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Cognitive learning strategies to mimic knowledge of results manipulation

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COGNITIVE LEARNING STRATEGIES TO MIMIC KNOWLEDGE OF RESULTS MANIPULATIONS

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Dedicated to my Mom and Dad

and for a Peaceful World

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ABSTRACT

This thesis compared the effectiveness of traditional KR manipulations to another condition where the subject assumed an active role in the learning process. It was expected that increasing the participants' autonomy would enable them to develop transferable knowledge regarding the provision of feedback within learning, which would enhance their transfer of learning from one motor task to another.

Some recent studies have indicated that reduced frequencies of KR seem to facilitate motor learning by helping subjects to develop their own error detection capabilities (Winstein & Schmidt, 1990). This thesis takes the view that both the development of error detection capabilities and the timing of feedback provision could be optimised by focusing more closely on the role of the learner, and seeking ways to enhance their cognitive involvement in the feedback process. The hypothesis of the experiments was that the expected superiority in retention of a reduced frequency KR group, in relation to a 100% KR control group, could be matched by a cognitive strategy group.

The reduced frequency KR groups (bandwidth, relative frequency and summary KR) in the first four experiments failed to support the experimental hypotheses. The fifth experiment was designed to rectify the shortcomings of these experiments. Three summary KR conditions (1-trial, 15-trial, & strategy groups) performed a linear slide task. In retention, the 3 group one-way ANOVAs for |CE| and VE were significant, revealing that the 1-trial summary group's scores were poorer than either the 15-trial summary and strategy groups.

In conclusion, these findings provide some evidence that informing subjects of the importance of problem solving activities during practice can reduce the need for supervision of feedback provision, without risking impaired retention. This

research is a first step towards demonstrating that cognitive factors involved in learning motor skills can be incorporated in the learning session to increase the autonomy of the subject.

CHAPTER ONE

Introduction

Manipulating Learning Variables to Facilitate Autonomy within of Motor Skill Acquisition

Imagine a classroom full of children trying to learn and acquire new knowledge and skill, and a teacher trying to teach a physical education class. In this day and age, where the size of the classes is increasing year after year, one can see the frustration of the teacher wishing that there were fewer students to deal with so that s/he could afford to pay the necessary attention to each student.

As having less students per class may not be a reality in near future, it would seem appropriate to try to develop "skilful learners", who share in the control of the learning environment in some way. It would certainly be useful if the learner could be made more active in the learning process so that the demand on the instructors could be minimised.

In attempting to facilitate such a learning situation, a good starting point would seem to be to search for controllable factors that influence the learning process. Perhaps the most widely studied and influential learning variable is that of information feedback. This area will form the primary focus of this thesis. Specifically, the goal of the thesis will be to show that the passive approach to learning adopted within the information feedback literature can be replaced with more active learning strategies. These learning strategies should be at least as effective as those currently used, and may be expected to be more effective in the transfer of skill acquisition.

Information Feedback Research - A Brief Introduction

In recent years, there has been an upsurge of interest in the study of information feedback, which has been found to facilitate error correction, reinforcement and motivation. Generally, the primary focus of the information feedback research has been on the error correction properties of feedback helping the learner to change behaviour to reduce error in performance. The way this study area has tackled the problem has been to ask how frequently should information feedback be provided to enhance the learner's error detection mechanism. A general finding of the research is that withdrawing feedback on some trials, although depressing immediate performance, ultimately enhances learning (Winstein, 1988). This general finding has promoted a number of avenues of research, seeking ways to maximise learning through manipulating feedback scheduling. A simple conclusion from this research is that the trials without feedback are as important as the trials with feedback in developing the performer's error detection capabilities.

The focus of these studies has shifted towards ever more specific and smaller changes that may be made to the practise experiences of the subjects so as to optimise the benefit of trials without feedback. This has led to some curious and non-theory driven findings. One such example is provided in the comparison between Schmidt, Young, Swinnen and Shapiro (1989) and Sidaway, Moore and Zohdi (1991). The findings of these two papers contradict each other despite the only difference between the two studies being movement time (550 ms & 750 ms respectively). In explaining the reasons for the differences in the findings, Sidaway et al. (1991) suggested that "Summary KR may operate differently when subjects are required to move as fast as possible than when a more leisurely pace of movement is required." (p. 31). Such a conclusion, although offering a potential explanation for the difference between the two studies, cast serious doubts over the generalizability of KR theory beyond the simple laboratory tasks on which it was founded. Findings such as these call into question the merits of these research papers, and perhaps the direction of the research area as a whole. Motor learning research should seek to establish general principles, the generalisation of which is well founded in theory.

One way of expanding the scope of KR research is suggested by recent interest in the role of cognition in the learning process, which has highlighted the value of allowing the learner to engage in problem-solving activities (Lee, Swinnen & Serrien, 1994; Pollock & Lee, 1992). Cognitive activities such as problem solving allow the learner to be more active than passive in their learning, a difference that is now being perceived as valuable for motor skills.

In explaining the difference in cognitive styles of novice and skilled performers, Kremer and Scully (1994) point out that "...the differences between the novices and the expert lie in how the individual uses the information available to him/her rather than in terms of some underlying differences in the 'hardware' of the central nervous system." (p. 48). Generally, novice motor skill performers interpret their early skill performance as being indicative of general ability levels; an interpretation which often leads to learned helplessness and is normally invalid (Magill, 1993). If novices were taught how to use the available information more appropriately then this negative attribution may be diminished. As Lee et al. (1994) have hinted, when the learner engages in cognitive practices such as problem solving activities, it is beneficial to learning in general.

A recognisable attribute of almost all the KR research is that it has not followed the trait of making the learner more active. Yet, one could still interpret the KR findings with respect to this trait, because KR scheduling is all about denying the learner the information feedback after every trial. What this means is that the learner is being forced to think about their movement and to estimate their own error. Thus, when the number of no-KR trial is increased and the number of KR trials is decreased, the resulting increase in skill retention could be due to an increase in the problem-solving activities being engaged in by the learner.

The same interpretation can be applied to bandwidth KR scheduling where a learner receives information feedback only if the error is outside a pre-determined range of correctness. This type of KR schedule maximised the development of learners' error correction capabilities and provided extra motivational incentive to engage in the learning process for themselves. The reason for this is that KR scheduling such as bandwidth KR is sensitive to each individual's particular feedback needs (Lee & Carnahan, 1990). It enables the learners to receive KR when it is most urgently needed for the purpose of error correction. KR scheduling such as relative frequency does not share this sensitivity, as feedback is withheld for some trials (that is every 5 or 10 trial) without regard to the learner's performance. As such, it does not contain the reward element inherent in bandwidth KR.

However sensitive bandwidth KR is to the needs of the learner, still certain choices are being enforced and subjects are being limited in some way (i.e. the determined range of correctness). To maximise the subjects' problem solving activities all choice should be handed over to the learner. To achieve this, the learner could be allowed KR whenever they request it according to their own particular needs and progress.

Although this notion of handing over all the control to the performer during learning seems to promote full and active engagement in learning on the performer's behalf, it has its limitations and assumptions. The limitation is the presumption that the learners already know how to use information feedback once all the control is handed over to them. For expert performers, this assumption might be valid but for novice learners this is not the case. Often novices do not know what to do or how to learn a motor skill. In a classroom situation where the teacher's concern is to get the most out of the students, it is impossible for the teacher to expect all the students to know when to ask for the feedback. Nevertheless, it is possible for the teacher to respect the needs and wishes of the students. One way of achieving this is to allow the students to have as much choice as possible and allowing them to have information when they want it, which in turn will motivate them to learn.

It is fair to say that KR research has become somewhat more mature and the time has come to apply the research to a broader base. The implication of the problem solving studies is that the more active the learner the better the learning will be. The general question that needs to be asked at this point is whether the benefit of the learning episode can be transferred to a new episode or to a new task or possibly both? It is clear that to achieve this the learner's role as a problem-solver needs to be maximised. Then what should be done is to hand over the control to the learner in a guided sense. While maintaining the knowledge derived from KR research, the learner can be made more of a problem-solver by progressively handing over control.

The hope is that this transfer of control to the learner will lead to far greater transferable skills and/or knowledge for efficient learning of motor skills. This in turn should be of greater use to the learners and teachers in general because at the end there will not be just a learning of one task within a learning event but there will be some knowledge taken from each event for later use.

CHAPTER TWO

Review of Literature

This chapter will address the research literature related to information feedback and cognitive strategies in motor learning. Specifically, it will discuss the research related to the optimal scheduling of feedback for motor learning, incorporating bandwidth, relative frequency and summary KR. The strategy experiments, particularly those conducted by Singer (1984, 1985) will be discussed with reference to the role of learning strategies in facilitating motor learning. Finally references will be drawn from both KR and strategy experiments to suggest that cognitive strategy may be usefully applied to KR scheduling.

Knowledge of Results in Motor Learning

In the existing theories of human motor control and learning there is a general acceptance of the need to provide the learner with mechanisms to handle both the organisation of outgoing signals and stored information against which any feedback is to be compared. Much of the theory regarding the function of comparison mechanisms in learning is derived from research which has typically focused on those elements of feedback which can be conveniently manipulated by the experimenter. This mechanism has been investigated periodically since Thorndike (1927) first drew attention to the central role of the KR in human learning (Adams, 1987). Thorndike's view on the information feedback was that

> "Feedback strengthens association between stimulus events and particular movements, thus forming the basis of learning. Factors that increase the amount or frequency of such feedback presentations strengthen these bonds to an increased degree, further increasing learning. This basic notion

> naturally gave rise to the general idea that feedback should be presented as often as possible…"(Schmidt, 1991. p. 244)

Hence, if Thorndike's law of effect was to be accepted, feedback should be varied to provide immediate, precise and frequent information during acquisition if learning is to benefit.

KR has been widely accepted as the most important variable for determining learning (apart from practice) (Wulf & Schmidt, 1989; Schmidt, 1988). Because of its importance, many studies have been conducted in order to understand the ways in which KR affects learning. Both Adams's (1987) and Salmoni, Schmidt and Walters' (1984) reviews emphasise the extent to which KR has been studied. One of the major considerations in KR research has been the relative importance of trials with KR versus trials without KR in facilitating learning. In answering such questions, two primary variables have been driven from this research (Salmoni et al., 1984; Schmidt, 1988). One of these is the "absolute frequency of KR", which is the absolute number of times a person receives KR in a series of trials and the second is the "relative frequency of KR" which is the proportion of trials on which KR is received (or the absolute frequency of KR divided by the total number of trials), and is normally expressed as percentage.

Early research by Bilodeau and Bilodeau (1958) indicated that the relative frequency of KR was irrelevant for learning, while the absolute frequency was the critical determinant factor. According to Bilodeau and Bilodeau (1958) "Absence of KR does not usually signify anything at all" p.379. The same view was iterated earlier by Trowbridge and Cason (1932). They stressed that absolute frequency of KR had a powerful performance effect during acquisition. It was also found that this effect remained during a no-KR transfer test. However, one problem with the Bilodeau and Bilodeau (1958) study was the lack of transfer design to separate the transient effect of feedback from the learning effects, thus making it difficult to know whether varying relative frequency affected learning. Some more recent studies by Ho and Shea (1978), and Johnson, Wicks and Ben-Sira (1981) used transfer procedures in their experiments that were similar in design to the Bilodeau and Bilodeau (1958) study. Results have consistently shown that an increase in the relative frequency of KR produces improvement in performance during acquisition. However, the results are equally consistent in showing reversal of the order during no-KR transfer tests (Sparrow & Summers, 1992). The results of Ho and Shea (1978), and Johnson et al., (1981) studies contradicted the previous findings by suggesting that both absolute and relative frequencies were important for learning. These findings were suprising to many, because they suggested that rather than being useless for learning as was the case in the Bilodeau and Bilodeau (1958) study, the no-KR trials appeared to be as beneficial in some way to learning.

Salmoni, Schmidt and Walter (1984) have introduced the "guidance hypothesis" term as a possible explanation as to the reason why practising less frequent and less immediate KR is more detrimental for performing but more beneficial for retention. The guidance hypothesis assumes that early in training KR provides information on how to achieve the movement. Thus frequent KR provides a strong guiding role and makes performance very effective during training. However, when it is not available it leads to worsening in performance, as there is no reference to check. The guidance hypothesis goes on to suggest that if the guidance is frequent (i.e., after every trial) and immediate it may force the subject to rely too much on KR and not engage in subjective error correction. The end result would be degraded performance due to the dependency on KR when feedback is unavailable or withdrawn. Due to this detrimental effect of KR, the question of how frequent KR should be giving has been studied extensively.

Knowledge of Results Scheduling

One important outcome of the absolute frequency and relative frequency debate was that scheduling the information feedback was discovered to be an important variable. A recent experiment by Winstein and Schmidt (1990) further supported this view. Winstein and Schmidt (1990) showed that providing reduced relative frequency of KR (50%) during training resulted in improved performance in the retention phase.

Several feedback scheduling methods has been proposed and extensively studied since the absolute and relative frequency distinction. These scheduling methods are relative frequency, bandwidth, faded and summary KR feedback schedules. In the following section relative frequency KR, bandwidth KR and summary KR feedback schedules will be discussed in detail.

Relative Frequency Knowledge of Results

The role of relative frequency and absolute frequency of KR has been examined extensively in human motor learning. One of the recent interests in this area was whether reducing relative frequency could be shown to improve performance in a no-KR retention test. However, early research like Bilodeau and Bilodeau (1958) was only interested in finding the effect of absolute and relative frequency of KR. Bilodeau and Bilodeau (1958) in their study have manipulated the relative frequency of KR by using a simple linear-positioning task. Subjects (N = 273) were given 10 trials with varying no-KR trials between KR trials forming four conditions with 10%, 25%, 33% and 100% relative frequency. The conditions showed almost identical performance on Groups-by-Trials analysis of variance when the performance accuracy on the trials immediately following KR (every trial for the 100% relative frequency, every four trial for 33% relative frequency groups, etc.) were compared. It was concluded that learning was independent of relative frequency and positively related to absolute frequency. However, as the study lacked a retention test, it was arguable whether the effects of relative frequency were permanent or only temporary.

Ho and Shea's (1978) study was an extension of Bilodeau and Bilodeau's (1958) study with no-KR retention tests. A simple linear positioning task was used where the criterion position was 250 mm from the starting position. The absolute frequency of KR was held constant at 10 KR presentations, and the relative frequency was varied by altering the total number of trials forming 10%, 30% and 100% relative frequency conditions. In acquisition, subjects' overall accuracy (AE) was found to be same for the 10 trials immediately following the presentation of KR. However, in retention tests (5 min), the 10% group retained its performance relatively well compared to the 100% group, which suffered reduction in performance. Although, the analyses of variance did not show a significant difference between groups, the accuracy on the retention was directly related to the relative frequency in acquisition, with the 100% conditions having greatest error, and the 10% conditions having the smallest. The outcome of the Bilodeau and Bilodeau (1958) and Ho and Shea (1978) study raised the question of how relative frequency during practice could depress performance initially and yet increase learning retention.

Schmidt, Shapiro, Winstein, Young and Swinnen (1987) conducted an experiment to find the long-term retention effect of relative frequency KR while controlling the amount of practice and varying the relative frequency condition. The task in this experiment was a simple ballistic-timing task involving reversal (left-right-left) movement of a slide along a trackway with 550 ms goal movement time. Two treatment groups (n = 16) performed 102 trials in acquisition where they differed in relative frequency of KR. First group received KR on every trial (100%) and second group received KR on every third trial (33%). Additionally, a third group was also used to control the absolute frequency by only performing 34 acquisition trials (34/1) and had 100% relative frequency. Schmidt et al.'s (1978) argument was that if the absolute frequency was the only determinant of learning, then 34/1 group and 33% relative frequency group (both having the same absolute frequency) should be similar in retention. Analyses of variable error (VE) and absolute constant error(|CE|) in acquisition revealed that decreased relative frequency resulted in larger errors and slower improvement with practice. Specifically, the two 100% relative frequency groups being treated identically for the first four trial blocks (first 32 trials) showed smaller error and faster improvements than 33% relative frequency group. In immediate (10 min) no-KR transfer test 34/1 group showed greater |CE|, however, not significant, but significant inconsistency (VE) than both 100% and 33% groups. Also, relative frequency variations in acquisition appeared not to have a differential effect on consistency and accuracy of delayed (2-day) no-KR transfer performances.

Winstein and Schmidt (1990) also examined the effect of variations on acquisition KR relative frequency in a series of experiments. In three experiments, the task was to produce a goal movement pattern using a lever in 800 ms criterion time. In first experiment, specificity hypothesis was tested with two KR relative frequency conditions (100% & 33%). In addition, four retention test conditions were employed with a varying KR relative frequency (i.e. 0%, 33%, 66%, & 100%) thus totally eight separate acquisition-retention test groups (two acquisition conditions x four retention conditions). Although relative frequency variations were not significant, compared to a 100% KR practice condition, the reduced KR relative frequency conditions were found to be as effective for learning as measured in various retention tests (10-min after the second day of practice). The interesting findings which were the base of the further experiments were (a) specificity hypothesis was not supported as predicted by the interaction of the acquisition-retention condition, (b) low KR relative frequency practice conditions suspected to be not detrimental to learning but no evidence for this was provided. In the second and third experiments a variable-ration schedule (starting from 100% to 25% relative frequency) with an average of 50% relative frequency was employed. The reduced averaged relative frequency of 50% was found to enhance learning in a delayed no-KR retention test (experiment two) and in a KR provided retention test (experiment three). The result of the Winstein and Schmidt (1990) together with Sherwood's (1988) study have suggested that lower KR relative frequencies promote consistency and reduce trial to trial variability. With their study Winstein and Schmidt (1990) claimed to have an empirical support for the KR "guidance hypothesis" (Salmoni, Schmidt & Walter, 1984; Schmidt, 1991). Wulf (1992) explains this hypothesis as "...KR has a powerful informational content in that it guides the learner toward the correct response and facilitates performance". KR especially in the stages of learning guides the learner toward the appropriate movement pattern. It is argued however that the guidance properties of KR can have a negative effect upon learning when given too much. Guidance properties of feedback given during acquisition may generate an over-reliance to produce the next responses, which leads to a reduction in performance when KR is removed during transfer trials.

Bandwidth Knowledge of Results

Bandwidth (BW) feedback scheduling has been proposed as a method for avoiding the effect of frequent feedback, which produces the dependency on outside sources of information. In BW KR scheduling "KR is only given if gross error in performance occurs" (Sherwood, 1988. p. 536). In Sherwood's experiment, information about the performance was only provided if the subject's response fell outside a particular performance bandwidth. The task was a rapid elbow flexion task with a goal to complete the movement in 200 ms. The 0% bandwidth group received KR after every trial regardless the amount of error. The two other groups received KR only when their error about their movement time exceeded bandwidths of 5% and 10% of the 200 ms target movement time (hence errors of greater than 10 ms & 20 ms respectively). In acquisition the 5% group received KR on more trials than the 10% group (54.5% vs. 31.4%, respectively). The performance accuracy (|CE|) of the groups were not significant in both acquisition and retention. The 10% bandwidth condition achieved greater consistency in a retention tests than did the 0% bandwidth condition. This result, which is also replicated by Lee, White and Carnahan (1990), supported the point made earlier that information about movement error was not always needed to learn a motor skill. Furthermore, it shows that in some cases it may negatively influence learning. However, Sherwood's results may be attributed to the relative frequency effect found by (Winstein & Schmidt, 1990 and others), as increased BW size automatically decreases RF of KR. To resolve this issue, Lee and Carnahan (1990) contrasted the effect of varying the relative frequency of KR as in Winstein's (1988) work with conditions created by delivering KR when the error falls outside some arbitrary limits of tolerance as in Sherwood's (1988) bandwidth KR experiment. In Lee and Carnahan's (1990) study, subjects in 5% and 10% bandwidth groups were matched (yoked) with a subject who received KR on the same trials on which the bandwidth subjects received KR. This arrangement allowed the effect of bandwidth KR to be separated from that of reduced relative frequency KR (i.e., if the bandwidth effect was a frequency effect, then subjects in both conditions should perform similarly). Subjects practised an arm movement task for 60 trials, where the target time was 500 ms. The yoked frequency KR group were less consistent in retention than the bandwidth KR group, which suggested that the facilitation of retention via bandwidth KR was not simply a relative frequency effect. Bandwidth KR scheduling seems to allow the control system to adapt to the demands of the task and develop appropriate error correction processes needed to perform the skill correctly. As Lee and Carnahan (1990) stated

> "...Bandwidth procedures have the advantage of being sensitive to the needs of the subjects...Since the delivery of KR is determined by the subject's performance, bandwidth procedures also provide for frequency schedules that are sensitive to individual differences in both the amount and the rate of improvement in performance over acquisition trials." (p. 788-789)

Lee and Carnahan's findings extend those of the relative frequency research by showing that subjects' generation of their own error correction capabilities may be further facilitated by providing KR only when subjects' error indicate its need.

Summary Knowledge of Results

The term summary KR is used to describe the KR condition where the KR is given after some predetermined trial, and provides information for each of the preceding trials within the block. Summary KR introduces a delay of some trials between each presentation of KR, but keeps the relative frequency of KR at 100%. It was expected that the KR delay introduced by summary KR would serve the same purpose as the No-KR trials in the reduced relative frequency schedule, while maintaining the overall relative KR frequency at 100%.

An early experiment by Lavery (1962) investigated the learning implications of summary KR by administering different treatments to subjects performing a simple motor task. Lavery (1962) used a ball propulsion task, and the acquisition phase was completed over six days. In this experiment, one group received immediate KR about every trial, a second group received KR as a summary graph after every 20 trials (in effect a summary KR group). A third group received mixed forms of KR scheduling (i.e., KR after every trial and summary KR after every 20 trials). After the acquisition phase, performance in retention tests was measured after 4 days, 1 month and 3 months. The results showed that although the summary KR group had higher error scores than the other two groups during acquisition, it yielded the best performance in the retention phase.

Schmidt, Young, Swinnen and Shapiro (1989) employed a ballistic timing task to measure the performance of 1, 5, 10 and 15 trial summary KR groups in an effort to replicate the results of Lavery (1962). The subjects practised a simple ballistic-timing task in which they had to move a lever back and forth along a frictionless trackway in a fixed target time (550 ms). KR was presented to subjects via a graph on a piece of paper during the 90 acquisition trials. One group received the KR graph after every trial (100% KR), while the other three groups received summaries of their performance after 5, 10 or 15 trials respectively. Subjects' absolute constant error improved over trials during acquisition, and performance level was inversely related to summary length. There were little differences between the groups in a subsequent 10-min retention test. However, in a delayed retention test after 2 days, there were significant differences between groups, with the quality of performance being inversely related to the number of trials being summarised during acquisition. Overall, the results supported Lavery's (1962) findings, where with 20 trials were summarised in the training phase.

Explanation of the summary KR effect are similar to those offered for the relative frequency effect, in that the No-KR trials are supposed to promote the subjects' generation of their own error-correction capabilities.

The benefit of the summary KR has been considered to be related to the factors similar to the frequency of KR benefit.

Cognitive Learning Strategies

The theoretical basis of strategy research in motor skills operates within the framework of information processing and cognitive psychology. This conceives of the individual as a structure for the reception, regulation and transmission of information in which hypothesised functional models are utilised to characterise the cognitive processes and corresponding mechanisms involved in the processing of information in skilled performance.

In analysing the components of motor skill learning, Singer (1980) criticises the traditional approach to skills teaching and coaching that he describes as concentrating solely on the physical constituents of the task. It is, he continues, with the incorporation of the information processing conception of skill that a greater understanding of both the physical and psychological factors involved in skills, and greater efficiency is achieved.

The method Singer and his colleagues (Singer, 1980; Singer & Gerson, 1981; Singer & Cauraugh, 1984) advocate therefore involves an analysis of the processing demands of the task formulating a model of the functional components or mechanisms of the skill. This thereby identifies the important cognitive processes performed by these mechanisms in the production of the skill. In doing so, Singer then proposes that by enhancing the processing of information at these critical stages, with the successful application of pertinent strategies, the level of learning and performance is increased. A strategy therefore is defined as the specific, though transient organisation of mechanisms for the utilisation of specific cognitive processes in the performance of a task.

This methodology has been successfully applied in verbal skills with for example mnemonics and encoding techniques in verbal memory (Bemont & Butterfield, 1971; Craik & Lockhart, 1972) but prior to Singer's (1980) inquiries had not been successfully applied to motor skills. In accordance with the hypothesis that successful application of strategies is dependant on the identification of the task demands (cognitive processes inherent in the performance of a task), Singer and Cauraugh (1984) proposed a task classification scheme for motor skills to assist this identification. This was a modification of an original proposal (Singer & Gerson, 1981). The scheme involved analysing motor skills in terms of "informational analysis" (the processing of information prior to the response) "response generation and organisation" (processing during and in preparation for the response) and "utilisation of feedback".

Singer and Gerson (1984) suggest that the most effective enhancement of performance is achieved by application of a relevant strategy to each of the three main processing stages. Recent research has successfully applied this methodology to various motor skills under laboratory conditions. Singer and Cauraugh (1984) achieved significantly less error with a strategy compared to non-strategy group in terms of time off target on a pursuit rotor task with an anticipatory strategy encouraging awareness of stimulus change, a rhythmic strategy for controlled response movement and a strategy to encourage the utilisation of the auditory feedback produced with stylus movement.

In addition Singer, Cauraugh, Lucariello, and Brown (1985) demonstrated the generalizability of strategies with a significant performance effect on both a primary and a related task with imagery, rhythmic and feedback utilisation strategy group compared with a non-strategy group on a maze traversal task. A further paper published by Brown, Singer, Cauraugh, and Lucariello (1985) investigated the relationship between specific cognitive styles of impulsives and reflectives and effectiveness of strategies on performance of motor skills. Four groups were used. Two strategy groups of impulsive and reflective types and two control groups of impulsive and reflective types. Two methods of performance assessment were utilised which were error scores in terms of time off target and the overall completion time for a maze traversal task. Singer hypothesised that the impulsive groups would perform with significantly less overall time than the reflectives, whereas the reflectives would perform with significantly fewer errors. Error scores and overall completion time for the maze task were significantly less for both strategy groups of reflective and impulsive types compared to the control group. However, no significant differences were found between cognitive types. Contrary to the hypothesis, strategy reflectives did not perform with significantly less error than strategy impulsives nor did the strategy impulsives perform with significantly less overall time than the reflectives.

Further evidence for the effectiveness of strategy application in the performance of motor skills is found in another paper published by Singer and Suwanthada (1986) which assess the effectiveness of a previously devised five step global strategy (Singer & Cauraugh, 1985). This strategy is applicable to closed motor tasks that are environmentally independent in which individuals can maximise control over their performance as opposed to open motor skills that incorporate environmental variables affecting performance. In this study, a significant performance effect was obtained for the group utilising the strategy that involved steps of readying, imagining, focusing, executing and evaluating on a primary and related task.

