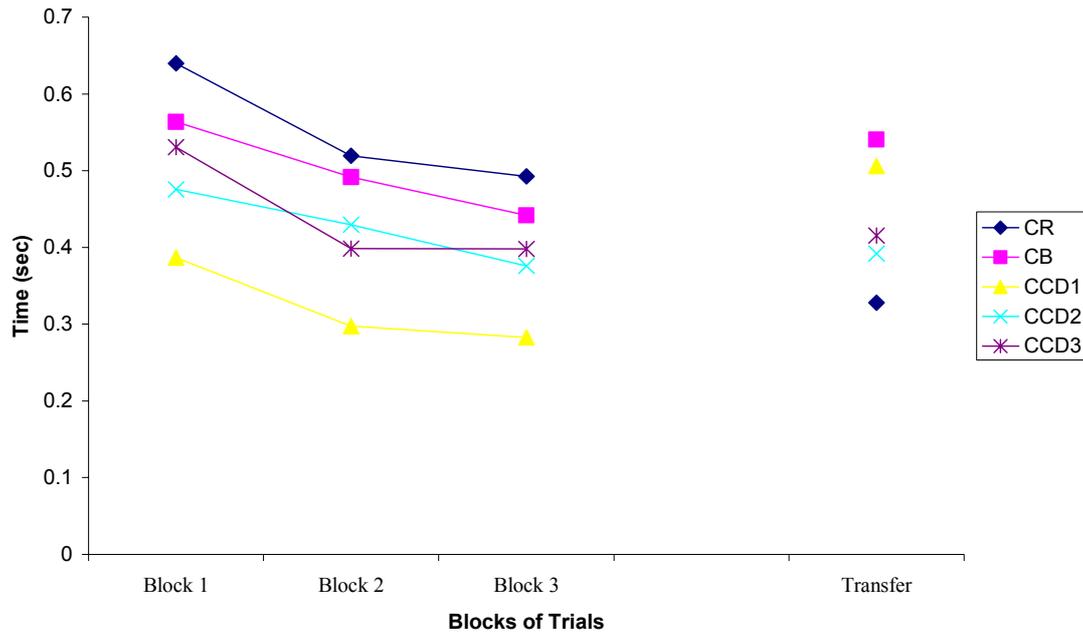movement times in transfer were about the same as the first block of acquisition.
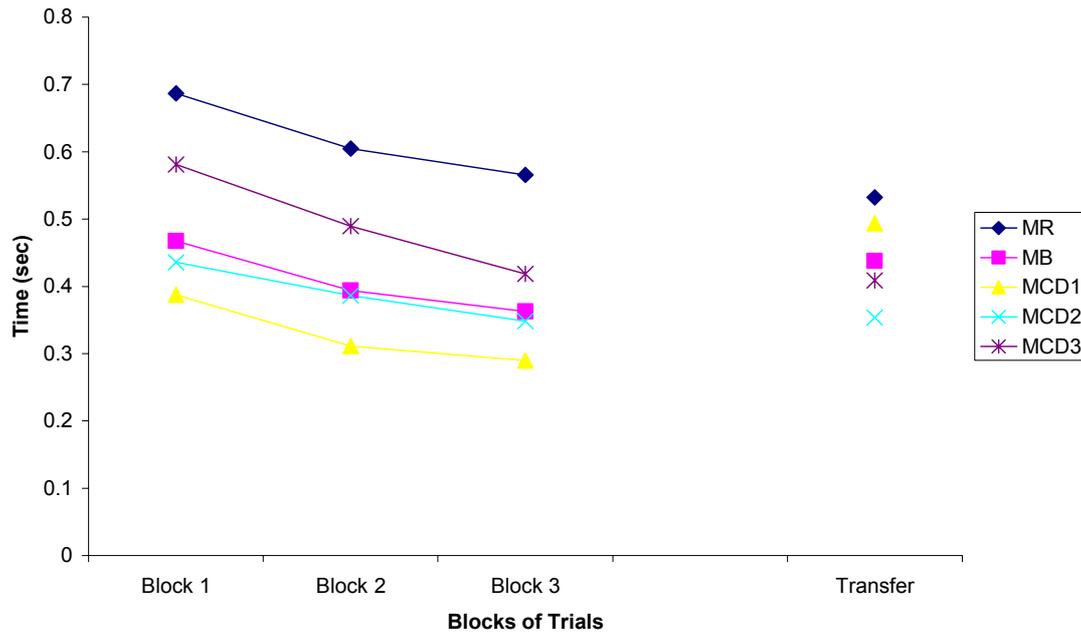
Figure 5.02. Mean Movement Times for Each Block of Trials for Acquisition and Transfer for the Motor Mode.