To describe the theoretical basis of strategy research, Rigney (1978) introduced a distinction between two types of strategy. Though not utilised by Singer, this may offer a valid insight into the operation of strategies and their relationship to performance of psychomotor tasks. The distinction Rigney proposes is between embedded and detached strategies. An embedded strategy is defined specifically in relation to the necessary components or constituent elements of the task and is therefore implicit in the performance of the task. A detached strategy on the other hand, is one that is independent and additional to the subject matter of the task and therefore explicit to performance. An example of a detached strategy would be a relaxation strategy designed to prepare a nervous competitor for an important event, whereas an example of an embedded strategy would be a cricketer's awareness of different hand movement in a bowler's delivery to predict the movement of the ball.

Singer does use both embedded strategies (feedback utilisation & concentration strategies) and detached strategies (preparation & rehearsal strategies). However, he fails to differentiate between them, only classifying them according to the processing stage to which they are applicable.

Cognitive Learning Strategies and Knowledge of Results Manipulations

An alternative approach to examine the KR effects is concerned with how and when concurrent feedback influences the performance of a task. Carlton (1983) showed that feedback has to exceed a threshold before any correction takes place or disturbance occurs as a result of the disturbance in the performance conditions. Such observation suggests that disrupting or distorting feedback instead of withholding it should be a way of examining the function of error detection. On the basis of this suggestion Fazey (1986) has established that by distorting outcome information, subjects on a movement time task and in a throwing task ignore externally provided KR that exceeded ± 2 standard deviation of their current level of performance away from target.

Feedback disruption and distortion experiments underline one thing which is that subjects seem to employ their own strategies when information is available whatever the experimenter may do to manipulate KR provisions. Clearly the strategies that subjects employ seem to allow them to overcome the problem of making gross corrections that usually occur early in practice, when it might be assumed that the translation of intention into action is controlled by conscious mechanisms (Schneider & Shiffrin, 1977). Furthermore subject employed strategies seem to allow them to refrain themselves from attending to and trying to correct small deviations from a correct performance in later performance thereby benefiting a sort of automatic translation of intention of action (Schneider & Fisk, 1983).

The observation that the use of feedback might be under some sort of strategic control suggests the need for an examination of the KR and provisions of information from the perspective of how learners can control a given learning situation rather than how KR (by experimenter's manipulation) controls their learning.

Statement of the Problem

The following study investigates the application of an imposed cognitive learning strategy to simple laboratory motor tasks to find out whether subjects are capable of applying learning strategies in situations where KR is available all the time. The goal of this research was to investigate the effect of reduced frequency KR conditions and strategy conditions (also reduced frequency KR conditions) to a control condition (100% KR) across acquisition and retention trials.

Two tasks were chosen for the experiments first of which was the barrier-knock down task of Lee and Carnahan (1990) and the second one a double reversal linear slide task of Schmidt et al., (1989).

Hypotheses

It was hypothesised that the improved learning scores in the reduced frequency KR condition (experimenter controlled) could be matched by having the learner chose when to receive or attend to the information (reduced frequency KR subjects controlled). It was also hypothesised that all reduced frequency KR conditions would perform better than the control condition (100% KR) in retention.

CHAPTER THREE

Bandwidth Experiment

Introduction

The experiments reported in this and subsequent chapters were designed to compare the traditional experimenter controlled information feedback manipulations with conditions where subjects were given a learning strategy which was designed to mimic the experimenter's manipulation of feedback. The purpose of the experiments were to show that passing control to subjects (i.e., choosing when to receive feedback) would not inhibit learning relative to a KR condition that is controlled exclusively by an experimenter. This forms part of a wider perspective within which the purpose is to demonstrate that increasing the level of autonomy given to the subjects in deciding on when to receive feedback will promote the development of learning skills which are transferable to novel learning situations.

To investigate the extent to which subjects' control or autonomy might be duplicated in a KR condition, two KR scheduling methods were selected from among those available. These two KR scheduling methods were bandwidth and the relative frequency KR. These procedures were selected as they were representative of the success of certain KR schedules in facilitating retention relative to a 100% KR condition.

Because of the wish to test the strategy manipulation against each schedule, two experiments were initially run concurrently, one on each of the two schedules.

Hypotheses

The hypothesis of the first experiment was that KR presented only when the trial error exceeded ± 5% (50 ms) of the target time (1000 ms) would lead to enhanced retention performance compared to a control group (100% KR). It was also hypothesised that a similar enhancement of retention performance would be obtained by giving subjects a strategy of ignoring KR that lay between 950 and 1050 ms (± 5%).

Method

Subjects

The subjects were 18 right-handed students (12 male & 6 female) from University of Wales, Bangor. Subjects' age ranged from 20 to 38 years (*M* = 28.3, *SD* = 5.6). All the subjects volunteered to participate in the experiment and were unaware of its purpose. Four subjects who failed to participate in the retention test were not included in the statistical analyses.

Apparatus and Task

The apparatus and task were adapted from those used by Lee, Magill, and Weeks (1985). The apparatus consisted of two micro switches and two 8 x 11 cm hinged plastic barriers (see Figure 1).

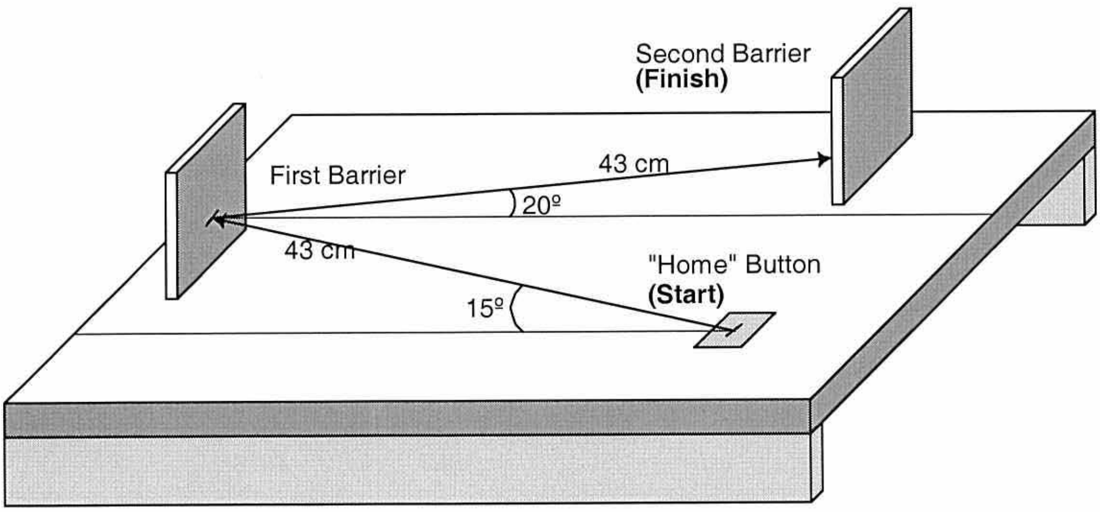

Figure 1. Illustration of the apparatus and the direction of the arm movement in bandwidth and relative frequency experiments.

Movement times were recorded by using a 380Z Research Machine computer, which was interfaced with two micro switches. The first micro-switch was the "home" button, which initiated the clock when subjects left it. The second micro switch was placed underneath the second barrier ("finish") and stopped the timer when the barrier was knocked down. A compiled BASIC program was used to control how the information appeared on the screen (see Appendix A for a listing of the experimental program).

The task was to move from the "home" button to "finish" by knocking down the two hinged barriers in 1000 ms.

Procedure and Design

The 18 subjects were assigned to one of three KR conditions that differed in terms of the amount of KR received during the acquisition phase. These groups were (a) 100% KR control group (CON), (b) 10% bandwidth group (BW 10%) and (c) 100% KR strategy group (STR). Subjects in the CON group and STR group received KR after each trial but the BW group received KR only after trials in which subjects erred by more than ± 5% from the target time. In addition to this subjects in the STR group were given a strategy of ignoring KR that was within ± 5% of the target time.

Prior to the experiment, each subject received information about the task and feedback they were going to receive. They were allowed to practice the correct movement five times. Each subject was given 60 trials during the acquisition phase of the experiment. Ten no KR trials were performed immediately after the acquisition phase. Following a 5-minute rest, twenty more trials were performed in a retention phase. During the experiment KR regarding subjects' movement time was presented in ms (e.g., 950) to each subject on a 30.5 cm (12 inch) monochrome screen positioned at eye level behind the apparatus (see Figure 2). For the CON and STR groups, the movement times were presented in a row across the centre of the screen. Each movement time was laterally displaced from the centre of the screen by an amount proportional to the trial error. The exception to this was that movement times which fell within the bandwidth of ± 5% of the target time (i.e., between 950 & 1050 ms), which always appeared in the centre of a column drawn down the centre of the screen after every trial. When the subject began the next trial, the screen went blank.

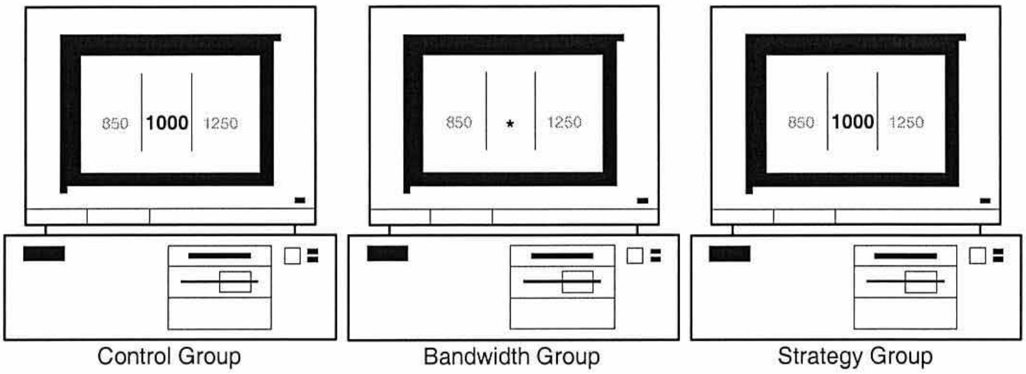

Figure 2. Illustration of KR presentation to subjects in bandwidth experiment for CON, BW and STR groups respectively.

The subjects in the strategy group were given additional instruction that was intended to mimic the bandwidth condition. These subjects were instructed to use the feedback presented only when it appeared outside of the central column drawn on the screen. The bandwidth group received KR on the very first trial and thereafter KR was given only after trials in which the bandwidth was exceeded. The movement time for these trials was presented in the same location to that used for similar scores for the CON and STR groups.

At the beginning of the experiment, the preparation of the barriers and the required movement pattern were demonstrated by the experimenter. The instructions given to all subjects were to lift their finger from the home button and knock down the two barriers in the appropriate manner and in a time as close to 1000 ms as possible. The subjects were instructed to raise the barriers and place a finger on the home button to begin a trial. The controlling program checked and prompted for the appropriate barrier arrangement and displayed a "Go When Ready" message on the screen in front of them. The inter-trial interval was kept relatively constant for all groups (approx. 10 sec.).

A schematic representation of the statistical design is given in Table 1. A significance level of $p < .05$ was set for all statistical tests.

Table 1. Statistical Design for Bandwidth Experiment

Groups (n=x)		BLOCKS								
		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	S1 - S6									
BW 10%	S1 - S6									
Strategy	S1 - S6									

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Results

Subjects' performances during the experiment were analysed in blocks of 10 trials. The dependent variables across acquisition and retention analyses were absolute constant error (|CE|) and variable error (VE).

A Groups by Blocks (3 x 6) analysis of variance (ANOVA) with repeated measures on the block factor was used to examine the group differences in each of the dependent variables across acquisition trials. A 3 group one-way ANOVA was used to examine the group differences in immediate retention. A Groups by Blocks (3 x 2) analysis of variance was also used to examine the group differences in each of the dependent variables across retention trials (see Appendix B for copies of the ANOVA tables and Tukey's HSD test, and Appendix C for a complete listing of the raw data).

Acquisition

Absolute Constant Error.

The two way ANOVA for |CE| revealed a significant main effect only for blocks, $F(5,75) = 3.13, p < .05$. Follow-up tests revealed an improvement in the performance by groups as they progressed through the acquisition trials. The main effect for groups and groups by blocks interaction failed statistical significance $F(2,15) = .66, p = .53$ and $F(10,75) = .65, p = .77$, respectively. The |CE| scores for each group over 6 blocks of ten trials are shown in Figure 3.

Variable Error.

The analyses of VE revealed similar results to that of |CE|. Figure 4 shows the VE for blocks of ten trials. The main effect for groups and the groups by blocks interaction failed statistical significance, $F(2,15) = .59, p = .57$ and $F(10,75) = .45, p = .919$ respectively. There was a main effect of blocks, $F(5,75) = 10.14, p < .001$, showing a decrease in the VE score across the blocks. Follow-up tests indicated that the subjects were improving in consistency throughout the acquisition phase.

Immediate No-KR Phase

Absolute Constant Error.

The one-way ANOVA on groups in immediate retention revealed no significant effect for |CE| scores, $F(2,17) = .42, p = .67$. Figure 3 shows one block of 10 trial immediate retention for |CE|.

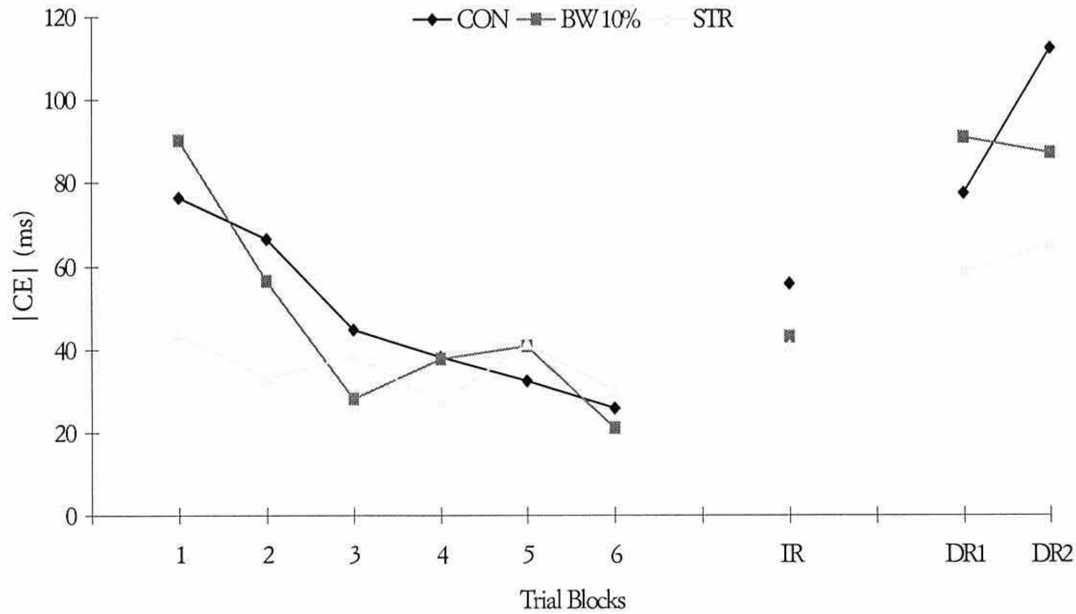

Figure 3. Absolute Constant Error (|CE|) scores in milliseconds for acquisition and retention trial blocks (BW Experiment).

Variable Error.

The one-way ANOVA on groups also revealed no significant results, $F(2,17) = .06, p = .94$. Figure 4 shows one block of 10 trial immediate retention for VE.

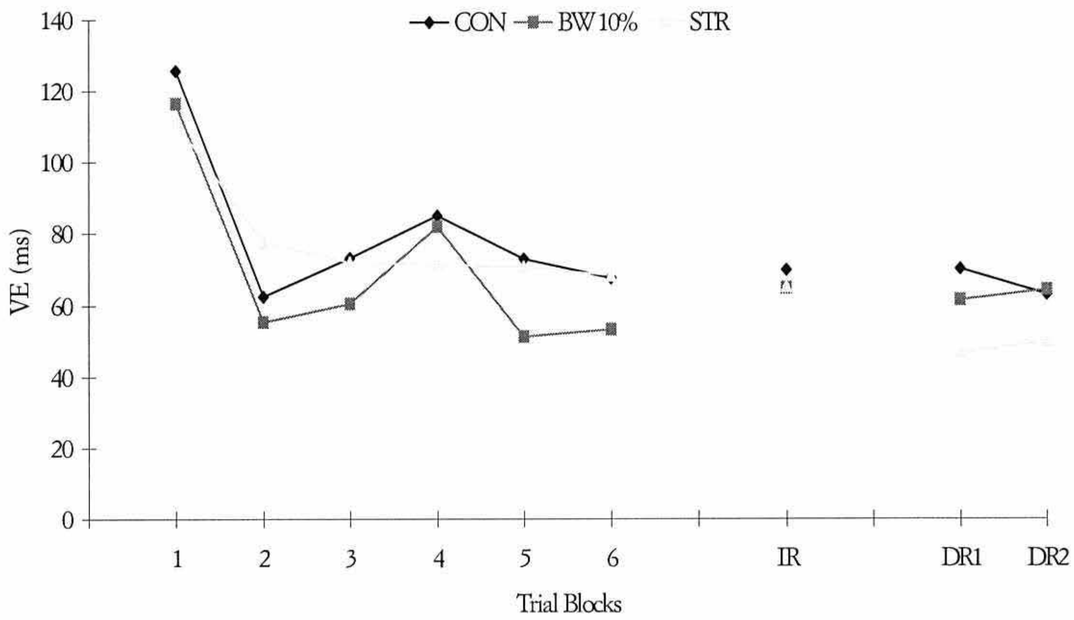

Figure 4. Variable error (VE) scores in milliseconds for acquisition and retention trial blocks (BW Experiment).

Retention Phase

Absolute Constant Error.

The |CE| scores for the three groups across the two 10-trial blocks in the retention phase are shown in Figure 3. A 3 (Group) by 2 (Block) ANOVA revealed neither a significant group nor a significant block main effect, $F(2,15) = .59, p = .57$ and $F(1,15) = .67, p = .43$ respectively. The interaction was also insignificant, $F(2,15) = .58, p = .57$.

Variable Error.

The results of the VE analysis was same as that of |CE|. The Group main effect $F(2,15) = 1.11, p = .36$, block main effect $F(1,15) = .01, p = .95$ and the group by block interaction $F(2,15) = .24, p = .79$ all failed statistical significance.

Table 2. Means and Standard Deviations of |CE| (in milliseconds) for Acquisition and Retention tests in Bandwidth Experiment.

		BLOCKS								
Groups (n=6)		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	*M*	76.44	66.40	44.64	38.27	32.54	25.85	55.64	77.67	112.33
	SD	31.14	89.79	56.85	17.00	31.47	17.66	31.57	72.56	63.88
BW 10%	*M*	90.13	56.28	28.07	37.63	40.80	21.16	42.93	91.00	87.00
	SD	65.82	41.85	15.73	30.24	22.10	19.96	23.32	71.69	82.78
Strategy	*M*	43.71	33.18	38.30	27.11	41.45	30.08	40.52	58.67	65.17
	SD	57.14	18.91	22.88	25.96	30.57	17.47	36.53	47.62	38.41

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Table 3. Means and Standard Deviations of VE (in milliseconds) for Acquisition and Retention tests in Bandwidth Experiment.

Groups (n=6)		BLOCKS								
		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	*M*	125.54	62.47	73.13	85.07	73.06	67.54	69.89	70.15	63.03
	SD	74.16	16.87	22.48	54.27	20.34	39.83	34.35	8.80	48.13
BW 10%	*M*	116.43	55.21	60.51	81.81	51.14	53.32	64.86	61.38	64.14
	SD	40.96	15.26	9.84	35.89	17.34	15.41	24.01	30.72	23.36
Strategy	*M*	111.01	77.60	71.95	71.30	70.69	68.32	65.37	46.50	49.79
	SD	28.53	24.38	21.85	15.34	23.65	25.14	24.09	15.26	18.64

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Discussion

This study examined the effect of using a strategy on the retention of a simple barrier knockdown task in comparison to bandwidth KR and control conditions. The hypotheses of the experiment were that KR presented only when the trial error exceeded ± 5% (50 ms) of target time (1000 ms) would lead to enhanced retention performance compared to a control group (100% KR), and that a similar enhancement of retention performance would be obtained by giving subjects a strategy of ignoring KR that lay between 950 and 1050 ms (± 5%).

The results failed to support either of the hypotheses. In particular no group differences were observed for either VE and |CE| across retention trials. Neither the bandwidth KR (10%) nor the strategy conditions facilitated retention performance relative to the control group.

A close look at the data showed that the standard deviation in most of the cases were very high. This indicated that the range of movement times was variable within all the groups, especially the control group (see Table 4). The standard deviations for VE did not appear to be as high as those for |CE| but still the BW 10% and the STR groups were not statistically different from the CON group. The data suggested a trend that the consistency and response bias of the strategy group was lower than the other groups but this effect was also not significant (p's>.5).

In general, the outcome of the present experiment ran contrary to the current literature on the effect of bandwidth KR on motor learning. Many recent studies have shown superior performance of a bandwidth group over a 100% relative frequency KR condition (Butler & Fischman, 1996; Lee & Carnahan, 1990; Lee & Maraj, 1994). The most successful current explanation of the effect is that the constant provision of KR after performance in the 100% RF condition prevents subjects focusing on intrinsic sources of information feedback, which are supposed to be important for retention performance (Lee & Maraj, 1994; Schmidt, 1991). The bandwidth effect seems to be successful because it allows the performer to focus on these intrinsic sources of information feedback, at times when performance is successful (Lee & Maraj, 1994). This rationale is supported elsewhere in the literature, where both the instant provision of KR (Swinnen, Schmidt, Nicholson, & Shapiro, 1990) and the performance of distracter tasks in the KR delay interval (Swinnen ,1991) have been shown to be detrimental to retention performance. This finding may be related to the guidance hypothesis, in that the guidance hypothesis suggests a reliance on extrinsic sources of KR fostered by a high relative frequency of KR during acquisition. However, it does go further than the guidance hypothesis in that it suggests that the withdrawal of KR in retention is detrimental to performance not only because of a reliance on extrinsic feedback, but also the failure to have developed an awareness or understanding of internal sources of information (Swinnen, 1990).

Table 4. Mean (*M*) and Standard Deviations (*SD*) of groups in Delayed Retention in Bandwidth Experiment

	DR Block 1		DR Block 2	
Groups (n = 6)	*M*	*SD*	*M*	*SD*
Control	77.667	72.561	112.333	63.877
BW 10%	58.667	47.622	65.167	38.411
STR	91.000	71.691	87.000	82.779

Note. DR = delayed retention. Block = represents 10 trials.

Given the recent strength of support for bandwidth procedures, the lack of statistical support obtained here is puzzling. It would seem that a comparison of the design and task used in previous studies to that used in the present study would be useful. The studies by Lee & Carnahan (1990) and Lee & Maraj (1994) both used the same apparatus as was used here, and so seem to provide an appropriate comparison. Lee & Carnahan (1990) used 60 acquisition trials, a 5-min retention interval, and 20 retention trials. Lee & Maraj used 100 acquisition trials, a 10-min retention interval, and 20 retention trials. This compares to 60 acquisition trials, 10 immediate no-KR trials, a 5-min retention interval and 20 retention trials in the present experiment. In terms of expected results, Lee & Carnahan (1990) found significant bandwidth effects in VE but not in |CE|, whereas Lee & Maraj (1994) found the opposite pattern of results. On balance, in other studies |CE| has been the most sensitive to BW effects (Butler & Fischman, 1996; Butler, Reeve & Fischman, 1996; Cauraugh, Chen & Radlo, 1993; Goodwin & Meeuwsen, 1995).

From this set of comparisons, it does not appear that there is any drastic difference between the design of this experiment and those which have elicited bandwidth effects. Also, a visual inspection of Figure 3 suggests that the |CE| results were at least in the predicted direction. Under these circumstances, and given the apparent success of the BW paradigm elsewhere, the non-significance of the results obtained here were attributed to methodological factors which are listed below, rather than to a fault in the design of the experiment or a the weakness of the bandwidth effect itself. The methodological factors which follow are discussed in detail in the 'Cross-roads' chapter later in the thesis, when the full impact of these factors on the results was realised.

The subjects used in the experiment
the number of subjects used in the experiment
the subjects' heterogeneity in age and sport related experience
the subjects' level of concentration
the subjects' level of motivation
The validity of the experimental treatment used in the experiment
The subjects' lack of understanding of the procedures of the task
The environment in which the data were collected

CHAPTER FOUR

Relative Frequency Experiment One

Introduction

The first experiment was an attempt to show that giving more control to subjects would not inhibit learning relative to a BW KR condition. This experiment was designed to show the same the same effect under a reduced relative frequency (RF) KR condition. RF KR scheduling was chosen because of its applicability to strategic manipulation from the view of subject's control and autonomy.

A recent review of the role of KR (Salmoni et al., 1984) and some experiments (Winstein & Schmidt, 1990) have shown that low relative frequency KR enhances learning despite impairing acquisition performance. This view has been interpreted in terms of "guidance hypothesis" for the role of KR (Salmoni et al., 1984). According to the guidance hypothesis, less frequent KR may lead to a dependency on the extrinsic feedback, which prevents the processing of other sources of information intrinsic to the task.

Hypotheses

The hypotheses of the experiment were that reduced frequency KR (20%) during training would lead to enhanced retention performance relative to a control group (100%) and that similar enhancement of retention performance would be obtained by giving subjects a strategy of ignoring four out of every five KR presentations (effectively 20% of KR).

Method

Subjects

The subjects were 18 right-handed students (12 male & 6 female) from University College of North Wales, Bangor. Subjects' age ranged from 20 to 39 years (*M* = 28.8, *SD* = 5.6). All the subjects volunteered to participate in the experiment and were unaware of its purpose. Each subject received information about the task and the KR they were to receive prior to the experiment.

Apparatus, Task, Procedure and Design

The apparatus, movement task, and procedures were the same as those described for bandwidth experiment, with a few exceptions outlined below.

The 18 subjects were assigned to one of three different KR conditions that differed in terms of the amount of KR received during the acquisition phase. These groups were (a) 100% KR control group (CON), (b) 100% KR strategy group (STR) and (c) 20% relative frequency group (RF 20%).

For the CON and the STR groups the movement times were presented in a column centred on the screen (see Figure 5). For every five trials, the KR for a trial was presented below that of the previous trial. Hence the first score in a 5-trial block appeared at the top of the screen, and the fifth appeared at the bottom of the screen in a box. When the subject performed the next trial the screen went blank and the cycle repeated.

The subjects in the strategy group were given additional instruction that was intended to mimic the experimenter's manipulation of KR. These subjects were instructed to ignore all the feedback presented except when it appeared in the box at the bottom of the screen. The RF 20% group received KR on the very first trial and thereafter KR was given only after every fifth trial. The movement time for these trials was presented in the same manner, in the same location and in a similar box to that used for every fifth trial for the CON and STR groups.

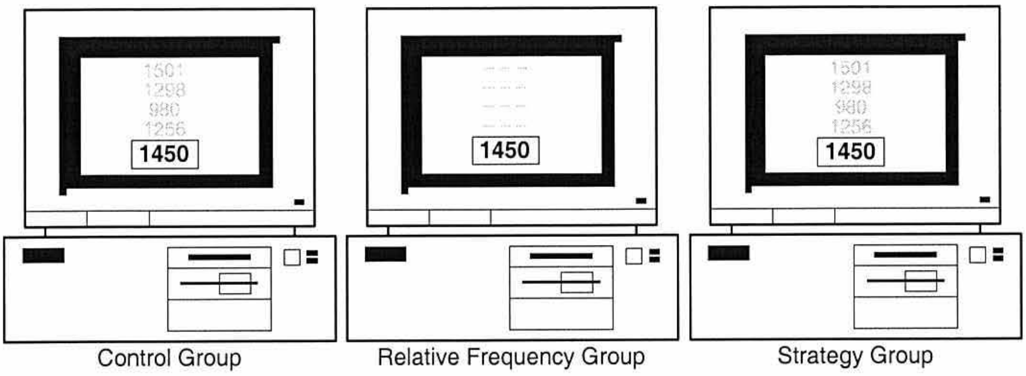

Figure 5. Illustration of KR presentation to subjects in relative experiment for CON, 20% RF and STR groups respectively.

Blocks of 10 trials were used to calculate measures of performance accuracy and consistency (following Lee & Carnahan, 1990). Performance accuracy was assessed by absolute constant error (|CE|) and performance consistency by variable error (VE). Statistical analyses were performed for |CE| and VE. A schematic representation of the statistical design is given in (**Table 1**).

Results

Subjects' performance during the experiment was analysed in blocks of 10 trials. The dependent variables for each subject and condition were absolute constant error ($|CE|$) and variable error (VE).

A Groups by Blocks (3 x 6) analysis of variance (ANOVA) with repeated measures on the block factor was used to examine the group changes in each of the dependent variables across acquisition trials. A 3 group one-way ANOVA was used to examine the group differences in immediate retention. A Groups by Blocks (3 x 2) analysis of variance was used to examine the group changes in each of the dependent variables across retention tests (see Appendix B for copies of the ANOVA tables and Tukey's HSD test, and Appendix C for a complete listing of the raw data).

Acquisition

Absolute Constant Error.

The two way ANOVA for $|CE|$ revealed a significant main effect for blocks, $F(5,75) = 6.49, p < .001$. Tukey's follow-up test revealed an improvement in the performance of all groups as they progressed through the acquisition trials. The main effect for groups and groups by blocks interaction failed statistical significance $F(2,15) = .11, p = .94$ and $F(10,75) = .13, p = .999$ respectively. The $|CE|$ scores for each group over 6 blocks of ten trials are shown in Figure 6.

Variable Error.

The analyses of VE revealed similar results to that of $|CE|$. Figure 7 shows the VE score graph for blocks of ten trials. The main effect for groups and the groups by blocks interaction failed statistical significance, $F(2,15) = .99, p = .396$ and $F(10,75) = 1.17, p = .342$ respectively. There was a main effect of blocks, $F(5,75) = 2.45, p < .05$, for which follow-up tests indicated that the subjects were improving in consistency throughout the acquisition phase.

Immediate No-KR Phase

Absolute Constant Error.

The one-way ANOVA on groups in immediate retention revealed no significant effect for |CE| scores, $F(2,15) = .113, p = .89$.

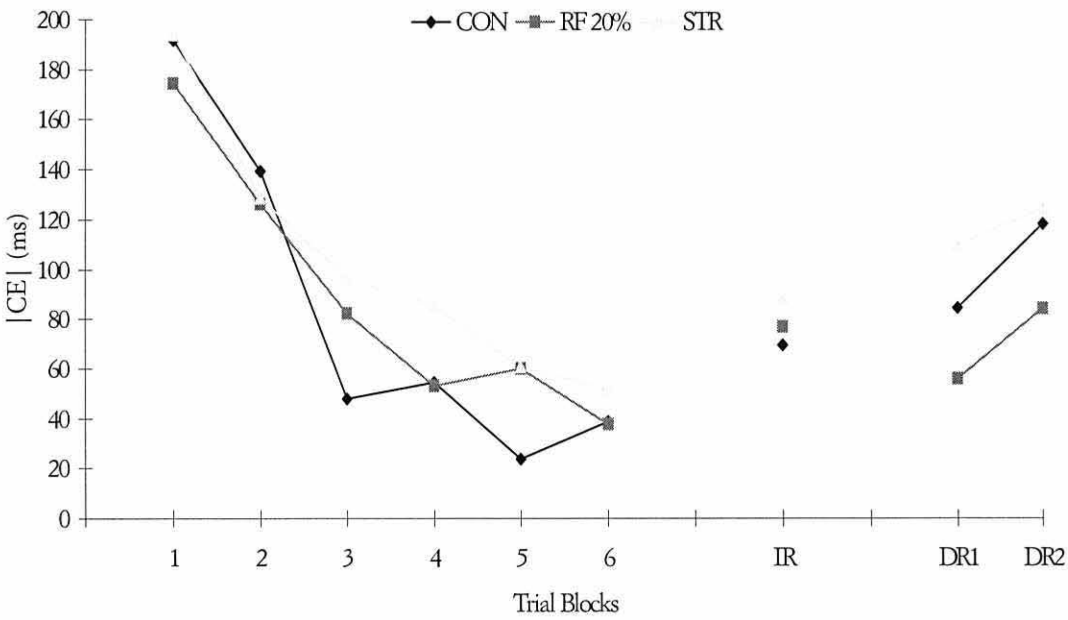

Figure 6. Absolute Constant Error (|CE|) scores in milliseconds for acquisition and retention trial blocks (Relative Frequency Experiment 1).

Variable Error.

The one-way ANOVA on groups also revealed no significant results for VE, $F(2,15) = .169, p = .947$. Figure 7 depicts one block of 10 trials immediate retention for VE.

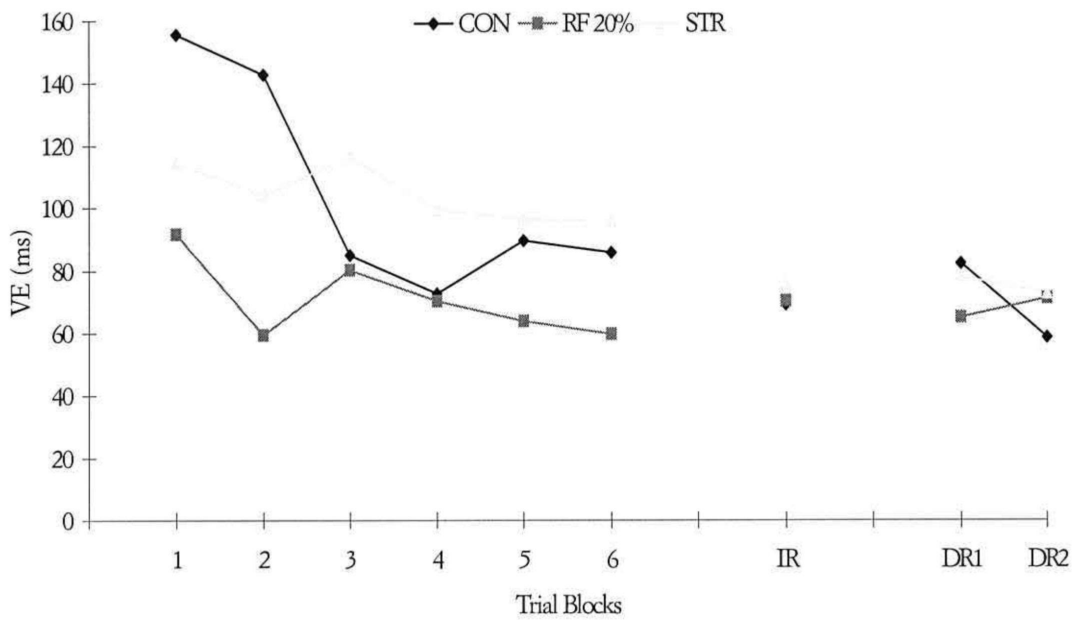

Figure 7. Variable Error (VE) scores in milliseconds for acquisition and retention trial blocks (Relative Frequency Experiment 1).

Retention Phase

Absolute Constant Error.

The |CE| scores for the three groups across the two 10-trial blocks in the retention phase are shown in Figure 6. A 3 (Group) by 2 (Block) ANOVA revealed neither a significant group nor a significant block effect, $F(2,15) = 0.58, p = .572$ and $F(1,15) = 2.82, p = .11$. The analyses of variance also yielded no significant group by block interaction, $F(2,15) = 0.14, p = .87$.

Variable Error.

The VE analysis also failed to produce significant results. The group main effect $F(2,15) = 0.21, p = .816$, block main effect $F(1,15) = 2.20, p = .159$ and the group by block interaction $F(2,15) = 2.90, p = .086$ all failed statistical significance.

Table 5. Means and Standard Deviations of |CE| (in milliseconds) for Acquisition and Retention tests in Relative Frequency Experiment One.

Groups (n=6)		BLOCKS								
		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	*M*	191.70	139.16	47.80	54.43	23.71	38.75	69.42	84.36	118.00
	SD	248.60	143.21	52.73	42.25	15.86	36.21	46.22	65.48	119.15
RF 20%	*M*	174.37	126.18	82.34	53.13	59.84	37.64	76.95	55.88	84.22
	SD	179.97	95.84	70.37	48.20	48.42	15.36	69.73	54.12	82.81
Strategy	*M*	193.92	128.59	96.19	85.09	60.79	51.67	87.74	109.72	124.42
	SD	191.11	169.02	120.05	76.01	77.81	49.45	80.76	45.97	106.53

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Table 6. Means and Standard Deviations of VE (in milliseconds) for Acquisition and Retention tests in Relative Frequency Experiment One.

Groups (n=6)		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	*M*	155.62	142.85	84.73	72.42	89.59	85.56	69.02	82.32	58.40
	SD	114.07	150.20	36.18	21.45	28.61	26.09	13.17	25.99	25.13
RF 20%	*M*	91.57	59.42	80.17	70.31	63.70	59.82	70.08	64.83	71.06
	SD	36.10	11.04	32.22	22.28	17.24	26.54	31.94	11.38	36.22
Strategy	*M*	114.36	104.23	116.50	99.49	96.67	95.79	75.87	77.86	72.56
	SD	71.70	61.44	73.87	59.80	75.38	55.99	16.22	17.43	7.76

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Discussion

This study examined the effect of using a strategy over retention of a simple barrier knockdown task in comparison to relative frequency and control conditions. The hypotheses of the experiment were that reduced frequency of KR (20%) during training would lead to enhanced retention performance relative to a control group (100%) and a similar enhancement of retention performance would be obtained by giving subjects a strategy of ignoring four out of every five KR presentations in an attempt to give more control to subjects and mimic the experimenter's manipulation of KR.

The results of this RF experiment failed to support the hypotheses outlined in the original experimental design. First of all the results failed to show that less frequent KR during training would lead to enhancement of motor learning. Secondly, it also failed to show that giving a strategy to subjects would produce similar benefits to those of RF 20% group whose feedback was manipulated by the experimenter.

The results indicated that the performance of the RF 20% and the STR groups were not different from the CON group in retention indicating that receiving less frequent feedback had no effect on the long term retention on this task. The 'classical' pattern of results for reduced RF KR in comparison to 100% RF KR, according to Salmoni et al. (1984), is that the 100% RF KR condition elicits superior performance throughout acquisition, but inferior retention in comparison to the lower RF conditions. As mentioned above, the strategy group was expected to show the same pattern of results as the 20% RF KR group. Neither the acquisition nor the retention findings for either of the two dependent variables supported this contention. Even in terms of the ordering of the means, the RF 20% and the CON group were only in the expected order for the |CE| of delayed retention. Where the meaningfulness of the results rested on the replication of the relative frequency effect, this was a discouraging finding. Finally, the ordering of the means of the STR group with respect to the other two groups suggested, if anything, that their retention performance was more similar to the CON group than the RF 20% group.

As was the case for the BW experiment, the failure was attributed to two possible causes. The first of these was related to the strategy that was used in the experiment and the second was related to methodological factors.

The strategy used to mimic experimenter's manipulation of the KR was to 'ignore' four out of every five-feedback presentations. This way it was hoped to duplicate the experimenter's manipulation of KR in the RF group, where subjects were only shown feedback every fifth trial. At the end of the experiment, it was observed that the subjects either intentionally failed to ignore or simply could not ignore the feedback when required to do so. If this observation was correct, this would explain why the strategy group performed similarly to the CON group. Still, the problem with the strategy effectiveness does not explain why the RF 20% did not perform significantly better than the control group. As with the bandwidth experiment, this latter outcome was attributed to methodological weaknesses.

The methodological weaknesses of the experiment might have been the number of subjects used in the experiment, which had a bearing on the power of the study (Cohen, 1988) and possible causes related with the subjects like, their heterogeneity (age difference & background) and the environment where the data was collected (these factors are discussed in more detail in later in the thesis), each of which may have contributed to a large standard deviation in scores within the group, which with a small group might swamp between group differences. These problems might in turn have affected the internal and external validity of the experiment, thereby affecting its possible outcome. It was proposed that a further experiment was needed to find the real causes of the failure of this study.

CHAPTER FIVE

Relative Frequency Experiment Two

Introduction

This second relative frequency experiment was in effect a replication of the first RF experiment. Because of the failure of the first experiment to support the experimental hypotheses was attributed to methodological weaknesses, this second study was conducted after some methodological changes were made.

The changes made to the design of this experiment were

1. an increase in the number of the subjects
2. employment of a more homogeneous group of subjects
3. a greater control over the experimental environment.

At the end of the first experiment, it was also felt that a post-experimental interview with the subjects to find out whether they were able to employ the given strategy would be of great value. This will be further discussed and explained in the discussion section of this chapter.

The number of subjects in this second replication RF experiment was increased from 18 to 24 with an increase of two subjects per group making 8 subjects in each group.

To ensure a more homogeneous group of subjects only second year right handed male physical education students of University of Wales Bangor served as the subjects. In the first experiment, both male and female adults with different backgrounds had participated to the experiment.

It was also felt that the environment in which the experiment was conducted might have had an effect on the subjects' concentration and motivation. Therefore, the experimental room where the first experiment was conducted was changed to another room to ensure that outside distractions would be minimal. The experimental room was also arranged in a way that the subjects' motivation would not be negatively effected.

Hypotheses

The hypotheses of the experiment were that reduced frequency of KR (20%) during training would lead to enhanced retention performance relative to a control group (100%) and that similar enhancement of retention performance would be obtained by giving subjects a strategy of ignoring four out of every five KR presentations (effectively receiving 20% of KR) in an attempt to RF group.

Method

Except where described below, the methodology and procedure of this experiment replicated that of the first relative frequency experiment.

Subjects

The subjects were 24 right-handed male physical education students from University College of North Wales, Bangor. Subjects' age ranged from 19 to 26 years (M = 23.3, SD = 2.0). All the subjects volunteered to participate in the experiment and were naive as to the purpose of it. Each subject received information about the task and the KR they were to receive before the experiment (see Appendix D for a copy of the instructions given to the subjects).

Apparatus and Task

The apparatus and the task used in this experiment were identical to that used in the first Relative Frequency experiment.

Procedure and Design

For this reason three groups of eight subjects were randomly allocated to each of the experimental groups (CON, STR & RF 20%). At the completion of the experiment, subjects in CON and RF 20% groups were asked whether they would be able to follow the instructions and apply the strategy that the subjects in the STR group were asked to use (see Appendix E).

Blocks of 10 trials were used to calculate measures of performance accuracy and consistency. Performance accuracy was assessed by absolute constant error (|CE|) and performance consistency by variable error (VE). Statistical analyses were performed for |CE| and VE.

Results

In this experiment the same statistical analyses and same procedures were followed as in the first experiment. In summary, the dependent variables of |CE| and VE were analysed using groups by blocks ANOVAs with repeated measures on the block factor (see Appendix B for copies of the ANOVA tables and Tukey's HSD test, and Appendix C for a complete listing of the raw data).

Acquisition

Absolute Constant Error.

A similar pattern of results was observed in this second experiment. The two-way ANOVA for |CE| yielded only a significant block main effect, $F(5,105) = 11.38, p < .001$. Follow-up test revealed an improvement in the performance by groups as they progressed through the acquisition trials. The group main effect $F(2,21) = 0.57, p = .574$ and group by block interaction $F(10,105) = 0.31, p = .977$ were not significant. The |CE| scores for groups are shown in Figure 8.

Variable Error.

Figure 9 shows the VE scores for blocks of ten trials. The ANOVA revealed only a significant main effect for blocks, $F(5,105) = 6.39$, $p < .001$, showing a decrease in the VE score across the blocks. Follow-up tests indicated that the subjects were improving in consistency throughout the acquisition phase. The main effect for groups and the groups by blocks interaction failed statistical significance, $F(2,21) = 2.77$, $p = .085$ and $F(10,105) = 1.21$, $p = 0.294$ respectively.

Immediate No-KR Phase

Absolute Constant Error.

The one-way ANOVA on groups revealed no significant effect for |CE|, $F(2,23 = 1.477, p = .25$. Figure 8 shows the |CE| data graphically.

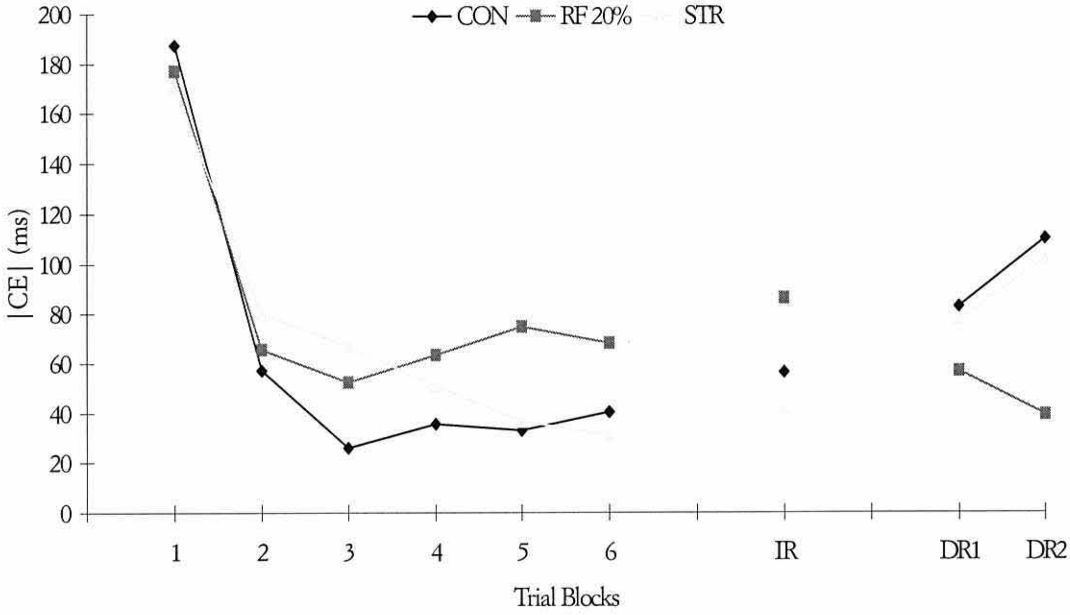

Figure 8. Absolute Constant Error (|CE|) scores in milliseconds for acquisition and retention trial blocks (Relative Frequency Experiment 2).

Variable Error.

The one-way ANOVA on groups also revealed no significant result, $F(2,23) = 3.20, p = .061$. Figure 9 represents the VE data graphically.

Retention Phase

Absolute Constant Error.

The |CE| scores for this second experiment also failed to produce any significant effects. The group $F(2,21) = 0.58, p = .570$) and block $F(1,21) =$

0.73, p = .404) main effects and the group by block interaction, $F(2,21)$ = 1.18, p = .327 all failed statistical significance. These data are graphically presented in Figure 8.

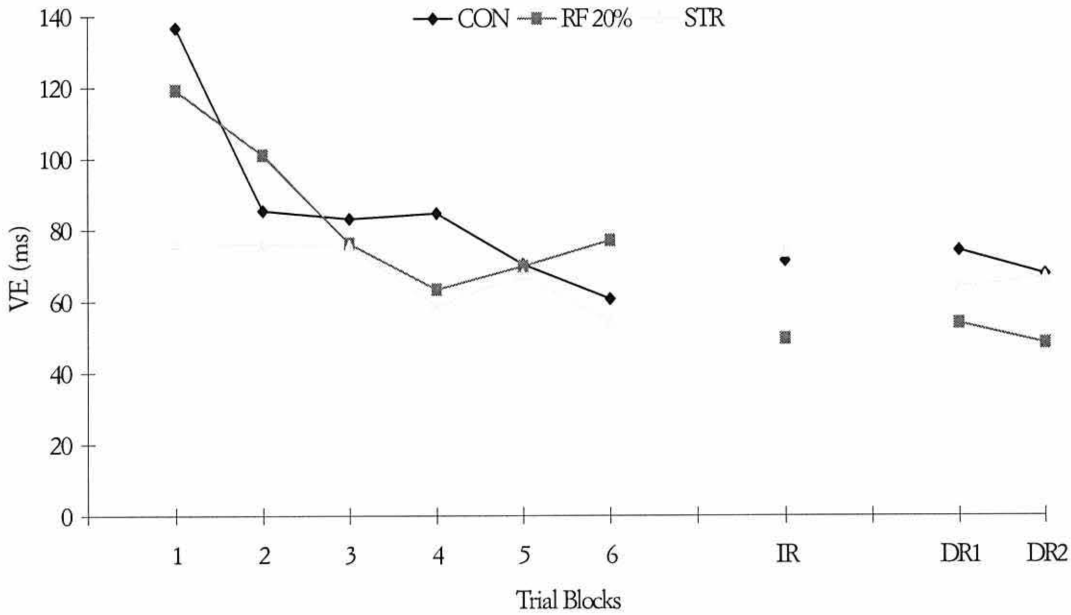

Figure 9. Variable Error (VE) scores in milliseconds for acquisition and retention trial blocks (Relative Frequency Experiment 2).

Variable Error.

The statistical analyses of VE in retention also produced non-significant results. The group main effect $F(2,21)$ = 1.69, p = .208, block main effect $F(1,21)$ = 0.53, p = .474 and group by block interaction $F(2,21)$ = 0.46, p = .636 all failed statistical significance. Figure 9 presents the VE data graphically.

Table 7. Means and Standard Deviations of |CE| (in milliseconds) for Acquisition and Retention tests in Relative Frequency Experiment Two.

Groups (n=8)		BLOCKS								
		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	*M*	187.13	57.00	25.99	35.29	32.80	40.19	56.48	82.56	109.80
	SD	156.52	45.17	14.73	28.99	14.67	31.71	45.68	84.80	154.56
RF 20%	*M*	176.90	65.33	52.18	63.21	74.42	67.96	85.76	56.69	39.10
	SD	144.07	44.90	47.56	92.28	29.94	33.18	49.13	40.70	40.31
Strategy	*M*	170.45	79.69	67.07	51.00	36.59	31.01	40.81	77.26	101.70
	SD	186.37	86.46	52.60	32.07	31.81	20.72	62.98	111.97	127.77

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Table 8. Means and Standard Deviations of VE (in milliseconds) for Acquisition and Retention tests in Relative Frequency Experiment Two.

Groups (n=8)		BLOCKS								
		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	IR Block	1st DR Block	2nd DR Block
Control	X	136.66	85.51	83.14	84.74	70.31	60.53	71.42	74.10	67.45
	SD	54.60	41.15	29.87	24.99	21.07	15.79	24.37	29.97	28.12
RF 20%	X	119.14	101.00	76.34	63.27	69.90	77.03	49.41	53.80	48.16
	SD	64.04	50.70	28.79	28.66	28.78	32.56	15.29	18.02	14.59
Strategy	X	76.19	75.99	75.47	58.50	67.33	54.63	73.84	64.11	66.84
	SD	35.45	32.68	28.98	29.03	31.24	15.43	23.07	29.09	24.30

Note. Each block represents average mean of 10 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Discussion

This second RF study which was a replication of the first RF study due to the failure of the first, almost confirmed the findings of the first one. No statistically significant result was found in this study in support of the hypotheses of the experiment. This lead to the rejection of the hypothesis that reduced frequency of KR (20%) during training would enhance retention performance relative to a control group (100%). The performance pattern of the CON and RF 20% group did not change between the first and second RF experiments, although within this experiment there was a trend for the RF group to be more consistent than either of the other two groups during immediate retention ($p=.06$). Also, the ordering of the means was as predicted for both |CE| and VE within delayed retention, and for |CE| within acquisition. Although slightly more encouraging than the first relative frequency experiment, these effects were still not significant, so the results as a whole still contradicted Salmoni et al.'s (1984) proposition that reduced frequency of KR leads to poorer acquisition but better retention performance than 100% RF KR.

The second hypothesis of the experiment, that the STR group would also perform better than the CON group in retention, was also rejected. With these studies, it was intended to find out whether subjects could use strategies as a way of processing and controlling the information available to enhance their learning during motor activities. It seems both from the results of both relative frequency experiments and the outcome of the informal questioning of subjects regarding their ability to conform to the requirements of the strategy that the strategy was not effective within the relative frequency paradigm.

The importance of finding the reason(s) for failing even to replicate the findings that many papers report regarding the use and benefits of reduced frequency of KR in motor learning was obvious. The reason for this second RF experiment was to replicate the first RF study as it was felt that some methodological factors relating to the power of the study and the internal and external validity of the first experiment might have been compromised. The changes that were felt necessary were:

1. to increase the number of the subjects from 6 per group to 8 per group between the two RF experiments to increase the power of the study
2. to conduct the experiment with a more homogeneous group of subjects as their experience prior to the experiment may have confounded the data.