Note. The constant distance groups are included in the graph in the acquisition phase to indicate their performance over the three blocks.

Although speculative, there is the possibility that if the groups had attained the same level of proficiency at the end of acquisition, the random group would have further improved its movement times (e.g., Gabriele et al., 1987) and possibly managed to surpass the blocked group.

There would appear to be little support for variability of practice predictions in the cognitive mode, as the blocked group did not perform better than constant practice. In the motor mode there is some support for variability of practice as the blocked group performed better than the constant distance one group (the group that practiced at a target in acquisition that was the greatest distance from the transfer target), but

transferred poorly to the novel target when compared to the constant distance groups that practiced at a target in acquisition that was close to the transfer.

An explanation for the differences between modes can be extracted from an examination of the reaction time results. These indicate that there were significant differences across the two modes in reaction times in acquisition and transfer, that is, the cognitive random group had increased reaction times when compared to the motor random group. It would appear that the necessity to differentiate between targets in the cognitive mode led to increased pre-response planning and associated increased reaction times. The experimental design attempted to increase the cognitive effort involved in practice for all the groups in the cognitive mode by compelling the participants to differentiate between the targets and choose the correct geometric shape. However, the very nature of constant and blocked practice enabled the participants to ignore the geometric shapes in their decision-making processes as they already knew which target to move to. This is reflected in the lack of significant differences in reaction times between the modes for the blocked and constant practice schedules.

Each groups' reaction times were largely unchanged from the last block of acquisition trials to transfer, with the notable exception of the cognitive blocked group, which markedly reduced its reaction times (see Figure 5.03 and Figure 5.04). This led to the blocked groups and random groups having significant differences across mode for transfer reaction times, the cognitive random group having higher reaction times than the motor random group, and the motor blocked group having higher reaction times than the cognitive blocked group.

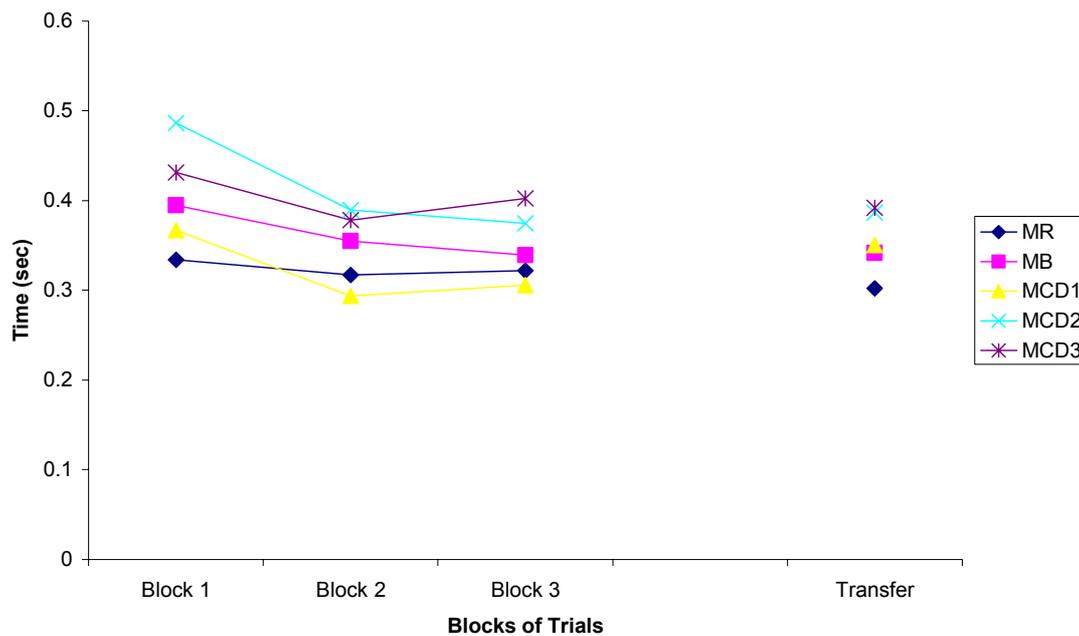Figure 5.03. Mean Reaction Times for Each Block of Trials for Acquisition and Transfer for Motor Mode.
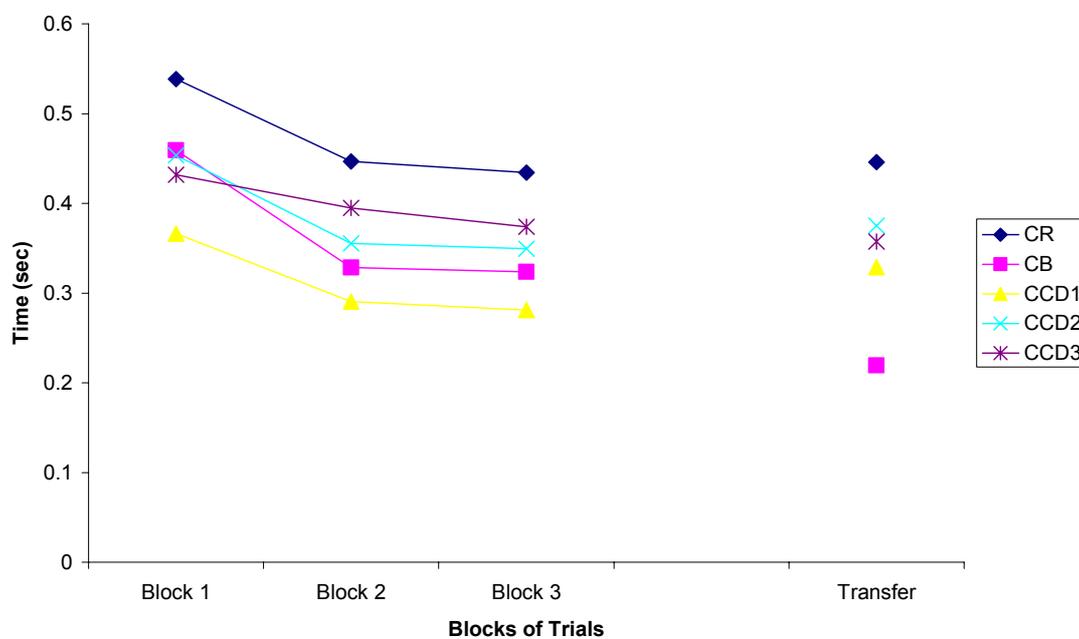

Figure 5.04. Mean Reaction Times for Each Block of Trials for Acquisition and Transfer for Cognitive Mode.

An explanation for the differences in reaction times between the blocked schedules, and in particular, the marked decrease in reaction times for the cognitive blocked group in transfer, is difficult to arrive at. The acquisition reaction time data indicated that there was no significant difference between blocked schedules in acquisition and an examination of the transfer raw data did not reveal any participants with extreme scores.