As the findings of this second experiment were also not significant, some other possible causes of the failure of the study were sought. First of all, as for the bandwidth experiment, it is worth examining the research to ascertain the reliability of the relative frequency effect. Salmoni et al. (1984) cite four studies to have supported the relative frequency effect. Three of these used positioning tasks (Baird & Hughes, 1972; Ho & Shea, 1978; Johnson, Wicks, & Ben-Sira, 1981) and the other used a key-pressing task (Taylor & Noble, 1962). Yet even with this evidence, Salmoni et al. (1984) recommended caution, as an attempt to replicate the Johnson et al. (1981) experiment failed. Subsequent research has found mixed results. Winstein & Schmidt (1990), in the first of three experiments, did not find any difference between a 33% RF KR group and a 100% RF KR group with a (relatively) complex lever positioning task involving several movement reversals. Subsequent experiments achieved greater support for the reduction of relative frequencies of KR, but only within a fading paradigm, where KR was reduced from 100% RF to 10% RF over the course of acquisition. Sparrow & Summers (1992) failed to find support for the effect using a simple positioning task, and found extremely limited support (a trend of decreasing error in one of three reduced relative frequency groups in the second of two retention tests in only one of three error scores) in a movement distance task. Wulf, Lee & Schmidt (1994), in extending the relative frequency effect to examine generalised motor programme learning, did obtain a relative frequency effect when comparing a 100% RF condition to a 50% RF condition, using a similar task to that of Winstein & Schmidt (1990). Only one paper could be found that used a task similar to that used here, and that failed to find any group differences despite the use of a faded relative frequency paradigm (Wishart & Lee, 1997).

In summary the level of support for a pure relative frequency effect, where a 100% RF KR condition is compared to a reduced relative frequency condition is equivocal at best. Of the studies reported here, only Taylor & Noble (1962) seems to offer clear support of the purported effect. Considering also that no study could be found which offered support for the effect with the task used here, it may be that the results obtained in the present experiment are less surprising than first thought.

The only other possible factor left that might have had a profound effect on the data was the apparatus used during data collection. A test was conducted to find out whether the 380Z Research Machine that was designed to record the trial duration was working correctly. The test revealed that there was an error within the Research Machine's timer that decreased the clock's accuracy from ± 3 ms to ± 20 ms. This would have drastically reduced the timer's reliability, such that differences of the order of 30-40ms (such as those found in Lee & Carnahan, 1990) may have been lost.

In conclusion, a further examination of the literature seems to lead to the recommendation that a new task be chosen for the next study, within a more reliable KR paradigm. Neither the equipment, nor the relative frequency effect, nor the application of the strategy were found to be reliable within the present experiment.

CHAPTER SIX

Summary KR Experiment One[1]

Introduction

The experiments reported in the previous chapters failed to provide support for the possibility of the subjects' mimicking the experimenter's manipulation of information feedback by a cognitive learning strategy. These experiments were designed to increase the subjects' involvement in the control of feedback in an effort to show that passing control to subjects would yield similar results relative to a feedback condition that was controlled by the experimenter.

Although the support for subjects' control of the information feedback variable did not materialise in the previous experiments, it also failed to replicate the findings of the similar research in the KR area. For example in the BW KR experiment, 10% BW KR was not significantly better than the control group in retention. This was contradictory to Sherwood (1988), where it was found that a 10% BW condition achieved less within-subject variability than the CON group.

The result of the BW and the two RF KR experiments having failed to support the KR effects suggested that it was not only the STR group that failed to support the hypotheses but reduced frequency KR group also failed as well. For this reason, the search for reasons for the failure was turned toward the general methodology rather than the STR group itself. At the end of the experiments conducted so far, it was suggested that some methodological factors such as (a)

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[1] Part of this chapter has been presented at the 1994 annual conference of the British Association of Sport and Exercise Science, Aberdeen, UK, and appeared in the Journal of Sports Sciences, 13 (1), 62-63 (see Appendix F).

the number of subjects used in a treatment group and the heterogeneity of the subjects, (b) the nature of the strategy used, and (c) the apparatus used in the experiments might have contributed to the failure of the experiments.

Changing the perspective

In this chapter a new KR scheduling experiment was proposed that was designed on the basis of power, ease of application of the cognitive learning strategy, and the reliability of the apparatus used. The KR scheduling chosen for this experiment was summary KR. In summary KR scheduling the information feedback is presented via a graph of error scores over a pre-set number of trials (Schmidt et al., 1989). Thus, subjects are presented with a summary of their previous performance. In this scheduling, although the absolute frequency of KR is constant (at 100%) the summary presentation of the feedback is being manipulated by the experimenter. Hence, this type of manipulation was considered susceptible to subjects' manipulation of the KR. As the controlling factor by the experimenter is the manipulation of the amount of trials to be summarised, it should to possible for the subjects' to mimic this manipulation and receive 100% absolute frequency of KR but control the amount of trials to be summarised by a learning strategy.

Perhaps among the methodological factors that were identified as possible source of weakness in the previous experiments, the power of the experiment is a very important factor that affects the outcome of an experiment (Cohen, 1988). For this reason in order to increase the power of the experiment, it was decided to increase the number of subjects used from 6-8 to 10 subjects per group. Furthermore, the apparatus used in the experiment was chosen and designed to increase the validity of the measurement taken during data collection.

In the light of these changes made this study was designed to examine the effect of using a learning strategy given over acquisition and retention of a simple ballistic timing task in comparison to summary-KR and control conditions.

The purpose of the present study was to investigate the effect of a 10-trial summary-KR condition, a summary-KR strategy condition and a summary-KR yoked strategy condition in comparison to a 1 trial summary-KR control condition across acquisition and retention trials.

Hypotheses

It was hypothesised that 10 trial summary-KR group would perform better than the 1 trial summary-KR control group in retention. It was also hypothesised that both summary-KR strategy groups would perform as well as the 10-trial summary-KR group in retention.

Method

The task and all procedures of this experiment closely followed those of Schmidt et al. (1989). Four groups were given acquisition and two retention tests on a double reversal linear slide task. In all conditions subjects performed the same amount of trials and participated in the same Immediate Retention (IR) trials and 2-day no-KR delayed Retention (DR) tests.

Subjects

The subjects of this experiment were 46 students (28 male & 18 female) from University of Wales, Bangor. Subjects' age ranged from 20 to 38 years (M = 27.33, SD = 4.76). All the subjects volunteered to participate in the experiment and were unaware of its purpose. They had no prior experience with the task. Of these 46 subjects, 6 were unable to participate in the retention test and were not included in the final data analyses.

Apparatus and Task

The task and apparatus closely followed that of Schmidt et al. (1989). The apparatus consisted of a horizontal stainless-steel bearing (100 cm) mounted on a table in front of the subjects. A vertical handle sat on a metal block containing ball bearings. This arrangement allowed the handle to slide almost frictionlessly along the steel track. Two optical switches were mounted on the apparatus to start and stop a digital millisecond timer. The first switch was placed at the right end of the track and started the timer when the slide moved from away it. The second switch was placed 40 cm to the left of the first and stopped the timer when the slide passed it. Two other optical switches were used to trigger an electronic counter that ensured that the subjects reversed at the correct place. All switches, including both start and stop, were connected to the electronic counter, which counted the number of times the slide passed through a switch during each trial. The count of 8 signified a correct movement. The counter was reset before each trial.

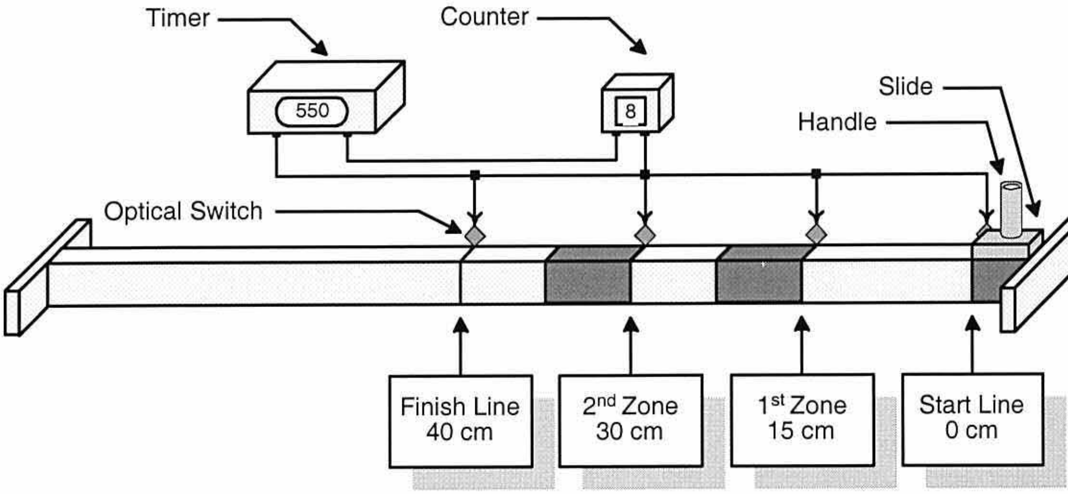

Figure 10. Illustration of the apparatus used in the summary KR experiment (including the counter and the timer).

Two 5-cm wide target zones were located under the track 15 and 30 cm to the left of the right end of the start switch. The 5-cm target zone located at 15 cm was marked as 'Zone One' and second target zone at 30 cm was marked as 'Zone Two'.

The subject's task was to grasp the handle, which was positioned at the right end of the track (at the start line), and to move the slide 30 cm leftward to 'Zone Two', then reverse 15 cm right to 'Zone One' and then again reverse the direction to move through the 40 cm finish line until the slide passed the optical switch with a follow through. Each subject's goal was to complete the task in as close to 550 ms as possible in every trial. Time was recorded with the digital millisecond timer, but spatial accuracy at the intermediate targets was only observed, not recorded. An early reversal of the movement was considered an incomplete movement and was replaced with a subsequent complete correct trial. The subjects were instructed to begin each trial after a verbal 'go' signal.

The initiation time of the movement was neither stressed nor recorded during the whole experiment.

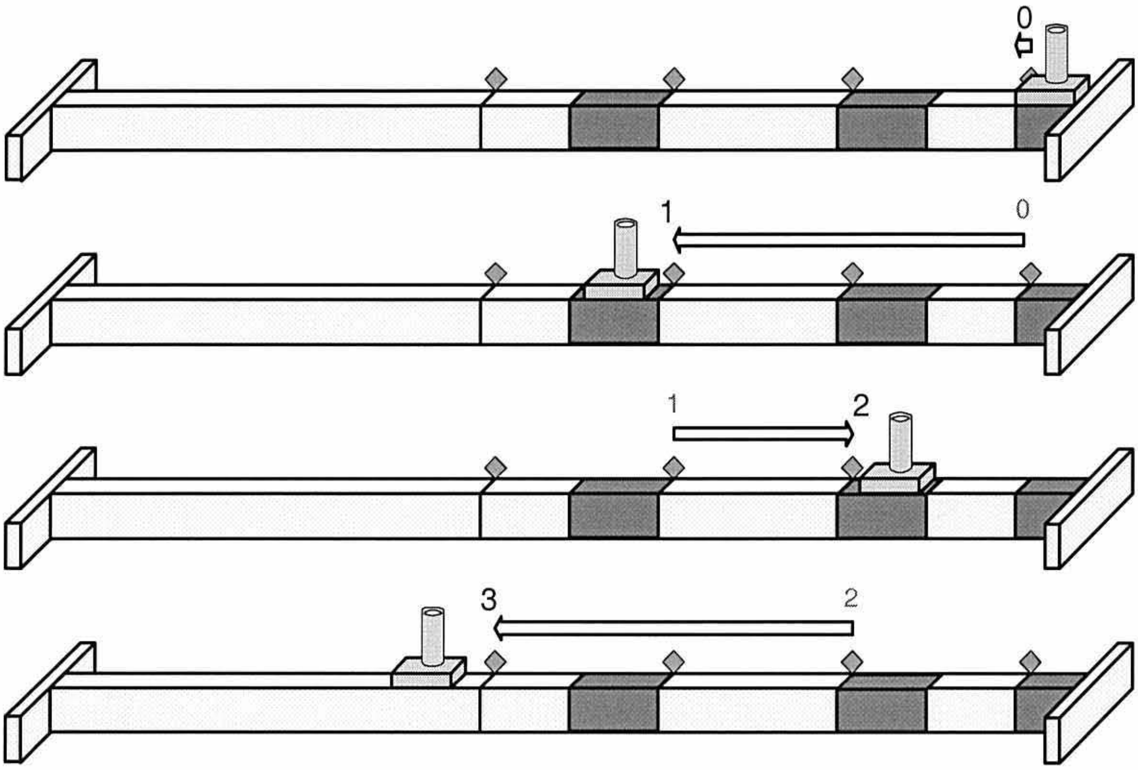

Figure 11. Illustration of a correct arm movement in summary KR experiment.

The data were inserted to an IBM compatible Personal Computer by using a spreadsheet package program (Microsoft Excel for Windows version 4.0c). The same program was used to display the feedback graph on the screen by using a macros (see Appendix A for a listing of the macros used in the experiment)

<u>Procedure and Design</u>

The 40 subjects were randomly assigned to one of four summary-KR conditions that differed in terms of summary-KR length. The four conditions were (a) 1 trial summary-KR control group (CON), (b) 10 trial summary-KR group (SUMKR10), (c) 10% summary-KR strategy group (STR) and (d) 10% summary-KR yoked strategy group (Y-STR). Prior to the experiment subjects were all introduced to the task and received information about the KR presentation they were to receive. In this experiment, only right-handed subjects were used all were allowed to perform a couple of trials, without any feedback, to ensure that they understood the movement before starting the experiment. After each trial (or set of trials), a graph was presented on a 36 cm (14 inch) computer screen depicting performance accuracy over trials. In each condition the subjects' constant error (with respect to sign, e.g., +25) was presented on a positive x-axis (representing trial number) and a positive/negative y-axis (representing error in milliseconds).

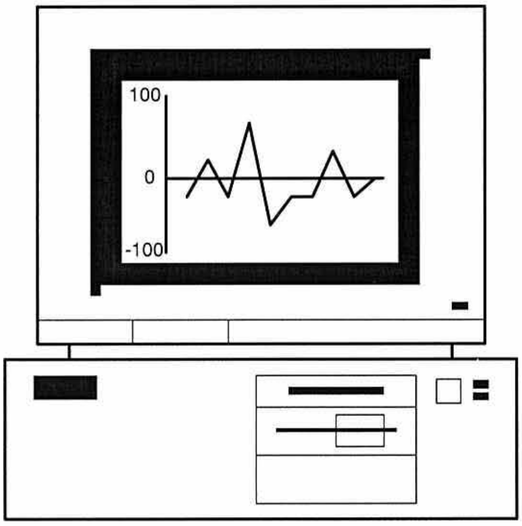

Figure 12. Illustration of the PC screen showing feedback graph in summary KR experiment.

The control group received information after every trial, with one KR point being displayed at any one time. In the SUMKR10 and Y-STR groups, the graph was shown only after completion of the appropriate number of trials for that summary-KR condition. In the strategy (STR) group, the graph was shown only when subjects asked to see it. The STR group was instructed that they would only be able to see the graph after 9 trials out of 90 (10% of their trials) and that only they would decide at which intervals to receive the feedback. They were therefore encouraged to actively develop a strategy for deciding when the information might be most useful. Each subject in the Y-STR group was matched with a subject in the STR group, and was given feedback according to the schedule selected by their individual counterpart. The data points in all summary-KR groups except the CON group were connected by line segments. No Verbal KR was given throughout the experiment.

All groups performed 90 acquisition trials, after which they rested outside the testing station for 10 minutes. Then subjects were given 30 trials without KR for the immediate retention test. Two days later, they performed 30 more trials, also without KR, for the delayed retention test.

Blocks of 15 trials were used to calculate measures of performance accuracy and consistency. Performance accuracy was assessed by absolute constant error (|CE|) and performance consistency by variable error (VE). Statistical analyses were performed for |CE| and VE. A schematic representation of the statistical design is given in **Table 1**.

Table 9. Statistical Design for Summary KR Experiment One

		BLOCKS							
Groups	n	1st Acq	2nd Acq	3rd Acq	4th Acq	5th Acq	6th Acq	IR	DR
(n=10)		Block	Block	Block	Block s	Block	Block	Block	Block
	S1								
Control	-								
	S1								
	0								
	S1								
SUMKR10	-								
	S1								
	0								
	S1								
Strategy	-								
	S1								
	0								
Yoked	S1								
Strategy	-								
	S1								
	0								

Note. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Results

Subjects' performances during the 90 trials acquisition phase were analysed in blocks of 15 trials, but performances during the two retention tests were analysed in blocks of 30 trials (following Schmidt et al. 1989). The dependent variables were absolute constant error (|CE|) and variable error (VE).

A groups by blocks (4 x 6) analysis of variance (ANOVA) with repeated measures on the block factor was used to examine the group changes in each of the dependent variables across acquisition trial blocks. A 4 group one-way ANOVA was used to examine the group changes in retention. Tukey's follow-up test was then used following significant group effects in retention (see Appendix B for copies of the ANOVA tables and Tukey's HSD test, and Appendix C for a complete listing of the raw data).

Acquisition

Absolute Constant Error

The 2 way ANOVA revealed a significant main effect for blocks, $F(5,180) = 39.67, p < .001$. Follow-up test revealed an improvement in |CE| as all groups progressed through the acquisition trials. There was no significant main effect for groups, $F(3,36) = 2.25, p = .099$. Although the Y-STR group performed poorly in acquisition and had almost twice as much error as the STR group at the sixth block, this effect was not significant. In addition to this there was also no significant group by block interaction, $F(15,180) = 1.61, p = .076$. The |CE| scores for the groups during acquisition test are shown in Figure 13.

<u>Variable Error</u>

The result of the VE scores in acquisition was similar to that of the |CE| scores. The main effect for block was significant $F(5,180) = 38.07, p<.001$, showing a decrease in the VE score across the blocks. Follow-up tests indicated that the subjects in all the groups were improving in consistency throughout the acquisition phase. The main effect for group and group by block interaction were not significant, $F(3,36) = 1.27, p = .301$ and $F(15,180) = 1.37, p = .165$ respectively. The STR group appeared to have low VE scores in 1st and 2nd acquisition blocks but this effect was not significant. The VE scores during the acquisition test are shown in Figure 14.

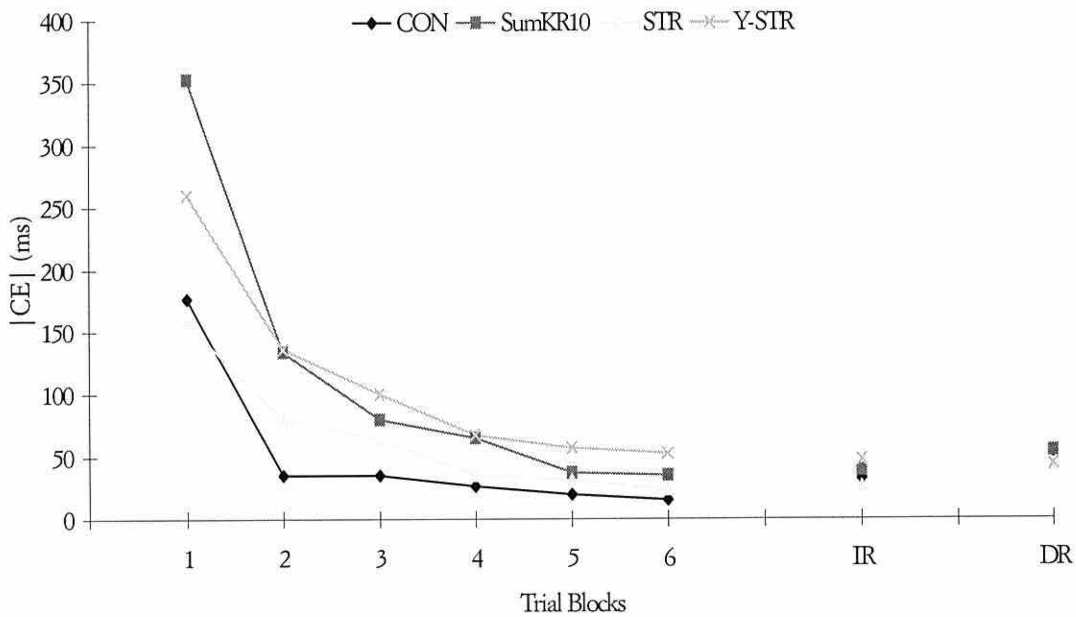

Figure 13. Absolute Constant Error (|CE|) scores in milliseconds for acquisition and retention trial blocks (Summary KR Experiment 1).

Immediate Retention

Absolute Constant Error

The |CE| scores for the groups in IR test after 10 min are shown in Figure 13. A one-way ANOVA revealed no significant group effect, $F(3,36) = 1.10, p > .05$ (see Figure 13).

Variable Error

The one-way ANOVA for VE scores across conditions revealed no significant group effect, $F(3,36) = 1.10, p > .05$ (see Figure 14).

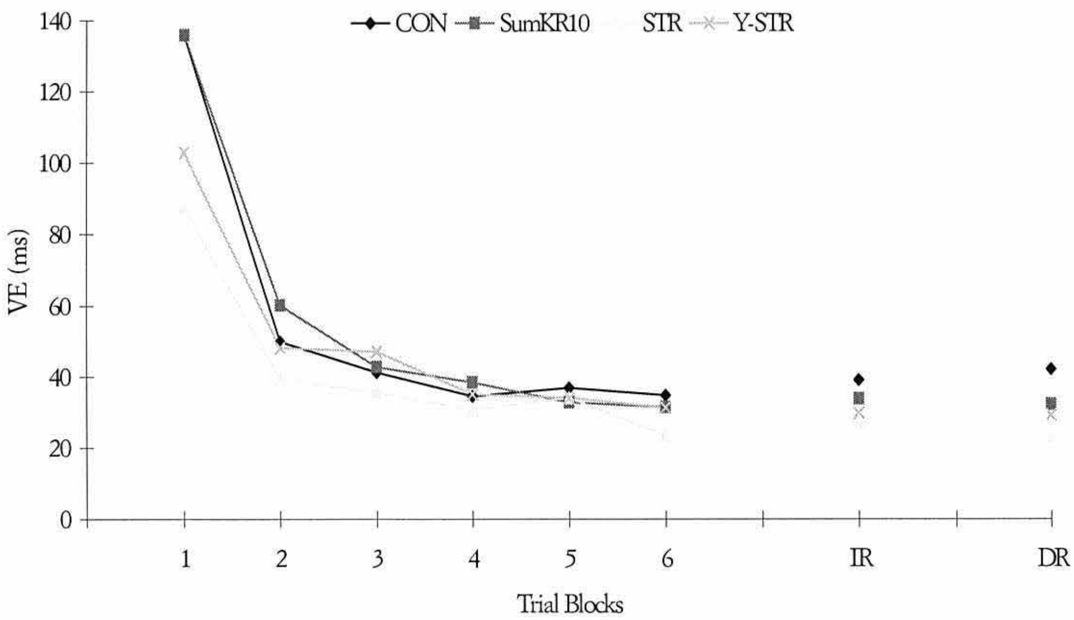

Figure 14. Variable Error (VE) scores in milliseconds for acquisition and retention trial blocks (Summary KR Experiment 1).

Delayed Retention

Absolute Constant Error

The |CE| scores for each group in the DR tests are shown at the right side of the Figure 13. The ANOVA test revealed no significant differences between groups in DR, $F(3.36) = .326, p = .806$. The standard deviation of the groups indicated that the range of movement times were variable within all groups. The mean and standard deviation of the |CE| scores for the CON, SUMKR10, STR and Y-STR groups for DR were $M = 53.73, SD = 36.18$; $M = 38.34, SD = 29.10$; $M = 40.49, SD = 21.92$ and $M = 43.69, SD = 55.23$ respectively.

Variable Error

The group effect for VE was significant, $F(3,36) = 5.30, p < .05$. The follow-up Tukey's test revealed that the CON group had significantly higher VE score than STR group and there were no significant differences among other groups. The mean and standard deviation of the VE scores for the CON, SUMKR10, STR and Y-STR groups for DR were $M = 41.77, SD = 15.69$; $M = 31.16, SD = 12.26$; $M = 21.53, SD = 6.10$ and $M = 29.23, SD = 9.55$ respectively.

Table 10. Means and Standard Deviations of |CE| (in milliseconds) for Acquisition and Retention tests in Summary KR Experiment One.

		BLOCKS							
Groups (n=10)		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block s	5th Acq Block	6th Acq Block	IR Block	DR Block
Control	*M*	179.42	32.41	30.88	18.57	20.29	16.40	26.34	53.74
	SD	133.54	38.43	29.71	18.86	20.90	9.20	18.54	36.18
SUMKR10	*M*	237.77	60.85	32.63	25.09	18.85	15.11	25.16	38.34
	SD	165.20	71.08	29.45	29.88	17.11	17.24	22.33	29.10
Strategy	*M*	106.69	55.76	49.06	26.43	22.23	19.60	26.65	40.49
	SD	106.12	65.86	58.66	40.32	30.45	25.19	17.88	21.92
Yoked	*M*	259.37	135.70	99.82	67.53	57.12	52.31	47.47	43.69
Strategy	*SD*	237.88	153.78	100.77	78.36	58.43	61.30	44.96	55.23

Note. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention.

Table 11. Means and Standard Deviations of VE (in milliseconds) for Acquisition and Retention tests in Summary KR Experiment One.

Groups (n=10)		1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block s	5th Acq Block	6th Acq Block	IR Block	DR Block
Control	*M*	105.60	141.16	48.04	38.75	31.39	33.05	32.61	31.78
	SD	3.20	79.74	40.09	20.37	15.54	16.60	12.25	13.45
SUMKR10	*M*	206.80	126.18	51.19	32.67	32.40	30.73	31.98	34.93
	SD	3.65	91.00	27.44	11.01	19.61	12.82	13.65	8.22
Strategy	*M*	305.80	73.15	37.37	32.11	30.80	32.79	23.18	27.14
	SD	3.43	62.75	20.07	7.20	12.02	11.64	8.52	6.57
Yoked	*M*	405.50	102.85	48.06	47.21	35.10	33.93	31.19	29.60
Strategy	*SD*	3.03	63.74	28.24	21.97	12.80	14.88	13.01	8.71

Note. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials. Acq = acquisition; IR = immediate retention; DR = delayed retention..

Discussion

This study examined the effect of using a given learning strategy over acquisition and retention of a simple ballistic timing task in comparison to summary-KR and control conditions. Specifically, the purpose of the study was to investigate the effect of a 10-trial summary-KR condition, summary-KR strategy condition and a summary-KR yoked strategy condition in comparison to a 1 trial summary-KR control condition across acquisition and retention trials.

The hypothesis of the experiment was that the summary-KR strategy group would perform as well as the 10-trial summary-KR group in retention, and that all reduced frequency summary-KR groups (SUMKR10, STR & Y-STR) would perform better than the 1 trial summary-KR control group in retention. The Y-STR group was expected to perform somewhere between the CON group and the two other groups, as it benefited from reduced relative frequency KR, but did not benefit from the freedom of choice of the STR group in determining when to receive their summary KR. Finally, it was also expected that the acquisition pattern of results found by Schmidt et al. (1989) would be supported in that the CON group would display smaller error scores throughout acquisition than any of the other three groups.