Figure 5.05 indicates that, after the first block of acquisition trials, the cognitive blocked and motor random groups had similar acquisition and transfer reaction times, and the possibility arises that practicing in a blocked fashion with the ability to develop a cognitive strategy did enable the cognitive blocked group to reduce its reaction times in a manner comparable to the motor random group across acquisition. An examination of the transfer reaction times showed that the cognitive random group dramatically decreased its reaction times over the course of the ten trials (trial one, M=.348, SD=.227; trial 10, M=.175, SD=.065). However, this did not translate to decreased movement times, as the blocked group had the highest movement times of the cognitive mode groups in transfer. Again, it is of interest to note some similarities between the cognitive blocked and motor random groups. Figure 5.06 shows that the groups had differences in movement times in acquisition, but their transfer performances were nearly identical.
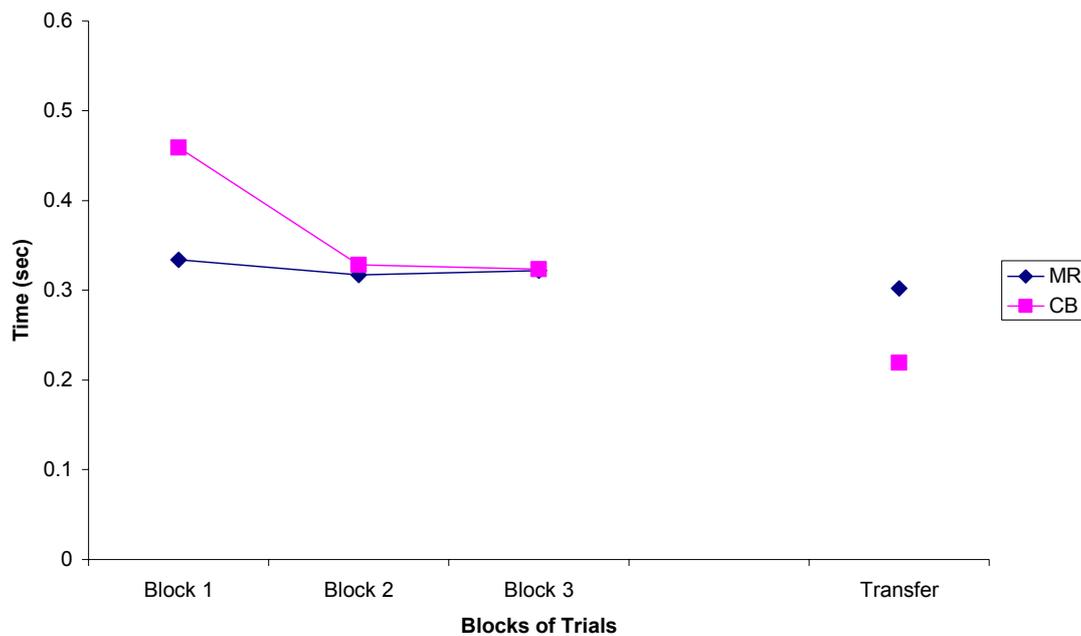
Figure 5.05. Mean Reaction Times for Each Block of Trials for Acquisition and

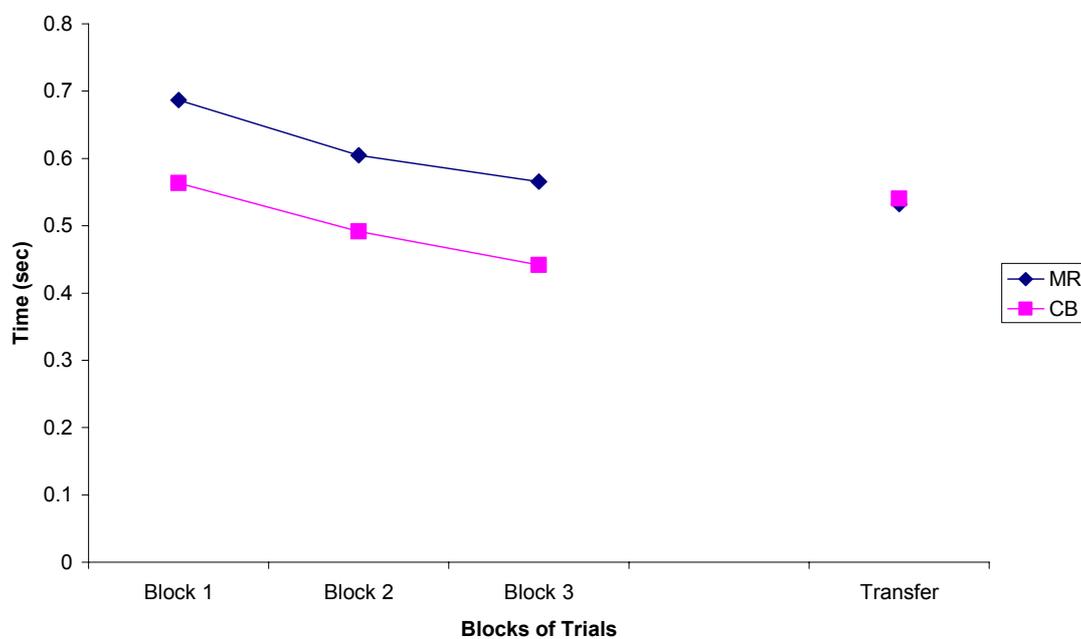Transfer for the Cognitive Blocked and Motor Random Groups.