The effect of group in the delayed retention test using VE as the dependent variable offered partial support for the main experimental hypothesis. The STR group was more consistent than the control group supporting the use of the self-governed strategic use of feedback as an aid to motor learning. However, the consistency of the SUMKR10 and Y-STR groups was not significantly better than the control group. Considering that the Y-STR group received the same number of trials and received feedback at same intervals as the STR group, their consistency was not as good as STR group who had the chance to control the way KR was given to them. Because of this result, it was hypothesised that merely giving control to the subjects over their own feedback requirements was sufficient to facilitate consistency.

To relate this finding to previous research on summary KR effects, the arguments offered in support of the summary KR effect by Schmidt et al. (1989) are useful. They suggest that the long periods of no-KR undergone by summary KR groups during acquisition fosters an awareness in the subject of the utility of response produced feedback as a substitute for the absent KR. Prolonged practice with this subjective reinforcement has been proposed elsewhere to lead to a greater sensitivity to the nature of the errors (Adams, 1971; Schmidt, 1975). This kind of explanation would seem to be especially pertinent here, as the effect emerged only in VE and in delayed retention, which provides a test of the subject's capability to maintain consistent performance two days after acquisition, in the absence of any guidance from KR. Where the effect suggests that the STR group performs better in relation to the CON group than either of the other two SUMKR groups, it offers some support for the notion that merely allowing subjects to specify where they wish to 'inject' the KR throughout acquisition in some way increases the utility of this attention. This can be accounted for in much the same way that bandwidth effects have been explained (Lee & Carnahan, 1990); allowing the subject more freedom to receive feedback when they feel they need it, while ensuring that a maximum number of KR trials is not exceeded, may in turn allow the feedback to be injected into the acquisition phase at junctures that are more appropriate for the learner's needs. If learning is not progressing well over the first few trials then early feedback may be beneficial. If the task is found relatively easy, then feedback may be used in a more precise way later to monitor small adjustments in performance. In any event, where summary KR can be seen to function as a consequence of subject's increased sensitivity to their own error, it seems sensible to offer them a chance to exploit that sensitivity in some way. The evidence produced here offers some support for the contention that this extra flexibility is of some use.

Notwithstanding the arguments offered above, the finding of an effect for VE in delayed retention was surprising, especially given the lack of effects in |CE|. Previous research that had used the linear slide had found summary KR effects in |CE| rather than VE (Guay, Salmoni & McIlwain, 1992; Schmidt et al., 1989). This pattern of results has been generally supported in the literature, with most summary KR studies finding effects in |CE| (Carnahan, Vandervoort, & Swanson, 1996; Gable, Shea & Wright, 1991; Guay et al., 1992; Schmidt et al., 1989; Weeks & Sherwood, 1994 (10min retention interval); Wright, Snowden, & Willoughby, 1990). However, some have reported the opposite trend (Guay, Salmoni, & Lajoie, 1997; Weeks & Sherwood, 1994 (2 day retention interval)), while still other studies either do not analyse components of response bias and consistency separately (Guadagnoli, Dornier, & Tandy, 1996 [used RMSE error]; Schmidt, Lange & Young, 1990 [used raw performance scores]) or do not obtain any support for the summary KR effect (Sidaway et al. 1991; Sidaway, Fairweather, Powell, & Hall, 1992). The unusual nature of this effect could be taken as further evidence of its separability from traditional summary KR effects, and its similarity to bandwidth-type effects, which have been quite common with the VE measure (Lee & Carnahan, 1990; Sherwood, 1988). Changes in VE are thought to reflect the effectiveness of the underlying motor program for the movement (Schmidt, 1975; Schmidt et al., 1989), whereas changes in |CE| are purported to reflect the effectiveness of the program's parameterisation (Schmidt et al. 1989). This is of course, a tenuous supposition, but worthy of further investigation.

Regardless of the reasons for the VE finding in delayed retention, the experiment still failed to provide an adequate comparison of the strategy condition to traditional summary KR manipulations. For this the traditional summary KR effect had to be obtained. Unlike the relative frequency effect, the summary KR effect found by Schmidt et al. (1989) has been successfully replicated (Guay et al., 1992), and has generalised well to other tasks such as force production (Gable et al., 1990; Guadagnoli et al., 1996) and lever positioning (Guay et al., 1997; Schmidt et al., 1990). Thus, it is hard to account for the lack of such a finding in the present experiment without returning once again to the methodological problems mentioned in earlier chapters. It is also hard to conclude that these methodological problems are anything but such things as the attentional focus of the subjects, or indeed the number of subject's used in the experiment (Schmidt et al., 1989, used 18 subjects per group to the 10 used in the current experiment). Such variables have a strong impact on such related factors as effect size and the power of the statistical tests used. Such problems may explain why the frequently 'correct' ordering of means within the experiments discussed thus far has failed to result in the expected significance. For example, in the current experiment the ordering of the means in the |CE| acquisition analysis looks like a perfect replication of Schmidt et al. (1989), yet only a trend was apparent in the analysis (p=.076).

In conclusion, it is suggested that a complete revision of the experimental protocols is required prior to another attempt to generate the traditional KR effect against which to compare the strategy condition. This revision is discussed in detail in the next chapter.

CHAPTER SEVEN

Cross-Roads

A series of studies has been conducted to find out whether subjects can take control of their KR requirement and in doing so can mimic the KR manipulations of the experimenter as in many traditional experiments. It was hypothesised that subjects in a strategy group and subjects in KR scheduling groups would perform better in retention than subjects in a control group who received feedback after very trial. To confirm this hypothesis, a combination of two group effects was necessary. Firstly, the much-cited benefit of a reduction in the frequency of KR promoting greater retention of skill needed to be replicated. Secondly, this facilitative effect had to be matched by the strategy group.

In total four experiments have been conducted; within which the sample size and the method of KR scheduling have varied. The KR schedule in the first experiment was bandwidth KR, in the second and the third experiment, it was relative frequency KR, and in the fourth experiment, it was summary-KR. None of these four experiments totally supported the original hypotheses, which would normally result in the experimental hypotheses being rejected on the bases of the results of the studies. However, it was felt within each of the studies that other factors relating to experimental control and statistical power contributed to their failure to confirm the experimental hypotheses. This suspicion was in part due to the apparent strength of the relative frequency effect of KR across a number of KR schedules, which none of the four experiment's had managed to replicate. Some attempts to rectify these problems were made in the third and the fourth experiments, but neither set of changes was particularly effective. Consequently, it was decided to analyse these problems in detail, so that they might be more appropriately dealt with in the next experiment.

This chapter will address the possible reasons for the equivocal results in each of the experiments. On the basis of this analyses a further experiment will be suggested which will take into account all the possible causes of the previous equivocality, and attempt to eliminate them.

Reasons for the failure of the experiments:

Some elements of the following discussion have been addressed in previous chapters. However, for the sake of completion it was felt necessary to cover all the issues together in this summary.

The equivocal results of the experiments were attributed to the following possible causes, each of which might have affected the internal and/or external validity of the findings:

1. The apparatus used in the first three experiments
2. The subjects used in the experiments
    a) The number of subjects used in the experiments
    b) The subjects' heterogeneity in age and sport related experience
    c) The subjects' level of concentration
    d) The subjects' level of motivation
3. The subjects' lack of understanding of the procedures of the task
4. The validity of the experimental treatment used in the first three experiments
5. The environment in which the data were collected
6. The way feedback was given to the subjects in first summary-KR experiment

Each of these factors is discussed below, under the relevant sub-headings. A summary of the factors affecting each experiment is presented in Table 12.

Apparatus:

In each experiment, time was the dependent variable. It was therefore imperative that the apparatus used in each experiment should be capable of performing to within two or three ms error. At the end of the bandwidth and relative frequency experiments, it was observed that there was a fault in the apparatus that generated some random error. Upon inspection, it was found that the central timing operation of the computer (380Z Research Machine) was faulty. The error of ±20 ms difference was calculated which obviously would have had a profound effect on the internal validity of these experiments. One possible effect of this machine error might explain the within-subject variability where the standard deviation of the subjects' scores was observed as high.

Subjects:

i. Numbers

It was recognised that a limitation in the experiments was the small number of subjects (n=6-8). Such a small sample size obviously reduced the probability of obtaining statistically significant differences in order to maintain an appropriately powerful experimental design (Cohen, 1977). To raise the power of the test to an acceptable level, Cohen (1977) recommends a sample size of close to 20 subjects per group.

ii. Homogeneity

Another factor, which could have compounded the effect of a small sample size, was the heterogeneity of the subject pool in terms of their experience with physical activity in general. The vast majority of research into Knowledge of Results, and other topics within motor learning, uses undergraduate Physical Education students as subjects (Wulf & Schmidt, 1989; Schmidt et al., 1990; Winstein & Schmidt, 1990; Gable et al. 1991; Goodwin & Meeuwsen, 1995). These students are all likely to share some level of sport-related experience.

The level of sport-related experience in the subject's used for the experiments reported here has to this point been variable, with some subjects being Physical Education students while others have been drawn at random from the undergraduate population of Bangor University. Such a marked variation in the physical skills of the subjects could have inflated the within-subject variation for all groups. This could have reduced the effect size between the groups (Cohen, 1977) and hence further reduce the power of the statistical tests.

iii. Concentration and motivation

Although the apparatus and experimental procedure of the summary-KR experiment replicated that of Schmidt et al. (1989), it failed to replicate their results. A possible contributory factor might have been that unlike Schmidt et al. (1989) subjects in this study were not participating in the experiment for course credit. During the studies, it was noted that a lack of interest or motivation was quite visible in the attitude of some of the participants. This observation was reinforced by the post-experimental comments that some of the subjects were invited to make. Some of the comments were; "I was not very interested with the experiment". "I could have done more to achieve the target but I found the task boring". It is recognised that subjects in Schmidt et al.'s (1989) study were naive as to the purpose of the experiment, however it is nevertheless, reasonable to suppose that students participating in an experiment for course credit might be more suitable as subjects, because of their extrinsic motivation. Although random allocation of groups should be sufficient to control any within-subject differences in motivation that might exist, members of the strategy and less frequent KR groups are inevitably more susceptible to losses of concentration as these subjects were required to practice the same simple arm movement without any feedback for longer times. For this reason, the subject's level of motivation and concentration must also be considered in any further study.

Use of strategy:

Another possible reason why the subjects in the strategy group in the bandwidth and relative frequency experiments did not perform as expected was highlighted by information gathered during debriefing at the end of the second relative frequency experiment. Half of the subjects interviewed pointed out that they would not be able to ignore the feedback they would receive and that they would register it and possibly use it in later trials. In addition, this one subject also answered saying that it would be difficult to ignore the score given on the screen.

Feedback presentation:

In the first summary-KR experiment, one of the procedural problems was related to the way the graph used to present feedback handled errors outside the ± 100 ms range of its y-axis. During the pilot test of this experiment, there were very few occasions where the subject's score was outside the graph's visible range and at the time it was not considered a major problem. In order to rectify this subjects were told that if they saw no data points or lines on the graph they should interpret it as either too fast or too slow movement and it would be highly likely that it was a slow movement. In line with the other studies, it was thought that verbal feedback relating to the subjects' movement time should not be given during the experiment. This procedural error may have led to some subjects in the control group receiving no precise KR at all at the beginning of the experiment, hence seriously affecting their performance. This may be seen from **Figure 13**, as the performance of control group subjects in the Summary KR One experiment seems to be impaired during the first 10-15 trials.

What next?

Having identified all of the above problems, the next step was to make the changes necessary to eliminate them from the final study. These changes are outlined below.

To investigate the extent to which subjects can mimic a KR manipulation, it was obviously necessary to select a task that had demonstrated its susceptibility to such effects. Initially an obvious choice was Lee, Magill and Weeks' (1985), and Lee and Carnahan's (1990) barrier knockdown task. As the problem with the timing mechanism of the apparatus used in the bandwidth and relative frequency experiments surfaced, another task had to be found. Schmidt et al.'s (1989) linear slide task was then the obvious choice. Indeed, the result of the first summary-KR experiment partially supported the experimental hypotheses but failed to replicate the Schmidt et al.'s (1989) findings.

Before we set out to find possibly a new task and/or new KR schedule some criteria were laid down because of the basic experimental design used in the study. The criteria were as follows:

1. The experimental design restricted the type of KR schedule used in this experiment because it had to allow the subjects to be able to mimic experimenters' KR manipulation.

2. The task had to be a simple and easy to perform motor task. It also had to be a novel movement in order to minimise within-subjects variability, as prior experience or familiarity with the movement would have a profound effect on the outcome of the experiment.
3. The experiment to be replicated had to show that the KR treatment was significantly better for learning a motor task than a control group. This was a limitation as one the hypotheses of our experiment was to show that subjects manipulating the provision of their own KR would perform as well as the subjects whose KR provisions were manipulated by the experimenter for them.
4. The experiment to be conducted had to be applicable within our laboratory and time limitations.

After a thorough review of related studies on KR scheduling (Salmoni et al., 1984; Schmidt et al., 1989; Lee & Carnahan, 1990; Winstein & Schmidt, 1990; Sidaway et al., 1991, 1992) it was finally decided to re-run the summary-KR experiment as it fulfilled all of the criteria laid down.

In order to limit the effects of the previously discussed factors on the next experiment, the following list of recommendations was drawn up:

1. Increase the number of the subjects from 6-8 to over 16 subjects per group.
2. Select a subject pool from the undergraduate population students of the Division of Health and Human Performance of University of Wales, Bangor.
3. Introduce a point scoring system to maximise the subjects' motivation to learn. Subjects would be awarded a number of points depending on the accuracy of their performance. These points would be displayed as a cumulative score after each trial or blocks of trials depending on the practice group.
4. Award course credits to maximise the subjects' motivation to participate in the experiment.

5. Increase the range of the feedback graph from ± 100 ms to ± 150 ms, and provide verbal feedback where necessary.

Table 12: A summary of the factors effecting each experiment

	Experiment			
Factors	Bandwidth	RF One	RF Two	Summary KR
Apparatus	Fault in apparatus	Fault in apparatus	Fault in apparatus	
Subjects	Low number of subjects [a]	Low number of subjects [b]	Low number of subjects [c]	Low number of subjects [d]
	Heterogeneity of the subjects	Heterogeneity of the subjects		Heterogeneity of the subjects
	Low motivation & concentration	Low motivation & concentration	Low motivation & concentration	Low motivation & concentration
Strategy	Weakness in strategy	Weakness in strategy	Weakness in strategy	
Feedback Presentation				Graph's limited y-axis range

Note. RF = relative frequency. Numbers of subjects per group who completed retention tests in each experiment [a]n = 6; [b]n = 6; [c]n = 8; [d]n = 10.

CHAPTER EIGHT

Summary KR Experiment Two[2]

Introduction

After a thorough analysis of the outcome of the first summary KR experiment, it was felt that the failure to support the experiment's hypotheses was due to methodological weaknesses. This experiment was conducted to overcome those methodological weaknesses, and therefore provide a true test of experiment's hypotheses.

The major changes made before this second test were;

1. An increase in the number of subjects.
2. The use of a more homogeneous group of subjects with respect to their understanding and approach to research projects from the first experiment.
3. A greater control over the testing environment.
4. The way the feedback was given to the subjects when their constant error score exceeded the graph's range of ± 150 ms.
5. Finally, a point scale was introduced to maximise the subjects' motivation to learn (see the Appendix E for full copy of the scale).

Hypotheses

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[2] Part of this chapter has been presented at the 1995 annual conference of the British Association of Sport and Exercise Science, Belfast, UK, and will appear in the Journal of Sports Sciences (see Appendix F).

The purpose of the present study was to investigate the effect of a 15-trial summary-KR condition and summary-KR strategy conditions in comparison to a 1 trial summary-KR control condition (100% KR) across acquisition and retention trials. Providing information feedback in summary form after the completion of a set of trials (e.g. every 10 or 15 trials) has shown to promote greater learning of a simple motor skill than providing it after every trial (Schmidt et al., 1989). It was hypothesised here that the improved learning scores in the summary condition could be matched by having the learner choose when to receive the information.

Specifically it was hypothesised that the summary-KR strategy group would perform as well as the 15-trial summary-KR group in retention. It was also hypothesised that both reduced frequency summary-KR groups would perform better than the one trial summary-KR control group in retention.

Method

The task and all procedures of this experiment closely followed those of Schmidt et al. (1989) and the first summary KR experiment. Three groups were trained on a double reversal linear slide task. In all conditions subjects performed the same amount of trials and participated in the same 2-day no-KR Delayed Retention (DR) test.

Subjects

The subjects of this experiment were 54 students (30 male & 24 female) from the University of Wales, Bangor. Subjects' age ranged from 19 to 37 years (M = 23.44, SD = 3.83). All the subjects volunteered to participate in the experiment in exchange for course credits and were unaware of its purpose. They had no prior experience with the task. In addition to 54 subjects 5 subjects who failed to participate to retention tests were not included in the statistical analysis.

Procedure and Design

The 54 subjects were randomly assigned to one of three summary-KR conditions with the restriction that an equal number of females and males were in each group. These summary KR conditions were (a) 1 trial summary-KR control group (CON), (b) 15 trial summary-KR group (SUMKR15) and (c) summary-KR strategy group (STR). On arrival at the laboratory, each subject entered an isolated testing room and sat in front of the desk, upon which was the apparatus. Prior to the experiment, details of the task and the nature of their particular feedback condition were given to all subjects. They all read general and specific instructions from the 'Instructions to Subjects' sheet (see Appendix D for a copy of the instructions given to the subjects). In this experiment, all subjects were allowed to perform ten trials, without any feedback, to ensure that they understood the movement before starting the experiment. Once the formal practice session began, after each trial (or sets of trials), a graph was presented on a 36 cm (14 inch) computer screen, which depicted performance accuracy over trials (see Figure 15).

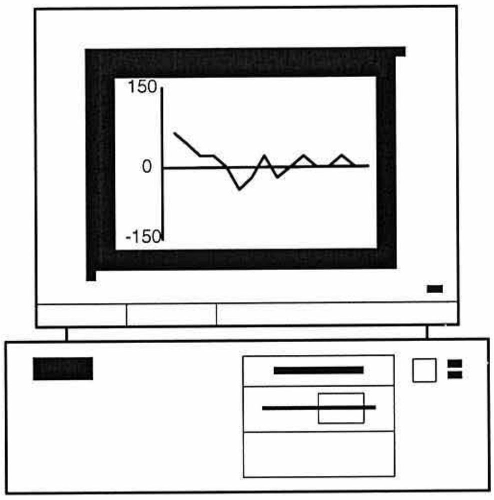

Figure 15. Illustration of the PC screen showing a typical feedback graph for either the STR or SUMKR15 groups in summary KR experiment two.

The control group received information after every trial, with one KR point being displayed at any one time. In the SUMKR15 group, the graph was shown after each block of fifteen trials. In the strategy (STR) group, the graph was shown only when subjects asked to see it. The STR group was instructed that they would only be able to see the graph 6 times during the 90 trials and that only they would decide at which intervals to receive the feedback. Furthermore, they were directed not to see the six graphs too early in the training, as this may have a negative effect on their accuracy. They were therefore encouraged to actively decide when the information might be most useful. The data points in all summary-KR groups except the CON group were connected by line segments. Verbal KR was only given when the data point(s) were outside graph's error range of ± 150 ms.

Following the first summary KR experiment, it was felt necessary to introduce a point scale (see Appendix E) to ensure that subject's attention and motivation stayed high throughout acquisition and retention. The number of points awarded was linked directly to performance accuracy, and was presented after each presentation of the feedback graph.

All groups performed 90 acquisition trials. Two days later, they performed 30 more trials, without any KR, as a retention test. At the end of the second day test subjects were given four open ended post test questions (see Appendix E for an exact list of the question asked to subjects), which served as a check on whether subjects had applied the information given to them by the instructor. A schematic representation of the statistical design is given in Table 13.

Table 13. Statistical Design for Summary KR Experiment Two

Groups (n=18)	n	BLOCKS 1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	Retention Block
Control	S1 - S18							
SUMKR15	S1 - S18							
Strategy	S1 - S18							

Note. Acq = Acquisition. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials.

Results

Subjects' performances during the 90 acquisition trials were analysed in blocks of 15 trials, but performances during retention test were analysed in one block of 30 trials (following Schmidt et al., 1989). The dependant variables for each subject and condition were absolute constant error (|CE|) and variable error (VE).

A groups by blocks (3 x 6) analysis of variance (ANOVA) with repeated measures on the block factor was used to examine changes in each of the dependant variables across acquisition trial blocks. One-way analysis of variance was used to examine simple main effects following a significant group by block interaction. A three group one-way analysis of variance (ANOVA) was used to examine group differences in each of the dependant variables in the retention test. Tukey's follow-up test was used to identify the locus of significant group differences in retention (see Appendix B for copies of the ANOVA tables and Tukey's HSD test, and Appendix C for a complete listing of the raw data).

Acquisition

Absolute Constant Error

The groups (3) x blocks (6) ANOVA with repeated measures on the second factor revealed a significant main effect for groups, $F(2,51) = 4.7, p < .05$, a significant main effect for block, $F(5,255) = 27.20, p < .001$ and a significant group by block interaction, $F(10,180) = 2.30, p < .05$ (see Figure 16). Follow-up one-way ANOVAs examined group differences at each block, finding significant differences at the fourth, fifth and sixth blocks, $F(2,51) = 5.81, p < .05$; $F(2,51) = 6.39, p < .05$ and $F(2,51) = 3.92, p < .05$ respectively. However, in block 1 to block3, there were no significant differences between groups despite the CON group performing twice as accurately as the STR and

SUMKR15 groups. In order to further examine the locus of group differences Tukey's follow-up tests were performed which showed that the CON group was performing better than the SUMKR15 group at the fourth, fifth and sixth blocks. Repeated measures one-way ANOVAs for |CE| examined each group's change across the six trial blocks, obtaining significant differences for CON group $F(5,85) = 9.25, p < .001$; the SUMKR15 group $F(5,85) = 12.06, p < .001$; and the STR group $F(5,85) = 9.6, p < .001$. These significant differences in group mean scores between trial block 1 and block 6 represented improvement in performance for each group. Hence, the cause of the interaction was a gradual separation of the group's performances as practice proceeded, resulting in better performance by the CON group than the SUMKR15 group over the fourth to sixth blocks.

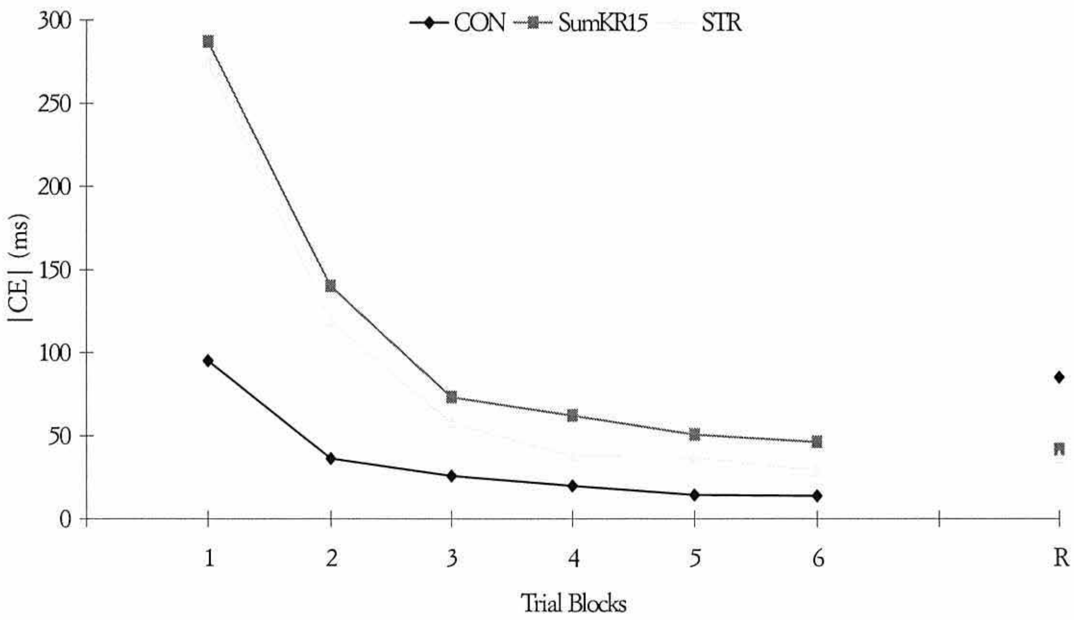

Figure 16. Absolute Constant Error (|CE|) scores in milliseconds for acquisition and retention trial blocks (Summary KR Experiment 2).

Variable Error

The result of the VE scores in acquisition was similar to that of the |CE| scores. The main effect for block and the group by block interaction was significant $F(5,255) = 55.40, p < .001$ and $F(10,255) = 2.70, p < .05$, respectively. The interaction is graphically depicted in Figure 17. The main effect for group was not significant, $F(2,51) = 1.50, p > .05$. Follow-up one-way ANOVAs examined group differences at each block, finding no significant differences between the groups. Repeated measure one-way ANOVAs examined each group's change across the six trial blocks, obtaining significant differences for CON group $F(5,85) = 30.0, p < .001$; the SUMKR15 group $F(5,85) = 16.12, p < .001$; and the STR group $F(5,85) = 13.92, p < .001$. These significant differences in group mean score between trial block 1 and block 6 represented improvement in performance for all the groups.

Retention

Absolute Constant Error

The |CE| score for each group in retention is shown at the right side of Figure 16. The one-way ANOVA among groups was significant, $F(2,51) = 6.6, p < .001$. The follow-up Tukey's test revealed that the CON group had significantly higher |CE| than both STR and SUMKR15 groups. The mean and standard deviation of the |CE| scores of CON, SUMKR15 and STR groups for DR were $M = 85.1, SD = 68.7$; $M = 41.4, SD = 29.4$ and $M = 36.9, SD = 26.7$ respectively.

Variable Error

The one-way ANOVA on groups also revealed a significant effect for VE scores, $F(2,51) = 5.4, p < .001$. Figure 17 depicts this significant difference graphically. The follow-up Tukey's test revealed that the CON group had significantly higher

VE than both the SUMKR15 and the STR groups (M = 35.6, SD = 15.9; M = 26.8, SD = 6.74 and M = 24.2, SD = 7.4, respectively.