Figure 5.06. Mean Movement Times for Each Block of Trials for Acquisition and

Transfer for the Cognitive Blocked and Motor Random Groups.

It would appear that the cognitive blocked participants decreased their reaction times but then had to increase their movement times in order to hit the target. This is consistent with Immink and Wright's (1998, experiment 3) study, in which the experimenters found that reducing the amount of self-selected study time before a movement from totally self-selected to either one or two seconds of study time, initially increased reaction times, but, more importantly, forced the participants to continue planning the response into the movement time for both blocked and random practice, resulting in increased movement times. Although speculating on results of no differences should be viewed with caution, it would seem that any extra cognitive effort was of assistance to the cognitive blocked group in pre-planning its responses and the added advantage of being tested in a blocked schedule enabled the group to react quickly but move relatively slowly in a fashion similar to purely motor random practice. The reasons for these similarities are not readily available from the present experiment or the literature and await further research.

Variable practice only facilitated transfer to the novel task when the amount of cognitive effort experienced by the participants in acquisition was increased. According to schema theory, blocked practice, as a form of variable practice, should have facilitated transfer to a novel task. This was not the case. According to contextual interference theory, random practice should have facilitated transfer compared to blocked and constant practice. However, this only occurred in the case of the cognitive mode. The lack of significant differences between blocked and constant practice is in line with other studies that have produced equivocal results when contrasting blocked with constant practice. Variable practice only outperformed constant practice in this experiment when a random group had to engage in additional

cognitive processing. This processing is demonstrated in the elevated reaction times during acquisition, that were carried over into transfer and as such indicate that improved transfer, as a result of variable practice, seems to stem from enhanced cognitive processing rather than the formation of stronger schema.

The inability of the motor random group to perform better in transfer is somewhat disconcerting, however, there are a number of possible explanations. In this study the transfer test was performed in a blocked schedule and this has been shown to diminish the degree of difference between random and blocked practice schedules in tests of learning (Shea & Morgan, 1979). Perhaps if the transfer test was in a random order the generally robust contextual interference effect would have been demonstrated in the motor mode as well as in the cognitive mode.

Another explanation for the lack of a contextual interference effect in the motor mode has to do with the nature of the transfer task. The transfer target in this experiment is of the type described by Lee et al. (1985, p.287) as a "within" transfer goal, that is, the transfer target, although novel, was within the range of movements made by the random and blocked groups during acquisition. Even though the constraints of the experimental apparatus would not allow a transfer target that was outside the range of movements made by the groups in acquisition, there was still a contextual interference effect demonstrated in the cognitive mode, in movement times, and the motor random group was the only group in the motor mode to show an improvement over their last block of acquisition trials, in transfer.

A final explanation for the lack of a contextual interference effect in the motor mode concerns the nature of the acquisition task. The more sophisticated planning operations assumed to be promoted by random practice elevated the cognitive random group's reaction times but not those of the motor random group. This raises the possibility that the reason the motor random group did not engage in increased pre-response planning, as indicated by reaction times that were not different to other motor mode groups, was due to the task variations being of the same generalised motor program. Magill and Hall (1990) hypothesised that the contextual interference effect would not be exhibited when random and blocked practice were contrasted using movements that had the same underlying generalised motor program as these movements were merely concerned with learning relatively easy parameter variations (but see Young, Cohen & Husak, 1993). Magill and Hall suggested that performing a motor task with the same generalised motor program while manipulating the number of parameters could be a method in which their hypothesis could be tested. As the number of parameters are increased the likelihood of finding a contextual interference effect should also increase. The present experiment appears to have found support for this hypothesis, in that as the amount of cognitive effort increased in a task with the same generalised motor program, a contextual interference effect arose. Wulf (1992) was also able to elicit a contextual interference in movements with the same generalised motor program by increasing cognitive processing through reduction of knowledge of results presented to participants after each trial and noted that increased elaborative processing (Shea and Zimny, 1983) necessary to perform each successive trial seems to explain the findings better than the reconstruction hypothesis.