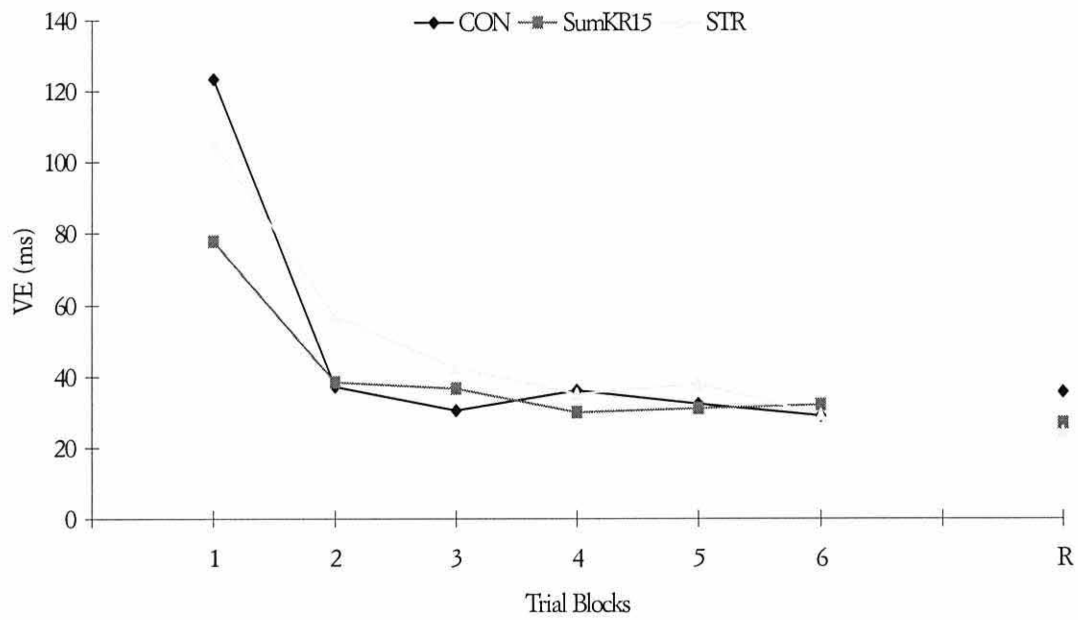

Figure 17. Variable Error (VE) scores in milliseconds for acquisition and retention trial blocks (Summary KR Experiment 2).

Table 14. Means and Standard Deviations of |CE| (in milliseconds) for Acquisition and Retention tests in Summary KR Experiment Two.

Groups (n=18)		BLOCKS 1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	R Block
Control	*M*	95.14	36.04	25.55	19.62	14.19	13.60	85.04
	SD	102.44	25.58	23.06	17.85	13.61	13.59	68.72
SUMKR15	*M*	286.65	139.59	72.98	61.97	50.60	46.15	41.44
	SD	273.94	137.55	80.95	45.49	42.46	53.34	29.38
Strategy	*M*	274.64	118.47	57.51	37.85	36.54	28.98	36.85
	SD	323.80	174.30	90.99	42.26	29.43	24.84	26.74

Note. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials. Acq = acquisition; R = retention.

Table 15. Means and Standard Deviations of VE (in milliseconds) for Acquisition and Retention tests in Summary KR Experiment Two.

Groups (n=18)		BLOCKS 1st Acq Block	2nd Acq Block	3rd Acq Block	4th Acq Block	5th Acq Block	6th Acq Block	R Block
Control	*M*	123.44	37.14	30.58	36.19	32.26	28.96	35.61
	SD	66.07	17.39	11.46	19.98	13.11	9.64	15.86
SUMKR15	*M*	77.85	38.36	36.55	29.99	31.02	32.03	26.95
	SD	41.46	15.81	21.74	13.32	15.36	20.46	6.69
Strategy	*M*	105.43	56.70	42.37	34.94	37.75	29.22	24.25
	SD	64.36	36.71	31.75	24.84	24.36	16.39	7.51

Note. Each acquisition block represents average mean of 15 trials and each retention block represents average mean of 30 trials. Acq = acquisition; R = retention.

Discussion

In this study, the effect of using a learning strategy in comparison to summary KR and control conditions was examined. The purpose of the study was to investigate whether the beneficial effect upon learning of 15 trial summary KR in relation to a KR on every trial condition could be matched by a strategy condition in which subjects were able to choose when to receive feedback. The hypothesis of the experiment was that the strategy group would perform as well as the 15-trial summary KR group in retention and that both these groups would perform better than the 1-trial summary KR control group in retention.

The findings supported the experimental hypothesis. Both the consistency (VE) and accuracy (|CE|) of the control group was worse during retention than that of either that STR or SUMKR15 groups, and the SUMKR15 and STR groups were not different from each other.

The acquisition results of the experiment are consistent with the findings of Schmidt et al. (1989, 1990), with the exception that significant group interactions were found for VE, which were absent from Schmidt et al.'s (1989) study. While all the experimental groups improved over acquisition blocks, the rate of acquisition was slower for the STR and SUMKR15 groups. This suggested that increasing the summary length resulted in poorer performance. The main reason for this was the fact that the STR and SUMKR15 groups had received feedback in blocks after performing some trials on their own. Therefore, the score of summary KR groups was higher and the rate of decrease in the score was slower than the CON group across acquisition. As the hypothesis of this experiment was not primarily related to the acquisition performance of the groups, it will not be discussed in detail. One observation was made regarding the early acquisition phase. In block one to block 3 although the CON group was performing better than the STR and SUMKR15 groups there was no significant group difference. An examination of the data revealed that the groups' standard deviations were very high which would have contributed to the lack of significance (see Figure 1).

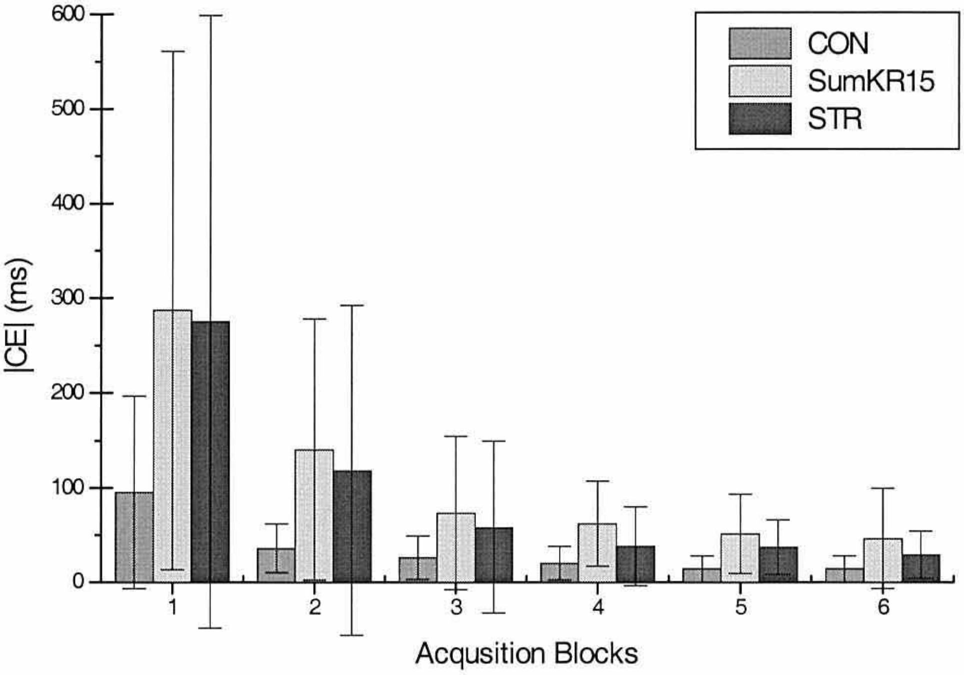

Figure 1. Absolute Constant error (|CE|) scores in milliseconds with error bars for acquisition trial blocks (Summary KR Experiment 2).

The groups' retention performance was inversely related to their acquisition performance. The accuracy of the control group as measured by |CE| had become worse than both the reduced frequency summary KR groups. The mean score of the control group from the last acquisition block to the retention block had increased six-fold. On the other hand |CE| scores of the SUMKR15 and the STR groups stayed roughly similar. This increase in the CON group's |CE| in retention resulted in a significant difference between CON, and SUMKR15 and STR. The larger error scores of the CON group could be attributed to the fact that they received feedback after every trial, which has been shown to result in a dependence on the KR to maintain performance. This in turn has been attributed to the failure of trial-to-trial feedback in promoting subjects' ability to analyse their own response-produced feedback, which is necessary if subjects are to learn to detect their own errors (Schmidt et al., 1989; Winstein & Schmidt, 1990). The SUMKR15 and STR groups had to perform some trials before receiving feedback, and were thus encouraged to analyse their own response produced feedback, and so become less dependent on extrinsic KR.

The findings for |CE| amount to no more than a replication of Schmidt et al. (1989). However, the results for VE go beyond those obtained by Schmidt and colleagues. The VE scores in this experiment followed a similar pattern to |CE| scores. Although all groups had roughly similar VE at the end of the acquisition trials, the CON group was significantly less consistent than the SUMKR15 and STR groups in retention.

As noted for summary KR experiment one, this finding runs contrary to the majority of summary KR research (Carnahan et al., 1996; Gable et al., 1990; Guay et al., 1992; Schmidt et al., 1989; Weeks & Sherwood, 1994 (10min retention interval); Wright et al., 1990). Although some studies have found summary effects in VE (Guay et al., 1997; Weeks & Sherwood, 1994 (2 day retention interval); Yao et al., 1994), none of them have offered anything but the most cursory explanation of the result, passing it off as a consequence of a multitude of differences in experimental design between their studies and those to find support from |CE|. In the previous experiment a suggestion of Schmidt's was mentioned in which differences in |CE| might be attributable to parameterisation of a motor programme, whereas differences in VE might be attributable to the central programme itself (Schmidt et al., 1989). It is not immediately obvious why, in relation to the current set of results, improvement in the central programme underlying control of the movement should be improved when other experiments (in particular that of Schmidt et al. 1989) fail to support such a contention. A more successful explanation may be suggested from Yao et al.'s (1994) study. They hypothesised that within summary KR conditions it is important to maintain consistent performance during acquisition in order to benefit optimally from the summary feedback. This is because, as performance variability increases within a summary episode, the general trend in performance conveyed by the summary feedback becomes less obvious (Schmidt et al., 1990). Indeed, for highly variable performance, there may be no trend in performance and so no useful information to pick up. Yao et al. (1994) proceeded to find that subjects exhibiting low variability within summary episodes in acquisition performed better in retention than subjects exhibiting high variability within those same summary episodes. Also, only the shorter summary condition (5 trials as opposed to 15) elicited a summary KR effect in VE in their experiment. This tends to suggest that the lack of effect in the summary 15 condition may have been due to inordinately high variability in performance by the majority of the subjects in that group, which prevented them making good use of the summary information. In the present study, it is possible that the very careful focus on subjects' motivation to succeed at the task resulted in high levels of concentration from the physical education students who served as subjects. This in turn may have resulted in low variability in performance, the optimal use of summary KR within each summary episode, and a more stable representation of the task resistant both to drift (|CE|) and inconsistency (VE).

The result of this experiment as measure by |CE| and VE clearly showed that the STR group developed the same pattern of performance and learning as the SUMKR15 group. This showed that giving the additional choice to subjects of when they might receive feedback did not affect acquisition or retention detrimentally. It did not support the contention expressed in the previous experiment that the strategy condition brought some other property to the learning experience in which the strategy's enhanced sensitivity to the subject's needs facilitated retention. Rather, it appears that the lack of a summary KR result in the previous experiment was due to a lack of methodological rigour. However, it is unfortunate that the present experiment did not include a yoked group, as this would shed further light on this point.

In summary, this experiment provides grounds for further research exploring the role of subjects' choice in learning and ultimately transfer of learning. It is expected that the ultimate benefit of the approach taken here lies in the increased transferability of the strategies learned to subsequent novel learning situations. This will be discussed in more detail in the final discussion section of the thesis.

CHAPTER NINE

General Discussion

In this chapter the general experimental hypotheses will be presented and the statistical results will be discussed. First only a superficial description of the findings will be given. Then findings related to strategic use of KR will be discussed within the context of theories of KR and use of cognitive strategies to enhance motor learning.

The series of experiments conducted tried to investigate the merits of applying a cognitive strategy to a simple motor task. The primary hypotheses of the studies were that a) the strategy groups and the less frequent KR groups (either in bandwidth, relative frequency or summary KR form) would perform better than a control group (which received KR on every trial) in retention, and b) the strategy group would perform as well as each of the KR treatment groups.

Bandwidth Experiment

The results of the bandwidth experiment failed to support the hypotheses by the Group by Blocks (3 x 2) ANOVA using |CE| and VE as the dependant variable and treatment groups as independent variable in retention.

Relative Frequency Experiments

The results of the first and second relative frequency experiments also failed to support the hypotheses by the Group by Blocks (3 x 2) ANOVA using |CE| and VE as the dependant variable and treatment groups as independent variable in retention.

Summary KR Experiments

The results of the first summary KR experiment partially support the hypotheses by the 4 group one-way ANOVA using VE as the dependant variable and treatment groups as independent variable. The results revealed that the strategy group was more consistent than the control group. This was a somewhat surprising finding, in that previous studies involving summary KR had not in general found that summary KR affected VE. However as the consistency of the summary KR group was not significantly better than the control group, and more importantly, the findings for |CE| were insignificant, it was felt that a further experiment was necessary to examine the strategy group's performance in comparison to a 'normal' summary feedback effect.

The results of the second summary KR experiment supported all the hypotheses by the one-way ANOVA using |CE| and VE as the dependant variable and treatment groups as independent variable. The results revealed that both the strategy group and the summary-KR groups were more consistent and accurate than the control group in retention. This went beyond what was expected of a replication of Schmidt et al. (1989). It was tenuously suggested that the VE findings were a consequence of the attention given to motivational level of the subjects, resulting in more consistent performance under no-KR conditions (between summary presentations) in acquisition, and therefore the optimal use of the summary information when it was available. It was also observed that there was no difference between the strategy group and the KR treatment group, suggesting that subjects' use of the strategy yielded the same results as the subjects whose KR was manipulated by the experimenter.

The results of the last two experiments have resulted in a detailed analysis of the contribution of summary feedback to both response bias and response consistency. It was noted that there appeared to be a pattern in the literature that summary feedback was more effective for reducing response bias as opposed to response consistency (Carnahan et al., 1996; Gable et al., 1990; Guay et al., 1992; Schmidt et al., 1989; Weeks & Sherwood, 1994 (10min retention interval); Wright et al., 1990), although there were some exceptions (Guay et al., 1997; Weeks & Sherwood, 1994 (2 day retention interval); Yao et al., 1994). It was further noted that there was no satisfactory explanation for this phenomena within the literature, rather that it was just accepted as the status quo. Having attempted to offer a resolution of this problem in the discussion to the last experiment, it is intended to move on from that point now to consider how the summary KR phenomena itself is thought to function, and how the strategy manipulation may fit into such thoughts.

Most current theorising regarding summary KR (and indeed relative frequency KR and bandwidth KR) has not progressed much since about 1990. From 1989 to 1992 several leading reviews and experimental studies were published which considered the processes underlying the various KR effects (Lee & Carnahan, 1990; Schmidt, 1991; Schmidt et al. 1989; Swinnen et al. 1990; Winstein & Schmidt, 1990; Young & Schmidt, 1992). These papers, although influential, were largely repetitive. Three main explanations were offered for KR effects as a whole. Each of these are seen as sub-components of the guidance hypothesis, which simply states that too much KR during acquisition leads to a dependence on KR which is detrimental to learning. The processes underlying the guidance phenomenon are not clear. The first of the three possibilities is that KR on every trial requires the subject to attempt to alter their performance on every trial. On some occasions, this may result in subjects attempting to correct errors that are simply a consequence of noise in the motor system; the movement is essentially correct, as far as the subject can manage, yet because the KR is precise, an error is still signalled. On the subsequent trial, the subject inadequate response results in a larger error in the opposite direction, which itself needs correcting, and so on. This process has been referred to as 'maladaptive short-term corrections' (Schmidt & Bjork, 1993).

The second possibility is the flip-side of the first; that the effect is less to do with the detrimental effect of KR on every trial, but is a benefit of practising without KR. Practice without KR provides less stimulus for change on a trial to trial basis, so there is a greater opportunity to develop stable task performance. This allows the learner to relate the KR to a more stable representation of task requirements, thus maximising the utility of the KR (e.g. Yao et al., 1994). Alternatively, Winstein (1988) has suggested that the no-KR trials result in drift from the correct performance, which in turn leads to larger errors for KR to correct and a clearer implication to the subject of how to use the KR. Sidaway et al. (1992) produced some evidence against this notion, by showing that blocks of trials within one summary episode did not deteriorate in performance as Winstein predicted.

Finally, there is the explanation that was presented in the previous chapters, that KR prevents the subjects' focus on their own response produced feedback, and therefore inhibits the subjects ability to learn aspects of the task that will be beneficial for retention. This viewpoint has been directly supported by Lee & Maraj (1994) for bandwidth KR effects, who termed it the blocking hypothesis as it specifies that response produced feedback is blocked. It also seems to be gaining some acceptance within summary KR papers (Weeks & Sherwood, 1994; Yao et al., 1994), though there does not seem to be sufficient evidence to justify any decisions as yet.

In summary, the research has not progressed a great deal in terms of distinguishing between the three or four proposed processes underlying the guidance effect, though what evidence there is supports the blocking hypothesis (Lee & Maraj, 1994). Fortunately, it was not the purpose of this thesis to distinguish between these three processes, but to extend the KR paradigm by introducing a component of subject choice in determining when they were to receive feedback. It was intended that subjects would be trained within specific KR schedules, where the provision of KR was to a certain extent handed over to the subjects. Following this experiments were to be run which would examine whether these subjects, through their involvement in such training, might develop an appreciation for the 'laws of KR', which might in turn facilitate their learning skills on subsequent tasks. The final question to be answered within this line of reasoning was whether such strategic knowledge on the part of the subject might lead to performance benefits over and above those of traditional KR manipulations, as a result of the subjects' incorporation of their knowledge of their own performance requirements into their KR demands.

Unfortunately, as a result of the methodological problems encountered throughout the early part of the thesis, it was not possible to fulfil the proposed sequence of experiments within the time constraints of the thesis. However, the final experiment does offer limited hope for further study.

The hope for further study is in the fact that the strategy did facilitate retention relative to the CON group as well as the summary KR group. The limit to this hope is derived from the constraints that were imposed on subjects in the strategy group so that they would at least receive a reduced relative frequency of KR. This might be interpreted as simply ensuring that the strategy group was no more than another summary KR group, and thus it is not surprising that they obtained similar performance. To provide evidence that is contrary to this line of reasoning it would have been necessary to have included a yoked group in the current experiment, which may have been expected to have produced performance levels between those of the CON and STR groups. There is some tenuous support for this contention in the summary KR one experiment, in as much as the STR group perform better than the CON group in retention and the Y-STR group do not. However, there was no significant difference between the STR and Y-STR groups either, so this support is also marginal. The truth of the matter is that this experiment is unlikely to show the required level of support for the ideas presented above. It was designed more as a means of training subjects to become aware of the way in which KR could benefit learning, rather than as the ultimate test of the strategy.

The true test of the strategy would be to take the subjects to have been exposed to this level of strategy and provide them with more freedom in a second experiment, so that differences between them and a traditional KR group were more apparent. The benefits of each subjects' knowledge of their own feedback requirements would have to be examined once again through the use of a yoked group, and as the subjects are allowed more freedom the differences between the Y-STR and STR groups may emerge.

It only remains to justify the expectations for this line of experimentation in terms of the literature. First of all, among the most beneficial KR manipulations have been those of faded feedback (Dunham & Mueller, 1993; Winstein, Pohl, & Lewthwaite, 1994; Winstein & Schmidt, 1990) and bandwidth feedback (Goodwin & Meeuwsen, 1995; Lee & Carnahan, 1990; Lee & Maraj, 1994). These KR manipulations both begin with large proportions of trials on which there is feedback, and slowly reduce the amount of feedback per trial block as learning progresses. Indeed, one of the supporting arguments for bandwidth feedback was that it achieved a faded feedback scheduling naturally, through its sensitivity to the subjects' errors. Thus it seems a larger proportion of feedback is useful early in learning, when the subject is obtaining a rough idea of the task demands. Secondly, Yao et al. (1994) suggest that performance variability must be low in order to maximise the benefit from sustained periods of no-KR practice, an observation supported by Schmidt et al. (1989). Though bandwidth feedback schedules come close to meeting both of these needs, the artificially imposed bandwidth does not take into account individual differences in performance accuracy, nor the change in performance accuracy as the subjects learn the task. Ways of achieving these last two alterations have only recently been recommended by Lee & Maraj (1994) as the next step forward in improving bandwidth effects. One way in which all these requirements might be incorporated into the same learning episode, and one way to maximise the sensitivity of the feedback scheduling to the needs of the learner as recommended by Lee & Maraj (1994), is to follow just such a training process as outlined in this thesis. Hence, some support for the line of research proposed above can be gleaned from the literature.