In the present task, the stated aim of contrasting schema theory and contextual interference theory dictated the task variations, as schema theory states that variability of practice will facilitate retention and transfer when the movements practiced are of the same generalised motor program (Schmidt, 1988, p.212). Therefore, it is possible that the absence of a classic contextual interference effect in the motor mode may have been due to a lack of deep elaborative processing in the random practice schedule.

The results appear to contradict the predictions made by the action plan reconstruction view (Lee and Magill, 1983). Presumably, forgetting of the action plan should have occurred for both the random groups, and in equal amounts as the movements were the same, however the two groups performed differently in transfer. The added dimension of searching for the correct geometric shape seems to have produced deeper conceptual processing, supporting the elaboration benefit explanation of the contextual interference effect (Shea and Morgan, 1979; Shea and Zimny, 1983).

Conclusion{ XE "Conclusion" }

The results of this study cast some doubt on the variability of practice prediction and its role in schema formation and subsequent strengthening. Blocked practice did not exhibit an advantage over constant practice as predicted by schema theory. The increased cognitive processing involved in practice by the cognitive random group enabled it to transfer to a novel target better than any of the groups and the elaboration hypothesis of contextual interference theory appears to be the best explanation of the result, rather than schema theory. It would seem that for simple motor tasks it is the amount of variability of practice that is important, while for tasks with a cognitive

component the schedule of practice is important. However, it must be noted, that to a large degree, the conclusions of this study are based on the fact that the cognitive random group outperformed the motor random group in transfer. The inability of the experiment to provide an "outside" transfer test, that the task was variations of the same generalised motor program (although this was necessary for the purposes of the experiment), and the fact that the transfer test was of a blocked design, possibly providing an advantage to the constant and blocked groups, are of concern. However, these concerns are lessened when one considers that the reason the motor random group did not perform well in transfer seems to be due to decreased cognitive effort in acquisition and this, in itself, is damaging to schema theory as it emphasises the cognitive aspect of practice, rather than the development of schema, in facilitated transfer.

The experiment aimed to increase the cognitive effort required to perform the task in acquisition in the cognitive mode for all the groups. However, due to the natures of constant and blocked practice, this did not appear to occur. The lack of significant reaction time differences between the corresponding groups in each mode (with the exception of the random groups) would appear to confirm this, and this seems to be due to the constant and blocked groups knowing which target was next, and therefore the need to distinguish between the different shapes did not arise in the cognitive mode. The influence of differing degrees of cognitive effort on the random practice is enough to draw conclusions in this study, but it would have been interesting to ascertain if the same effects would have been demonstrated in blocked and, especially, constant practice had cognitive effort been shown to be different between the modes.

It is of interest to note that the experiment has provided some support for the Magill and Hall (1990) hypothesis that the contextual interference effect would not be exhibited in parameter modifications of the same generalised motor program. That contextual interference effect was only apparent when increased cognitive processes were engaged, and due to the effect being seen only in the cognitive mode would point to an elaboration hypothesis explanation rather than the action plan reconstruction hypothesis.

Further research contrasting constant, blocked and random practice under conditions of no-cognitive and cognitive strategy is therefore indicated with other tests of learning. In addition, the use of real-world experiments, as opposed to laboratory-based, is always of interest to be able to more clearly extrapolate the results to actual training conditions. The present experiment would appear to have provided some additional insight into the influences of variable practice and the interaction of cognitive processes in schema development.

APPENDICES{ XE "APPENDICES" }

Appendix A{ XE "Appendix A" }

Letter to Participants Form{ XE "Letter to Participants Form" }

Australian Catholic University

Letter to Participants

In 1975 a theory of motor control and learning was proposed in which one of the major concepts was variability of practice. Variability of practice refers to a practice schedule in which many variations of a type of action are practiced and it has been shown that varying practice in this way leads to better learning of the task. However practising in situations of high contextual interference (where practice involves increased levels of cognitive effort) will lead to the same result. This experiment aims to determine if improved learning of a movement is due to variability of practice or to the contextual interference effect. The experiment will involve sitting in front of a computer screen and using a graphics tablet.