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APPENDIX A

Listing Of Experimental Programs And Spreadsheet Macros Used In The Summary Kr Experiments

```
1 REM ***** Bandwidth programmes updated for Sadettin April 92 *****
2 N=0
4 INPUT "Do you want to test the programme ";T$
5 PRINTER 4,4
6 T=800
10 PRINT "TEST SWITCHES? (Y IF YES, N IF NO)":LET ZZ=GET()
20 IF ZZ=ASC("N") OR ZZ=ASC("n") THEN GOTO 210
30 CALL "CLOPAD",7
40 CALL "CLOPAD",8,VARADR(A):CR=0
50 IF A=0 THEN PRINT "ALL BARRIERS DOWN":CR=1
60 IF A=2 THEN PRINT "ALL BARRIERS DOWN, BUTTON 1 DEPRESSED":CR=1
70 IF A=8 THEN PRINT "ALL BARRIERS DOWN, BUTTON 2 DEPRESSED":CR=1
80 IF A=16 THEN PRINT "BARRIER 1 UP":CR=1
90 IF A=32 THEN PRINT "BARRIER 2 UP":CR=1
100 IF A=64 THEN PRINT "BARRIER 3 IS UP":CR=1
110 IF A=48 THEN PRINT "BARRIERS 1 AND 2 ARE UP":CR=1
120 IF A=80 THEN PRINT "BARRIERS 1 AND 3 ARE UP":CR=1
130 IF A=96 THEN PRINT "BARRIERS 2 AND 3 ARE UP":CR=1
140 IF A=112 THEN PRINT "ALL BARRIERS UP":CR=1
150 IF A=56 THEN PRINT "BARRIERS 1 AND 2 UP, BUTTON 2 DEPRESSED":CR=1
160 IF A=82 THEN PRINT "BARRIERS 1 AND 3 UP, BUTTON 1 DEPRESSED":CR=1
170 IF A=88 THEN PRINT "BARRIERS 1 AND 3 UP, BUTTON 2 DEPRESSED":CR=1
180 IF A=10 THEN GOTO 210
190 IF CR=0 THEN PRINT "STOP MUCKING ABOUT"
200 GOTO 40
210 REM BANDWIDTH EXPERIMENTS - 11/6/90.
220 DIM X(18,5):WR=0
230 UL=1050:LL=950
235 INPUT "Drive Letter for data file record ";D$
240 INPUT "SUBJECT ID? ",S$
249 EC=2:GOTO 260
250 INPUT "EXPT.1, EXPT.2 OR EXPT.3 ? (TYPE NUMBER) ",EC
260 IF EC=2 THEN GOTO 280
270 INPUT "FEEDBACK CONDITION (1 OR 2)? ",FC:GOTO 290
280 INPUT "FEEDBACK CONDITION (1, 2 OR 3)? ",FC:FC=FC+2
290 IF EC=3 THEN FC=FC+5
291 GOSUB 400
300 FOR BL=1 TO 18
310 FOR TR=1 TO 5
320 LET X(BL,TR)=0
330 NEXT TR:NEXT BL
340 FOR BL=1 TO 18
345 IF BL=15 THEN GOSUB 2000:REM 5-MINUTE WAIT
350 FOR TR=1 TO 5
355 N=N+1
360 GOSUB 880:REM A TRIAL
365 IF BL>12 THEN GOTO 380
370 GOSUB 630:REM FEEDBACK
380 NEXT TR:NEXT BL
381 GOSUB 429
385 END
390 REM PRINT DATA TO FILE(S)
400 LET FC$=STR$(FC):LET FC$=RIGHT$(FC$,1)
410 LET F$=D$+":b10"+S$+FC$+".DTA"
420 CREATE #10,F$
421 PRINT #10,FC$
```

```
422 RETURN
429 REM store data
430 FOR BL=1 TO 18:FOR TR=1 TO 5
440 PRINT #10,X(BL,TR);
450 NEXT TR
460 PRINT #10," "
470 NEXT BL
480 CLOSE #10
570 PUT 12:TEXT
580 PRINT "THANK YOU VERY MUCH FOR YOUR HELP"
590 PRINT "THIS SUBJECT HAD ";WR;" REPEATED TRIALS"
595 LPRINT F$:LPRINT
600 LPRINT "BLOCK";TAB(16);"VE";TAB(26);"CE";TAB(36);"AE"
610 GOSUB 1050:REM VE SCORES
620 RETURN
630 GRAPH 1
640 GRAPH 0:GRAPH 1
650 CALL "RESOLUTION",0,2
660 CALL "PLOT",123,0,2
670 CALL "LINE",123,165,2
680 CALL "PLOT",166,165,2
690 CALL "LINE",166,0,2
700 REM SUBR TO DISPLAY FEEDBACK IN BANDWIDTH EXPTS
710 IF FC=2 AND X(BL,TR)>LL AND X(BL,TR)<UL THEN GOTO 830
720 IF FC=1 OR FC=2 THEN GOTO 840
730 IF FC=3 OR FC=4 OR FC=6 THEN K=INT(X(BL,TR)/5-130)
740 IF K>5150 THEN K=150
750 IF K<1 THEN K=1
760 IF FC=3 OR FC=4 THEN GOTO 850
770 IF FC=6 THEN GOTO 860
780 IF FC=5 OR FC=7 THEN GOSUB 1020
790 IF K>5150 THEN K=150
800 IF K<1 THEN K=1
810 IF CC=1 THEN CC=0:IF FC=4 THEN GOTO 840 ELSE GOTO 830
820 IF CC=2 THEN CC=0:IF FC=7 THEN GOTO 860 ELSE GOTO 850
830 PLOT 77,12,"*":K=77:GOTO 870
840 PLOT 70,12,STR$(X(BL,TR)):K=70:GOTO 870
850 PLOT K,12,STR$(X(BL,TR)):GOTO 870
860 PLOT K+7,12,"*"
870 RETURN
880 REM RUN A TRIAL
883 IF T$="y" THEN T=T+5:GOTO 980
884 IF T$="y" OR T$="Y" THEN T=1000-INT((200+200)*RND(1)-200):PRINT N:GOTO
    980
890 CALL "CLOPAD",7
900 CALL "CLOPAD",8,VARADR(A):IF A<>82 THEN PRINT "GET READY";N:GOTO
    900
910 PUT 12
920 PLOT K,12,"    "
930 PRINT "GO WHEN READY"
940 CALL "CLOPAD",8,VARADR(A):IF A=82 THEN GOTO 930
950 CALL "CLOPAD",0
960 CALL "CLOPAD",8,VARADR(A):IF A>0 THEN GOTO 960
970 CALL "CLOPAD",1,VARADR(T)
980 IF T<500 OR T>1500 THEN PLOT 40,30,"LARGE ERROR -TRY
    AGAIN":WR=WR+1:GOTO 900
```

```
990 PLOT 40,30,"            "
1000 LET X(BL,TR)=T
1010 RETURN
1020 IF X(BL,TR)>LL AND X(BL,TR)<UL THEN CC=1:RETURN
1021 IF X(BL,TR)=LL OR X(BL,TR)=UL THEN CC=1:RETURN
1030 IF X(BL,TR)<LL THEN K=INT(X(BL,TR)/5-130):CC=2:RETURN
1040 IF X(BL,TR)>UL THEN K=INT(X(BL,TR)/5-128):CC=2:RETURN
1050 FOR BL=1 TO 18
1060 CX=0:XX=0:ES=0:EX=0:VE=0:AE=0:CE=0
1070 FOR TR=1 TO 5
1080 CX=CX+X(BL,TR)
1085 CE=CE+X(BL,TR)-1000:AE=AE+ABS(X(BL,TR)-1000)
1090 XX=XX+(X(BL,TR)*X(BL,TR))
1100 NEXT TR
1105 CE=CE/5:AE=AE/5
1110 LET EX=CX/5:LET ES=XX/5
1120 VE=SQR(ES-(EX*EX))
1130 PRINT BL;TAB(16);VE;TAB(26);CE;TAB(36);AE
1131 LPRINT BL;TAB(16);VE;TAB(26);CE;TAB(36);AE
1135 NEXT BL
1140 RETURN
2000 REM 5-MINUTE BREAK
2005 CALL "CLEAR":PUT 12
2010 PLOT 40,30,"THERE IS NOW A 5-MINUTE BREAK":BT=5
2020 FOR I=1 TO 20
2030 PLOT 40,25,STR$(BT)+" TO GO  "
2040 LET ZZ=GET(1500):BT=BT-.25:NEXT I
2050 PLOT 40,30,"            "
2060 PLOT 40,25,"       "
2070 RETURN
```

```
1 REM ** Relative Frequency programmes updated for Sadettin April 92 **
2 N=0
5 PRINTER 4,4
10 INPUT "Test the programme.... y or n ";T$
20 DIM X(18,5)
25 INPUT "Drive letter for record of data ";D$
30 INPUT "Subject ID ",ID$
40 INPUT "Feedback control 1, 2 or 3 ",FC
50 FOR BL= 1 TO 16
60 FOR TR= 1 TO 5
70 LET X(BL,TR)=0
80 NEXT TR:NEXT BL
90 FOR BL=1 TO 18
100 IF BL=15 THEN GOSUB 3140
120 FOR TR=1 TO 5
121 N= N+1
130 GOSUB 470:REM A TRIAL
140 GOSUB 290
150 NEXT TR:NEXT BL
160 REM PRINT DATA TO FILE
170 LET FC$=STR$(FC)
175 LET FC$=RIGHT$(FC$,1)
180 LET F$=D$+":RF20"+ID$+FC$+".dta"
181 PRINT " SAVING FILE ";F$
190 CREATE #10, F$
195 PRINT #10,FC
200 FOR BL= 1 TO 18
205 FOR TR=1 TO 5
210 PRINT #10,X(BL,TR);
220 NEXT TR
230 PRINT #10," "
240 NEXT BL
250 CLOSE #10
260 PUT 12
270 PRINT "THANK YOU VERY MUCH FOR YOUR HELP....."
271 GOSUB 2998
280 END
285 REM ***************** Trial subroutine ********
290 GRAPH 1
300 GRAPH 0:GRAPH 1
310 CALL "RESOLUTION",0,2
320 CALL "FILL",125,25,163,48,3
330 CALL "FILL",127,27,161,46,0
340 REM SUBR TO DISPLAY FEEDBACK IN FREQUENCY EXPT.
350 IF BL=1 AND TR=1 GOTO 370
360 IF FC=3 AND TR<5 THEN 420
370 J=52-(TR-1)*10
380 IF BL>12 THEN RETURN
390 IF X(BL,TR)=0 THEN X$=" ":GOTO 410
400 X$=STR$(X(BL,TR))
410 PLOT 70,J,X$
420 RETURN
430 REM test routine for board
440 CALL "CLOPAD",7
450 CALL "CLOPAD",8, VARADR(A)
460 PRINT A:GOTO 440
```

```
470 REM RUN A TRIAL
471 IF T$="y" OR T$="Y" THEN T=1000-INT((200+200)*RND(1)-200):PRINT N:GOTO
    560
472 PUT 12
473 PRINT N
480 CALL "CLOPAD",7
490 CALL "CLOPAD",8,VARADR(A):IF A<>82 THEN PRINT "GET READY",N:GOTO
    490
500 PUT 12
510 PRINT "GO WHEN READY"
520 CALL "CLOPAD",8,VARADR(A):IF A=82 THEN 510
530 CALL "CLOPAD",0
540 CALL "CLOPAD",8,VARADR(A):IF A>0 THEN 540
550 CALL "CLOPAD",1,VARADR(T)
560 LET X(BL,TR)=T
570 RETURN
2998 LPRINT F$:LPRINT
2999 LPRINT "Block";TAB(16);"VE";TAB(26);"CE";TAB(36);AE
3000 FOR BL=1 TO 18
3010 CX=0:XX=0:ES=0:EX=0:VE=0:AE=0:CE=0
3020 FOR TR=1 TO 5
3030 CX=CX+X(BL,TR)
3040 CE=CE+X(BL,TR)-1000:AE=AE+ABS(X(BL,TR)-1000)
3050 XX=XX+(X(BL,TR)*X(BL,TR))
3060 NEXT TR
3070 CE=CE/5:AE=AE/5
3080 LET EX=CX/5:LET ES=XX/5
3090 VE=SQR(ES-(EX*EX))
3099 PRINT "Block";TAB(16);"VE";TAB(26);"CE";TAB(36);"AE"
3100 PRINT BL;TAB(16);VE;TAB(26);CE;TAB(36);AE
3110 LPRINT BL;TAB(16);VE;TAB(26);CE;TAB(36);AE
3120 NEXT BL
3121 LPRINT:LPRINT
3130 RETURN
3140 REM 5-MINUTE BREAK
3150 CALL "CLEAR":PUT 12
3160 PLOT 40,30,"THERE IS NOW A 5-MINUTE BREAK":BT=5
3170 FOR I=1 TO 20
3175 PLOT 40,25,STR$(BT)+ " TO GO   "
3180 PLOT 40,25,STR$(BT)+" TO GO  "
3190 LET ZZ=GET(1500):BT=BT-.25:NEXT I
3200 RETURN
3210 PLOT 40,25,"         "
3220 RETURN
```

MS Excel for Windows (v4.0c) macros used to create feedback graphs in first Summary KR Experiment

Create_Chart for_**Control**_Group (Select Only One Trial)

```
SELECT("R[13]C")
COPY()
CREATE.OBJECT(5,"R3C3",0,0,"R26C21",0,0,1,TRUE,4,1)
GALLERY.LINE(1,TRUE)
UNHIDE()
WINDOW.MAXIMIZE()
SELECT("Axis 1")
SCALE(-150,150,50,25,TRUE,FALSE,FALSE,FALSE)
PATTERNS(1,1,1,1,4,3,4)
SELECT("Axis 2")
SCALE(1,1,1,TRUE,FALSE,FALSE)
SELECT("S1")
PATTERNS(0,1,1,3,1,1,1,3,FALSE)
SELECT("")
RETURN()
```

Delete_Inserted_Chart (and Move One Cell Down)

```
ACTIVATE.NEXT()
CLEAR()
SELECT("RC")
SELECT.SPECIAL(9,,1)
SELECT("RC[1]")
RETURN()
```

Create_Chart_for_**SumKR10**_Group (Select Ten Trials)

```
SELECT("R[13]C[-9]:R[13]C")
COPY()
CREATE.OBJECT(5,"R3C3",0,0,"R26C21",0,0,1,TRUE,4,1)
GALLERY.LINE(1,TRUE)
UNHIDE()
WINDOW.MAXIMIZE()
SELECT("Axis 1")
SCALE(-150,150,50,25,TRUE,FALSE,FALSE,FALSE)
PATTERNS(1,1,1,1,4,3,4)
SELECT("Axis 2")
SCALE(1,1,1,TRUE,FALSE,FALSE)
SELECT("S1")
PATTERNS(0,1,1,3,1,1,1,3,FALSE)
SELECT("")
RETURN()
```

Delete_Inserted_Chart_and (Move One Cell Right)

```
ACTIVATE.NEXT()
CLEAR()
SELECT("RC")
SELECT.SPECIAL(9,,1)
SELECT("R[1]C")
```

```
RETURN()
```

Create_Chart for_**Strategy**_Group (Select Highlighted Cells)

```
SELECT()
COPY()
CREATE.OBJECT(5,"R3C3",0,0,"R26C21",0,0,1,TRUE,4,1)
GALLERY.LINE(1,TRUE)
UNHIDE()
WINDOW.MAXIMIZE()
SELECT("Axis 1")
SCALE(-150,150,50,25,TRUE,FALSE,FALSE,FALSE)
PATTERNS(1,1,1,1,4,3,4)
SELECT("Axis 2")
SCALE(1,1,1,TRUE,FALSE,FALSE)
SELECT("S1")
PATTERNS(0,1,1,3,1,1,1,3,FALSE)
SELECT("")
RETURN()
```

Delete_Inserted_Chart (and Move One Cell Down)

```
ACTIVATE.NEXT()
CLEAR()
SELECT("RC")
SELECT.SPECIAL(9,,1)
SELECT("R[1]C")
RETURN()
```

MS Excel for Windows (v5.0a) macros used to create feedback graphs in second Summary KR Experiment

Control Group 1 Trial Data Range

```
SELECT("R[10]C")
WORKBOOK.INSERT(2)
CHART.WIZARD(TRUE,,,,1,,,2,,"Trial(s)","Time (ms)",,0,0)
WAIT(NOW()+"00:00:5")
ERROR(FALSE)
WORKBOOK.DELETE()
SELECT("R[-10]C[1]")
RETURN()
```

Summary KR15 Group 1 Block (15 trials) Data Range

```
SELECT("R[10]C[-14]:R[10]C")
WORKBOOK.INSERT(2)
CHART.WIZARD(TRUE,,,,1,,,2,,"Trial(s)","Time (ms)",,0,0)
WAIT(NOW()+"00:00:10")
ERROR(FALSE)
WORKBOOK.DELETE()
SELECT("R[-9]C")
RETURN()
```

Strategy Group Highlighted Data Range

```
SELECT()
WORKBOOK.INSERT(2)
CHART.WIZARD(TRUE,,,,1,,,2,,"Trial(s)","Time (ms)",,0,0)
WAIT(NOW()+"00:00:10")
ERROR(FALSE)
WORKBOOK.DELETE()
SELECT("R9C4")
RETURN()
```

APPENDIX B

SUMMARISED ANOVA RESULT TABLES

ANOVA TABLES

Bandwidth Experiment

|CE|

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	2870.95	2	1435.48	.66	.529
Error Between	32423.05	15	2161.54		
	Within Subjects				
Blocks	22488.82	5	4497.76	3.13	.013*
Groups by Blocks	9338.73	10	933.87	.65	.766
Error Within	107729.34	75	1436.39		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	800.33	400.17	.418	.666
Within Groups	15	14377.67	958.51		
Total	17	15178.00			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	7456.06	2	3728.03	.59	.566
Error Between	94628.42	15	6308.56		
	Within Subjects				
Blocks	1381.36	1	1381.36	.67	.425
Groups by Blocks	2398.72	2	1199.36	.58	.570
Error Within	30774.42	15	2051.63		

Dependent Variable: Performance Time (Actual Time - Target Time).

VE

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	2564.13	2	1282.06	.59	.569
Error Between	32827.28	15	2191.15		
	Within Subjects				
Blocks	39948.52	5	7989.70	10.14	.000*
Groups by Blocks	3515.43	10	351.54	.45	.919
Error Within					

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	105.44	52.72	.068	.935
Within Groups	15	11675.67	778.38		
Total	17	11781.11			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	2295.50	2	1147.75	1.11	.355
Error Between	15519.75	15	1034.65		
	Within Subjects				
Blocks	2.25	1	2.25	.01	.944
Groups by Blocks	211.17	2	105.58	.24	.792
Error Within	6676.08	15	445.07		

Dependent Variable: Performance Time (Actual Time - Target Time).

Relative Frequency Experiment One

|CE|

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	7614.23	2	3807.12	.11	.894
Error Between	506311.67	15	33754.11		
	Within Subjects				
Blocks	286335.42	5	57267.08	6.49	.000*
Groups by Blocks	11794.00	10	1179.40	.13	.999
Error Within	661859.72	75	8824.80		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	1019.00	509.50	.113	.894.
Within Groups	15	67606.12	4507.08		
Total	17	6860			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
		Between Subjects			
Groups	13733.74	2	6866.87	.58	.572
Error Between	177386.51	15	11825.77		
		Within Subjects			
Blocks	5880.33	1	5880.33	2.82	.114
Groups by Blocks	572.71	2	286.35	.14	.873
Error Within	31268.14	15	2084.54		

Dependent Variable: Performance Time (Actual Time - Target Time).

VE

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
		Between Subjects			
Groups	27717.04	2	13858.52	.99	.396
Error Between	210790.84	15	14052.72		
		Within Subjects			
Blocks	22379.53	5	4475.91	2.45	.041*
Groups by Blocks	21445.85	10	2144.59	1.17	.322
Error Within	136980.75	75	1826.41		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	163.54	81.77	.169	.847
Within Groups	15	7277.94	485.20		
Total	17	7441.48			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	327.86	2	163.93	.21	.816
Error Between	11961.18	15	797.41		
	Within Subjects				
Blocks	528.23	1	528.23	2.20	.159
Groups by Blocks	1390.48	2	695.24	2.90	.086
Error Within	3598.11	15	239.87		

Dependent Variable: Performance Time (Actual Time - Target Time).

Relative Frequency Experiment Two

|CE|

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	9869.90	2	4934.95	.57	.574
Error Between	181753.12	21	8654.91		
	Within Subjects				
Blocks	325634.56	5	65126.91	11.38	.000*
Groups by Blocks	17831.45	10	1783.15	.31	.977
Error Within	600920.41	105	5723.05		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	8333.57	4166.79	1.477	.251
Within Groups	21	59241.01	2821.00		
Total	23	67600			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	21899.16	2	10949.58	.58	.570
Error Between	397698.74	21	18938.04		
	Within Subjects				
Blocks	1549.28	1	1549.28	.73	.404
Groups by Blocks	5044.29	2	2522.15	1.18	.327
Error Within	44858.98	21	2136.14		

Dependent Variable: Performance Time (Actual Time - Target Time).

VE

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	10060.37	2	5030.18	2.77	.085
Error Between	38116.87	21	1815.09		
	Within Subjects				
Blocks	35885.90	5	7177.18	6.38	.000*
Groups by Blocks	13588.46	10	1358.85	1.21	.294
Error Within	118081.98	105	1124.59		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	2898.54	1449.27	3.196	.062
Within Groups	21	9522.46	453.45		
Total	23	1242			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	3355.62	2	1677.81	1.69	.209
Error Between	20844.90	21	992.61		
	Within Subjects				
Blocks	121.60	1	121.60	.53	.474
Groups by Blocks	211.45	2	105.73	.46	.636
Error Within	4795.10	21	228.34		

Dependent Variable: Performance Time (Actual Time - Target Time).

Summary KR Experiment One

|CE|

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
		Between Subjects			
Groups	164104.85	3	54701.62	2.25	.099
Error Between	875017.96	36	24306.05		
		Within Subjects			
Blocks	837800.52	5	167560.10	39.67	.000*
Groups by Blocks	101796.69	15	6786.45	1.61	.760
Error Within	760208.64	180	4223.38		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	3	3452.12	1150.71	1.446	.246
Within Groups	36	28650.18	795.84		
Total	39	32102			

Dependent Variable: Performance Time (Actual Time - Target Time).

Delayed Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	3	1392.26	464.09	.326	.806
Within Groups	36	51178.47	1421.62		
Total	39	52570			

Dependent Variable: Performance Time (Actual Time - Target Time).

VE

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	8656.14	3	2885.38	1.27	.301
Error Between	82050.64	36	2279.18		
	Within Subjects				
Blocks	194786.90	5	38957.38	38.07	.000*
Groups by Blocks	21057.59	15	1403.84	1.37	.165
Error Within	184185.68	180	1023.25		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Immediate Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	3	328.55	109.52	1.192	.327
Within Groups	36	3307.94	91.89		
Total	39	3636.49			

* Denotes significant difference at the 0.05 level of significance.

Delayed Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	3	2087.76	695.92	5.303	.004*
Within Groups	36	4724.45	131.24		
Total	39	6812.21			

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Summary KR Experiment Two

|CE|

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	338752.41	2	169376.21	4.37	.013*
Error Between	1826448.87	51	35812.72		
	Within Subjects				
Blocks	1440061.32	5	288012.26	27.18	.000*
Groups by Blocks	241913.66	10	24191.37	2.28	.014*
Error Within					

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	25482.33	12741.17	6.064	.004*
Within Groups	51	107161.00	2101.20		
Total	53	133000			

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

VE

Acquisition

Two-Way ANOVA with Repeated Measures

Source of Variation	*SS*	*df*	*MS*	*F*	Sig of *F*
	Between Subjects				
Groups	5839.67	2	2919.84	1.57	.217
Error Between	94577.94	51	1854.47		
	Within Subjects				
Blocks	205761.84	5	41152.37	55.40	.000*
Groups by Blocks	19597.44	10	1959.74	2.64	.004*
Error Within	189427.72	255	742.85		

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Retention

One-Way ANOVA

Source of Variation	*df*	Sum of Squares *(SS)*	Mean Squares *(MS)*	*F* Ratio	*F* Prob
Between Groups	2	1268.04	634.02	5.404	.007*
Within Groups	51	5984.06	117.33		
Total	53	7252.09			

* Denotes significant difference at the 0.05 level of significance.

Dependent Variable: Performance Time (Actual Time - Target Time).

Tukey's Multiple Comparison Tests

The following formula (Equation 1) is used to calculate the Tukey's honestly significant difference (HSD) comparison between pairs of treatment means when a significant main effect was found in an experiment:

$$M_l - M_s = q_{.05}(r,\ df_{error})\sqrt{\frac{MS_{error}}{n}} \qquad \text{Equation 1}$$

Where:

M_l - M_s = the difference between the largest ($M_{largest}$) and smallest ($M_{smallest}$) treatment means

$q_{.05}$ (r, df_{error}) = is the table critical value

r = total number of means in the set

df = degrees of freedom associated with the MS_{error}

MS_{error} = the square root of the MS experimental error

n = number of observations.

From the calculation, a difference in means equal to or greater than the result value (the critical difference for comparison of means) would be judged significant, whereas a smaller difference would not.

Bandwidth Experiment

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 75
- Error Mean Square (ANOVA) = 1436.39
- n (Number of Observations) = 18

Calculations: for $r = 6$ and $df_{error} = 75$, $q_{.05} = 4.16$. Then

$$M_1 - M_s = 4.16\sqrt{\frac{1436.39}{18}}$$

$$M_1 - M_s = 37.16$$

Thus, the Critical Difference for Comparison of Means = 37.16

Table 16. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (BW, |CE|)

		Ordered Blocks					
Means		1	2	5	3	4	6
70.19	1	–	18.20	31.80	33.17	35.88	44.41_a
51.99	2		–	13.61	14.98	17.69	26.22
38.39	5			–	1.37	4.08	12.61
37.02	3				–	2.71	11.24
34.31	4					–	8.53
25.78	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Bandwidth Experiment

Variable Error (VE)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 75
- Error Mean Square (ANOVA) = 788.25
- $n\cdot$(Number of Observations) = 18

Calculations: for $r = 6$ and $df_{error} = 75$, $q_{.05} = 4.16$. Then

$$M_1 - M_s = 4.16\sqrt{\frac{788.25}{18}}$$

$$M_1 - M_s = 27.53$$

Thus, the Critical Difference for Comparison of Means = 27.53

Table 17. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (BW, VE)

		Ordered Blocks					
Means		1	4	3	2	5	6
117.72	1	–	38.39_a	49.33_a	52.78_a	52.78_a	54.61_a
79.33	4		–	10.94	14.39	14.39	16.22
68.39	3			–	3.44	3.44	5.28
64.94	2				–	0.00	1.83
64.94	5					–	1.83
63.11	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Relative Frequency Experiment One

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 75
- Error Mean Square (ANOVA) = 8824.8
- n·(Number of Observations) = 18

Calculations: for $r = 6$ and $df_{error} = 75$, $q_{.05} = 4.16$. Then

$$M_1 - M_s = 4.16\sqrt{\frac{88.24}{18}}$$

$$M_1 - M_s = 92.11$$

Thus, the Critical Difference for Comparison of Means = 92.11

Table 18. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (RF1, |CE|)

		Ordered Blocks					
Means		1	2	3	4	5	6
186.66	1	–	55.36	111.22_a	122.44_a	138.55_a	143.97_a
131.31	2		–	55.87	67.09	83.20	88.62
75.44	3			–	11.22	27.33	32.75
64.22	4				–	16.11	21.53
48.11	5					–	5.42
42.69	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Relative Frequency Experiment One

Variable Error (VE)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 75
- Error Mean Square (ANOVA) = 1826.41
- n·(Number of Observations) = 18

Calculations: for $r = 6$ and $df_{error} = 75$, $q_{.05} = 4.16$. Then

$$M_1 - M_s = 4.16\sqrt{\frac{1826.41}{18}}$$

$$M_1 - M_s = 41.90$$

Thus, the Critical Difference for Comparison of Means = 41.90

Table 19. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (RF1, VE)

		Ordered Blocks					
Means		1	2	3	5	4	6
120.52	1	–	18.36	26.73	37.20	39.77	40.13
102.16	2		–	8.37	18.84	21.41	21.78
93.79	3			–	10.47	13.04	13.41
83.32	5				–	2.57	2.93
80.75	4					–	0.37
80.38	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Relative Frequency Experiment Two

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 105
- Error Mean Square (ANOVA) = 5723.05
- n·(Number of Observations) = 24

Calculations: for $r = 6$ and $df_{error} = 105$, $q_{.05} = 4.12$. Then

$$M_1 - M_s = 4.12\sqrt{\frac{57.23.05}{24}}$$

$$M_1 - M_s = 63.62$$

Thus, the Critical Difference for Comparison of Means = 63.62

Table 20. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (RF2, |CE|)

		Ordered Blocks					
Means		1	2	4	3	5	6
178.16	1	–	110.82_a	129.75_a	128.33_a	130.22_a	131.78_a
67.34	2		–	18.93	17.51	19.41	20.96
49.83	4			–	-1.42	1.90	2.03
48.41	3				–	0.48	3.45
47.94	5					–	1.55
46.38	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Relative Frequency Experiment Two

Variable Error (VE)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 105
- Error Mean Square (ANOVA) = 1124.59
- n·(Number of Observations) = 24

Calculations: for $r = 6$ and $df_{error} = 105$, $q_{.05} = 4.12$. Then

$$M_1 - M_s = 4.12\sqrt{\frac{1124.59}{24}}$$

$$M_1 - M_s = 28.20$$

Thus, the Critical Difference for Comparison of Means = 28.20

Table 21. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (RF2, VE)

		Ordered Blocks					
Means		1	2	3	5	4	6
110.68	1	–	23.17	32.36_a	41.48_a	41.85_a	46.61_a
87.50	2		–	9.19	18.31	18.68	23.44
78.32	3			–	9.13	9.49	14.25
69.19	5				–	0.36	5.13
68.83	4					–	4.76
64.07	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Summary KR Experiment One

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 180
- Error Mean Square (ANOVA) = 4223.38
- n·(Number of Observations) = 40

Calculations: for $r = 6$ and $df_{error} = 180$, $q_{.05} = 4.10$. Then

$$M_1 - M_s = 4.10\sqrt{\frac{4223.38}{40}}$$

$$M_1 - M_s = 42.13$$

Thus, the Critical Difference for Comparison of Means = 42.13

Table 22. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (SKR1, |CE|)

		Ordered Blocks					
Means		1	2	3	4	5	6
195.81	1	–	124.63_a	142.71_a	161.41_a	166.19_a	169.96_a
71.18	2		–	18.08	36.78	41.56	45.33_b
53.10	3			–	18.69	23.48	27.24
34.41	4				–	4.78	8.55
29.62	5					–	3.77
25.85	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Summary KR Experiment One

Variable Error (VE)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 180
- Error Mean Square (ANOVA) = 1023.25
- n·(Number of Observations) = 40

Calculations: for $r = 6$ and $df_{error} = 180$, $q_{.05} = 4.10$. Then

$$M_1 - M_s = 4.10\sqrt{\frac{1023.25}{40}}$$

$$M_1 - M_s = 20.74$$

Thus, the Critical Difference for Comparison of Means = 20.74

Table 23. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (SKR1, VE)

		Ordered Blocks					
Means		1	2	3	5	4	6
110.83	1	–	64.67_a	73.14_a	78.20_a	78.41_a	81.09_a
46.17	2		–	8.48	13.54	13.74	16.43
37.69	3			–	5.06	5.27	7.95
32.63	5				–	0.21	2.89
32.42	4					–	2.69
29.74	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Summary KR Experiment Two

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Groups

- Degrees of Freedom (ANOVA) = 2, 51
- Error Mean Square (ANOVA) = 35812.72
- n·(Number of Observations) = 108

Calculations: for $r = 3$ and $df_{error} = 51$, $q_{.05} = 3.44$. Then

$$M_1 - M_s = 3.44\sqrt{\frac{35812.72}{108}}$$

$$M_1 - M_s = 62.64$$

Thus, the Critical Difference for Comparison of Means = 62.64

Table 24. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Group Means (SKR2, |CE|)

		Ordered Groups		
Means		SumKR	Strategy	Control
109.64	SumKR	–	47.35	75.60_a
92.29	Strategy		–	58.25
34.04	Control			–

Note. Means in the same row that have a subscripts differ at p < .05 in Tukey HSD comparison.