Risks to participants are minimal, but may include eye strain from looking at a computer screen for an extended period of time.

The experiment will be in one stage and will take approximately twenty minutes.

The experiment will aid in identifying practice methods that are most effective and will help parents, coaches and trainers at all levels.

Any questions regarding this project can be directed to the researcher,

Stephen Wrathall

On telephone number: (03) 9380 4635,

And/or to the supervisor; Dr Wayne Maschette

On telephone number: (03) 9563 3788

In the School of Human Movement

Australian Catholic University, Christ Campus.

This study has been approved by the University Projects Ethics Committee at Australian Catholic University.

In the event that you have any complaint about the way you have been treated during this study, or a query that the Researcher or Supervisor has not been able to satisfy, you may write care of the:

Chair, University Research Projects Ethics Committee

C/o Office of Research

412 Mt Alexander Road

Ascot Vale, VIC 3032

Tel: (03) 9241 4519

Fax (03) 9241 4529

Any complaint will be treated in confidence, investigated fully and the participant informed of the outcome. If you agree to participate in this project, you should sign both copies of the Informed Consent Form, retain one copy for your records and return the other copy to the researcher.

Appendix B{ XE "Appendix B" }

Letter of Informed Consent Form{ XE "Letter of Informed Consent Form" }

Australian Catholic University

Letter of Informed Consent

TITLE OF RESEARCH PROJECT:

The Effects of Contextual Interference and Variability of Practice on the

Acquisition of a Motor Task and Transfer to a Novel Task.

RESEARCHER: Stephen Wrathall.

I .... (the participant) have read (or, where appropriate,

have had read to me) and understood the information provided in the Letter to the

Participants and any questions I have asked have been answered to my satisfaction. I

agree to participate in this activity, realising that I can withdraw at any time.

I agree that research data collected for the study may be published or provided to

other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT

(blockletters)...……..

SIGNATURE...DATE..........…………

RESEARCHER: Stephen Wrathall

SIGNATURE...DATE..........……………

Appendix C{ XE "Appendix C" }

Experimental Groups Showing Identification Codes{ XE "Experimental Groups Showing Identification Codes" }

Experimental Group	Code
Random group experiencing cognitive cues	1001-1010
Blocked group experiencing cognitive cues	2001-2010
Random group experiencing motor cues	3001-3010
Blocked group experiencing motor cues	4001-4010
Constant distance 1 experiencing cognitive cues	5001-5010
Constant distance 2 experiencing cognitive cues	6001-6010
Constant distance 3 experiencing cognitive cues	7001-7010
Constant distance 1 experiencing motor cues	8001-8010
Constant distance 2 experiencing motor cues	9001-9010
Constant distance 3 experiencing motor cues	9051-9060

Appendix D{ XE "Appendix D" }

Course Credit Form{ XE "Course Credit Form" }

Australian Catholic University

This is to confirm that

………………………………………………………………………………………………

has satisfactorily completed research participation and is eligible to be credited five

hours of fieldwork experience.

Researcher: Stephen Wrathall…………………………………………………………

Staff Member: Wayne Maschette.

Appendix E{ XE "Appendix E" }

Tables Without Significant Differences Between Means{ XE "Tables Without Significant Differences Between Means" }

Table E1. Mean Cognitive Mode Movement Times for the Simple Main Effect of Schedule in Acquisition.

Schedule	M	SD
Random	.551	.349
Blocked	.499	.400

Note. The two means are not significantly different.

Table E2. Mean Motor Mode Reaction Times for each Schedule in Acquisition.

Schedule	M	SD
Random	.325	.088
Blocked	.363	.142

Note. The two means are not significantly different.

Table E3. Mean Motor Mode Reaction Times for each Block in Acquisition.

Blocks	M	SD
Block One	.365	.154
Block Two	.336	.096
Block Three	.331	.098

Note. The means are not significantly different.

Table E4. Mean Motor Mode Reaction Times for each Schedule in Transfer.

Schedule	M	SD
Random	.302	.097
Blocked	.342	.110
Constant Distance One	.351	.142
Constant Distance Two	.387	.174
Constant Distance Three	.392	.166

Note. The means are not significantly different.

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