Summary KR Experiment Two

Absolute Constant Error (|CE|)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 275
- Error Mean Square (ANOVA) = 10597.17
- n·(Number of Observations) = 54

Calculations: for $r = 6$ and $df_{error} = 255$, $q_{.05} = 4.10$. Then

$$M_1 - M_s = 4.10\sqrt{\frac{10597.17}{54}}$$

$$M_1 - M_s = 57.44$$

Thus, the Critical Difference for Comparison of Means = 57.44

Table 25. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (SKR2, |CE|)

		Ordered Blocks					
Means		1	2	3	4	5	6
218.82	1	–	120.80_a	166.83_a	179.00_a	185.07_a	189.26_a
98.02	2		–	46.04	58.20_b	64.28_b	68.46_b
51.98	3			–	12.17	18.24	22.43
39.82	4				–	6.07	10.26
33.74	5					–	4.19
29.56	6						–

Note. Means in the same row that have a subscripts differ at $p < .05$ in Tukey HSD comparison.

Summary KR Experiment Two

Variable Error (| CE |)

Tukey's Multiple Comparison Test

Dependent Variable: Actual movement time minus Target time (ms)

Main Effect: Blocks

- Degrees of Freedom (ANOVA) = 5, 275
- Error Mean Square (ANOVA) = 742.85
- n·(Number of Observations) = 54

Calculations: for r = 6 and df_{error} = 255, $q_{.05}$ = 4.10. Then

$$M_1 - M_s = 4.10\sqrt{\frac{742.85}{54}}$$

$$M_1 - M_s = 15.21$$

Thus, the Critical Difference for Comparison of Means = 15.21

Table 26. Tukey HSD Test Applied to the Differences Between Pairs of Ordered Block Means (SKR2, VE)

		Ordered Blocks					
Means		1	2	3	4	5	6
102.20	1	–	58.15 $_a$	65.70 $_a$	68.52 $_a$	68.63 $_a$	72.15 $_a$
44.06	2		–	7.56	10.37	10.48	14.00
36.50	3			–	2.82	2.93	6.44
33.69	4				–	0.11	3.63
33.57	5					–	3.52
30.06	6						–

Note. Means in the same row that have a subscripts differ at p < .05 in Tukey HSD comparison.

APPENDIX C

RAW DATA

Bandwidth Experiment

The data are stored according to the following format:

The code left of the subject data refers to group number, gender and subject number.

The codes are:

1 = Control; 2 = Strategy; 3 = Bandwidth. M = Male; F = Female.

1 F 1 1150 1179 1193 1049 1064 1006 1064 992 1136 1049 906 1021 1021 1222 1093 1049 934 934 906 848 1035 1107 1078 1035 1093 949 920 1049 1107 934 1049 1150 1064 963 1164 1150 891 1021 963 949 1466 1121 992 1107 1121 963 1006 1121 1193 877 963 877 1021 1107 1006 949 1193 1035 992 978 949 920 1021 863 834 891 877 863 891 963 1035 877 1107 1136 891 949 949 978 949 920 791 920 863 848 863 776 748 819 906 934

1 F 2 1066 795 840 945 780 675 1036 960 825 945 1036 915 1006 915 915 1111 1081 1006 1066 1036 1471 1096 1051 1051 1036 1021 960 960 990 1021 990 1051 1111 915 1126 1366 1171 1066 1036 1051 1066 975 1006 990 960 1006 1006 990 1036 1111 1081 1066 1036 1111 1036 1021 1021 1021 1036 960 1006 1051 1051 1126 1096 990 1036 1081 1021 1006 1006 1036 1006 1036 1036 1051 1081 1156 1111 1186 1156 1381 1231 1216 1201 1201 1171 1261 1321 1186

1 M 3 1124 992 1078 949 1236 1049 1164 877 1064 949 1251 963 1107 906 1107 949 963 877 1021 934 992 920 1049 877 1049 992 992 949 1136 1035 1021 1006 1064 1006 1064 1021 906 1006 992 1021 992 978 920 906 978 1049 1093 1021 1049 1035 978 963 992 920 1006 978 1006 1006 934 1006 949 1035 1035 1121 1064 1064 1107 1222 1150 1222 1150 1222 1207 1150 1136 1107 1322 1208 1236 1078 1121 1006 1136 1093 1107 1107 1193 1078 1179 1078

1 M 4 664 618 978 848 1064 1164 963 1049 978 1035 963 1064 1021 1035 978 1136 1049 963 963 1164 992 978 934 1107 1179 992 949 1179 834 992 906 906 1495 863 949 848 1121 920 877 834 920 805 1006 863 978 1093 978 819 891 805 848 1064 1064 963 949 1078 1380 992 949 1021 1021 819 1136 1236 1236 934 891 1064 1107 963 978 891 791 791 863 805 863 719 949 834 978 963 1078 1322 762 891 748 992 949 834

1 M 5 851 920 863 934 863 992 834 920 848 906 963 920 934 992 906 949 992 906 963 891 906 891 877 934 906 963 1035 1078 934 1021 949 963 978 906 1049 949 834 978 920 992 949 920 920 949 1093 1035 1035 1035 1164 1006 1064 978 1021 963 1064 1006 1021 949 963 992 978 1006 949 949 949 1021 920 1093 949 978 920 920 1035 1006 1035 992 1035 1121 1064 1093 1035 1107 1107 1064 1107 1107 1121 1107 1093 1265

1 M 6 1486 1471 990 990 825 1081 810 1276 810 780 795 705 750 690 615 750 690 675 645 720 720 645 810 750 780 810 825 975 915 855 870 945 1006 975 1051 945 960 825 990 945 870 1036 1141 1096 960 990 990 1051 1126 1021 1036 990 960 840 885 795 930 1051 1006 1006 1006 1006 930 1081 930 930 915 870 1426 1006 915 855 1006 1036 1051 1066 1066 1051 1126 1006 1036 1066 1081 1006 1021 1126 1081 1006 1066 1036

2 M 7 1051 1201 1261 1156 1051 1081 1066 960 960 975 945 975 1036 1036 1036 1051 1126 975 1051 1141 1111 1081 1051 1081 945 915 945 1021 945 1006 1021 1081 1081 900 945 1051 1036 1006 1051 1126 1096 1066 1066 990 1006 975 1051 1006 945 1051 1036 1051 1111 1081 1021 1006 975 1006 1036 1006 1036 990 1021 990 990 960 1036 900 990 975 915 900 915 915 885 855 870 870 855 900 825 855 930 915 930 945 885 870 915 900

2 F 8 885 930 885 990 1066 960 1006 1111 1051 1051 1126 1081 1081 1006 1036 960 930 1036 1036 1021 1021 960 990 1081 1006 1021 1051 1081 1156 1006 1186 990 1111 975 1201 975 1036 1096 1066 1126 1066 1126 1216 1186 990 1096 1036 1186 1021 1006 1081 990 960 1141 1081 960 975 1066 1096 1096 975 990 1021 1021 1006 915 1066 1096

960 900 975 1021 1111 1006 1066 975 1036 1021 960 945 975 990 1051 1096 1051 1021 1021 1066 1096 1081

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2 F 10 1153 934 906 949 1208 791 1093 834 863 1049 992 805 906 1093 920 863 848 1049 992 863 1006 992 920 963 949 992 949 848 978 1021 1035 920 877 1093 920 978 1107 1093 1035 1049 963 978 978 963 1006 1093 1064 1035 1078 1107 978 1107 1121 1049 978 920 920 920 992 920 1179 1021 1121 1121 1049 1093 1107 1006 1064 1006 992 1006 949 949 949 906 891 920 934 1021 1021 1064 1035 1049 1021 1078 963 1006 1078 891

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Relative Frequency Experiment One

The data are stored according to the following format:

The code left of the subject data refers to group number, gender and subject number.

The codes are:

1 = Control; 2 = Strategy, 3 = Relative Frequency. M = Male, F = Female.

1 F 1 1101 1996 1294 1504 1775 2242 1971 2132 1368 1307 2452 1602 1528 1467 1651 1381 974 1208 925 864 1147 925 1393 851 839 1024 950 925 950 962 900 999 1085 999 974 1233 913 1073 1061 1122 1048 1196 1011 925 987 802 987 950 1368 1701 888 1097 1036 876 937 937 987 802 1073 987 1048 987 1011 1122 1159 950 1024 987 999 900 987 999 900 827 851 814 1036 1024 1368 987 1602 876 888 900 827 962 777 790 839 1024

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1 M 3 657 716 704 814 704 765 913 900 913 974 1024 827 913 962 974 925 937 925 925 937 987 901 937 1110 937 987 913 1085 1418 1073 987 839 1011 888 950 888 900 987 950 987 950 1024 900 950 962 1048 987 999 913 1036 1048 1073 1036 999 1024 937 1085 974 1024 1011 913 1048 962 1085 1110 1061 1073 1048 1122 987 802 913 987 1134 999 1061 987 1036 1048 1110 1097 1134 1134 1122 1073 1110 1097 1011 1122 1073

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1 M 5 756 642 617 679 888 925 790 740 974 1073 851 716 864 740 790 777 679 691 925 974 802 740 962 876 962 925 937 790 753 839 814 888 1024 1024 802 814 888 950 1036 925 790 888 1134 1011 900 1048 1011 962 999 851 937 1122 1159 1073 888 913 950 925 950 1196 1073 987 962 1110 814 1061 1147 999 1061 1024 876 864 950 1134 864 937 962 950 937 937 974 987 1024 913 888 987 950 925 1011 950

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2 M 12 1421 987 1270 962 1110 864 888 1122 802 925 864 1024 900 827 999 987 864 876 925
827 987 901 962 1134 950 1171 925 864 876 864 925 802 925 888 900 900 900 777 962
999 913 1245 851 876 876 913 753 876 839 716 851 864 777 913 1011 1097 987 1024 962
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3 F 14 1137 753 679 654 753 704 765 790 716 667 839 888 777 814 704 753 888 876 876 814
765 679 888 716 704 900 1097 937 1048 851 1110 1073 1110 1245 999 925 1048 950
1097 1024 1393 1147 1085 1565 1430 1011 1011 1085 900 925 974 913 1393 974 925 937
987 999 925 937 864 937 1085 999 1097 1208 1061 962 1011 1036 1097 913 1024 962
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3 M 15 1101 1011 974 937 950 1011 999 1024 1011 999 950 1024 962 1011 1036 1110 1011
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1061 1011 1073 1048 974 1061 1048 1036 1036 1122 1036 1134 1110 1208 1184 1061
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1110 1036 1036 1024 1073 1024

3 M 16 853 936 1290 961 1170 1109 936 949 1084 1072 998 1096 1121 1133 1022 1121 1158
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924 862 1059 1121 1022 1010 998 1109 1059 1133 1109 1440 1059 1158 1022 1059 1084
986 1072 936 961 838 1109 986 949 986 899 1059 973 924 1010 899 986 1022 1047 1084
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3 M 17 1014 777 827 851 876 851 925 1085 1110 1011 1085 1122 1221 1196 1097 1024 1073
1061 1073 1048 1061 1011 962 974 937 962 974 1048 999 1147 999 1085 1061 1048 1134
1085 987 999 913 864 1134 1036 1122 1122 1134 1122 1073 1221 1171 1147 1048 1073
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1024 1085 1159 1097 1036 1110 1011 1024 1036 1085 1184 1085 1122 1184 1134 1196
1221 1110 1147 1159 1110 1061

3 M 18 842 790 679 900 679 765 790 827 765 765 888 913 1061 876 974 1036 913 950 790 925 999 1085 1147 987 962 1048 1110 1011 925 864 950 1122 1134 1085 1073 999 962 1122 1011 913 900 1048 1061 1085 1110 974 950 937 950 987 1134 1061 962 1097 974 937 1061 1097 1442 1208 1319 1036 1024 1196 1122 1122 1110 1319 1381 1294 1171 1061 1085 1134 1134 1159 1061 1159 1208 1270 1097 1294 1233 1184 1196 1184 1344 1270 1257 1196

Relative Frequency Experiment Two

The data are stored according to the following format:

The code left of the subject data refers to group number, gender and subject number.

The codes are:

1 = Control; 2 = Strategy; 3 = Relative Frequency. M = Male; F = Female.

1 M1 451 483 420 617 667 704 1073 913 937 987 1036 937 1011 1024 950 962 1073 1036 1122 962 974 950 1097 999 1147 962 1024 1073 1097 1011 1048 1036 987 937 1024 1011 950 1097 1011 1011 1122 1147 1110 1061 950 1011 1073 974 999 999 1307 827 1097 987 1024 987 1061 1257 1036 987 937 1196 1467 1085 1110 962 1122 1024 1184 1122 888 999 925 1024 974 950 925 937 1011 864 876 814 987 1048 950 876 974 1036 1024 1110

1 M2 596 531 580 617 568 470 556 642 580 704 704 999 876 1061 1085 950 962 876 999 925 1122 827 974 1122 1011 827 1011 1011 900 937 1036 1085 900 987 1122 913 999 864 1024 1073 925 888 1184 1134 827 999 999 888 1024 900 1011 987 1319 925 987 987 974 950 950 839 987 987 1011 1048 1134 1528 1172 900 937 876 728 851 999 888 950 937 1221 839 790 839 900 937 839 962 999 1048 925 925 913 901

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1 M4 657 667 654 593 482 544 445 642 1381 704 753 753 691 790 937 900 888 962 901 913 974 1171 974 1036 962 900 987 1048 999 1011 1184 1061 1073 900 790 900 814 1122 1073 901 987 1036 974 1073 1061 962 999 1024 1073 888 1048 1011 1048 901 1048 1011 1097 962 1085 962 1011 1024 950 1233 1122 1233 1196 1171 1245 1159 1171 1122 1171 1294 1171 1405 1528 1772 1134 1762 1639 1627 1565 1270 1331 1381 1578 1467 1491 1368

1 M5 756 974 974 925 913 1171 1011 999 1048 974 1097 1073 1011 1024 1184 1011 1122 1122 1221 937 1073 1061 1011 1061 999 1036 1011 1134 999 888 1159 925 999 1097 1110 1294 937 1085 1085 1073 987 1073 999 937 1036 1134 1011 1085 1122 1011 1061 925 1024 1122 962 1122 1061 1036 1024 1147 1097 999 1011 1073 1061 999 999 1061 1011 1061 1011 974 1158 1024 925 937 974 999 1097 962 962 962 987 925 962 925 974 1085 987 974

1 M6 559 617 839 728 888 851 1097 987 974 1097 950 974 962 1024 999 913 1036 925 999 974 1061 1061 1147 1011 1036 1036 913 974 974 900 1097 1122 901 1048 1061 1011 974 913 913 1073 1110 925 1024 974 1036 937 937 999 900 937 1061 1073 974 974 888 1011 1085 1073 1036 1085 913 1011 1134 1085 987 1208 1024 1147 1147 1097 1061 950 1061 1073 1097 1073 1085 1061 1147 1122 1097 1110 1134 1097 1011 1134 1171 1073 1097 1122

1 M7 460 1736 1196 1479 876 1637 864 839 876 1085 987 1073 925 1073 1036 987 1344 876 925 950 950 814 901 925 1270 1344 1048 1097 950 999 1085 974 1073 1085 1110 900 1159 999 913 1196 1073 1097 1011 937 1233 876 1061 1159 1048 987 1196 1134 999 1233 1110 1233 1110 950 1036 1061 1073 913 925 987 999 925 1061 1024 1097 913 777 802 974 937 987 1073 1048 937 962 937 913 937 925 950 888 1011 1036 1134 1073 1061

1 M8 694 802 740 950 950 937 999 790 1085 1307 1011 1085 925 1368 790 1270 1036 1048 1073 1061 937 937 1110 1122 1024 900 974 1061 974 1159 1097 1208 1048 1134 1159 999 987 1097 974 999 1011 1061 1085 1134 1011 1024 1789 974 974 987 1036 999 999

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3 M17 842 974 864 839 900 974 937 937 999 1036 974 974 913 1061 1011 974 1159 1011 1171 1097 1024 1048 1196 1196 1196 1048 1122 1110 1184 1085 962 950 937 1011 937 1011 974 1036 1024 1073 1036 1024 1085 1048 950 1024 1147 1122 1233 1134 1159 1122 1184 999 1097 999 1134 999 999 987 1024 1097 1196 1147 1085 1147 1097 1134

1122 1011 962 1024 1048 1085 1048 1073 950 962 1073 1024 937 987 987 974 950 913 1061 1061 1061 1097

3 M18 756 1036 1024 1011 900 913 987 1073 1184 1036 987 1011 1073 1159 1319 962 1011 1048 937 925 1048 1233 814 1024 876 1147 814 974 888 827 925 1800 962 851 987 1110 987 1048 1208 1208 1208 1122 1245 1270 1011 1011 1011 1208 1097 1208 974 1024 950 1221 987 1270 1208 1196 1085 1307 1122 1208 1061 1110 1171 1233 1233 1208 1171 1171 1159 1381 1110 1085 987 1085 1011 1048 1073 1085 1011 987 1036 999 950 1097 1036 999 999 962

3 M19 251 223 260 297 507 630 777 814 814 753 1208 814 1085 888 864 974 1024 1061 876 950 937 1024 888 1085 1048 1171 1073 1011 950 925 974 1011 962 999 962 1048 913 1036 1061 1061 974 1036 1233 1344 999 1110 1048 1024 1134 999 1024 1024 1011 1171 1011 1011 1221 1159 1073 1011 1134 1159 1085 1061 1171 1184 1171 1159 1270 1381 851 728 851 950 950 987 962 864 999 950 913 999 913 962 1061 1011 1011 827 864 937

3 M20 645 876 790 790 568 876 851 913 1097 974 1011 888 950 790 1024 1147 999 864 962 937 1085 1024 1024 1011 1184 1011 839 839 876 962 864 1048 999 1048 999 888 1073 999 950 1024 900 876 1048 876 1048 962 814 802 900 1676 765 888 888 839 839 1171 962 1024 1331 1627 937 901 790 913 987 937 1073 1024 1011 974 900 839 851 765 790 753 962 925 913 937 1024 1011 937 937 900 1024 1024 937 937 888

3 M21 485 679 642 531 617 580 519 482 507 531 691 802 827 827 802 839 876 876 950 950 888 1110 937 974 900 974 962 1011 1036 1110 974 987 1110 1159 1319 1036 1024 1221 1097 1257 1159 1048 937 1048 1048 1073 1011 1134 1171 1061 1184 1097 1159 1122 1024 1147 1122 1171 937 999 1122 1036 1048 1097 1085 1122 1184 1147 1024 1024 925 999 913 900 999 950 876 864 888 1085 987 1073 1061 1110 1159 1110 1134 1134 1171 1122

3 M22 362 347 482 544 605 1073 1110 1159 1073 937 1061 1061 1245 1147 1085 1110 1122 1024 999 974 974 1085 974 1024 1085 1085 1073 1024 1036 1036 974 962 1024 1085 1134 962 1011 1036 1011 1011 1097 1061 1024 1073 1024 1011 1085 1061 1048 1073 987 1011 1085 1036 1036 962 1085 925 1036 999 1048 1024 1036 1073 1036 1036 1036 1061 1085 1097 913 950 1097 1159 1147 1036 1110 1110 1097 1184 1073 1134 1147 1048 1134 1134 1048 1048 1097 1036

3 M23 854 740 667 568 679 765 740 802 704 876 802 876 987 937 864 1454 1356 1147 1307 1233 1011 1196 1159 1233 1011 1110 1196 1147 1110 1159 1245 1270 1356 1331 1233 1159 1270 1257 1344 1319 1048 1208 1184 1073 1011 925 1036 1024 1036 839 1073 1134 1122 1024 925 1048 1122 1036 1073 999 999 1061 1073 1073 1085 1778 839 987 1011 1800 925 987 1048 999 999 1085 987 1048 1036 999 913 974 1036 987 1061 987 1073 987 913 1036

3 M24 830 1048 1184 1097 1061 999 1048 1245 1110 987 1073 1073 974 987 1110 925 1400 925 1061 1011 999 1085 1011 1097 1097 1110 1011 1073 937 974 974 913 901 962 937 913 925 962 950 999 937 913 888 987 950 950 913 925 962 925 1036 987 1011 1085 1073 1036 1036 1061 1048 987 913 1085 1110 1097 1061 1097 1011 987 1024 1036 925 987 950 974 1024 1036 987 962 974 974 950 999 962 1011 974 999 974 987 1011 1134

Summary KR Experiment One

The data are stored according to the following format:

The code left of the subject data refers to group number, gender and subject number.

The codes are:

1 = Control; 2 = Summary KR, 3 = Strategy, 4 = Yoked Strategy. M = Male; F = Female.

1 F 1 1397 1049 838 896 760 804 636 616 582 723 663 657 610 579 598 566 563 565 600 526 544 554 554 550 590 557 552 545 535 501 509 538 494 499 590 524 538 519 515 544 526 549 509 524 539 547 501 520 516 536 532 514 527 528 551 523 541 545 513 502 525 557 630 599 562 556 584 597 589 557 575 557 543 531 574 534 573 552 578 603 589 550 595 540 565 603 622 586 574 578 621 608 598 597 525 573 564 580 546 564 547 542 529 502 563 540 534 518 542 488 533 499 523 526 508 519 510 517 516 523 204 500 472 483 497 455 464 446 465 449 483 437 503 487 437 501 496 482 470 481 436 452 454 417 465 453 443 428 406 443

1 M 2 480 722 645 626 641 575 551 533 579 543 551 601 565 517 516 556 534 565 520 609 533 567 553 554 549 558 584 543 568 554 517 551 545 570 572 603 588 573 550 563 600 592 594 595 560 567 608 540 548 575 653 554 592 534 581 552 580 524 589 575 510 570 561 563 576 516 542 550 544 570 508 455 524 554 523 564 565 524 527 561 541 524 549 525 527 524 549 606 549 536 534 521 544 552 530 546 530 543 568 549 543 548 556 534 538 544 544 540 537 587 535 559 540 555 531 539 561 529 549 503 538 555 522 552 554 559 582 547 557 527 534 547 539 551 531 580 559 554 530 553 528 511 512 541 529 504 542 534 537 531

1 M 3 1570 1237 994 1105 924 900 832 839 784 720 676 624 654 679 619 611 611 590 563 571 582 592 608 614 560 573 518 722 569 646 644 676 706 627 664 617 648 673 691 636 663 629 606 675 589 614 612 673 659 644 619 631 620 570 683 602 570 561 571 587 581 638 584 604 606 611 622 651 641 628 610 634 680 625 682 599 556 530 566 587 584 628 588 616 662 554 562 548 550 575 498 557 488 540 533 515 488 547 571 524 516 622 554 571 592 582 548 560 598 539 486 586 536 513 534 574 540 535 511 510 750 604 673 598 659 719 628 684 637 672 649 684 589 574 596 631 622 635 576 635 698 596 649 685 627 696 636 650 640 593

1 M 4 1241 1140 1149 1097 1285 950 931 738 789 668 672 623 557 543 586 559 557 563 559 558 548 622 555 748 484 550 552 523 552 690 584 494 599 573 603 478 568 629 581 636 610 606 555 551 642 615 600 489 608 616 645 584 575 615 582 550 532 607 571 535 563 544 536 615 561 603 584 540 649 595 561 582 562 512 599 532 461 522 483 647 517 520 573 568 497 575 581 520 643 574 686 565 607 617 599 575 560 607 561 610 527 643 590 587 574 577 553 581 592 540 553 566 488 556 530 506 546 616 562 554 614 556 589 515 578 608 571 555 563 534 513 514 640 538 511 488 549 565 536 587 573 571 533 644 524 528 548 523 565 569

1 M 5 1075 530 1047 1058 1111 952 1065 805 1088 917 1027 830 851 768 785 791 783 895 924 924 624 539 519 601 531 568 498 565 511 518 689 508 541 665 491 478 480 539 432 545 497 588 633 414 705 509 554 517 763 598 537 557 506 490 517 561 532 577 664 501 549 554 516 558 633 793 477 529 533 548 487 565 474 557 481 484 462 649 597 581 555 524 593 473 516 520 450 539 492 493 658 706 592 556 548 570 583 624 697 654 693 660 728 606 583 537 513 560 499 516 510 524 509 552 556 668 606 565 573 628 814 693 561 543 621 618 617 630 531 633 578 646 696 526 557 686 600 590 564 567 581 543 560 578 582 551 597 543 540 612

1 F 6 1153 1027 891 829 696 762 685 645 689 741 717 643 613 635 611 743 672 634 686 597 629 636 645 675 671 594 597 671 624 665 596 705 680 676 638 642 648 596 565 579 586 547 547 590 609 567 597 581 574 556 550 526 562 559 527 535 563 537 529 572 578 549 550 548 564 558 511 563 557 541 574 563 541 684 520 611 531 580 620 549 589 499 574 578 630 576 554 548 559 543 642 583 559 602 540 589 532 554 537 552 572 602 523 538 572 553 573 549 545 573 539 535 610 524 538 596 535 525 484 547 573 641 561 618 575 552 528 576 567 562 571 530 578 584 579 643 550 567 575 530 531 579 589 561 614 591 541 629 659 627

1 F 7 750 595 566 590 548 583 548 504 650 548 585 564 534 569 530 541 562 563 592 500 596 506 544 560 521 576 616 539 578 604 489 579 662 494 645 567 578 548 636 525 623 629 561 544 582 565 541 578 527 588 574 596 506 606 546 558 522 554 572 576 608 560 573 537 560 614 554 581 575 574 589 509 604 536 546 587 544 599 540 508 562 539 657 534 543 604 527 573 543 577 531 543 534 566 547 508 539 493 513 514 545 524 513 513 498 477 461 538 508 518 544 481 517 512 615 518 509 529 526 503 484 516 481 507 484 493 554 464 443 463 453 466 458 469 483 458 459 448 458 405 507 484 393 554 546 456 556 448 535 472

1 M 8 918 748 707 730 715 636 634 584 626 586 592 552 567 589 516 577 530 532 556 522 570 629 553 521 524 547 555 550 610 529 570 552 518 578 515 546 576 492 539 539 532 536 577 556 551 542 548 546 578 598 547 570 527 521 520 548 547 561 582 521 546 543 540 524 506 567 566 559 532 553 514 554 539 524 552 572 562 538 516 514 535 528 555 560 538 513 523 494 498 517 521 535 482 521 477 506 527 512 525 535 499 496 471 513 513 500 491 485 490 487 496 471 469 476 468 480 473 469 464 503 669 689 705 707 524 708 533 708 603 672 700 702 701 707 701 574 534 530 576 624 577 503 529 667 590 563 547 633 673 652

1 F 9 483 529 504 631 520 602 516 570 574 503 475 521 488 541 527 482 551 506 608 585 500 504 525 549 574 595 508 540 610 528 539 535 562 506 600 494 552 566 561 533 528 541 570 533 506 615 476 540 510 553 586 539 545 567 523 558 556 546 543 545 583 493 548 508 523 570 492 516 483 577 542 543 580 561 534 526 541 571 520 518 578 559 522 558 501 561 547 529 558 552 514 480 480 519 493 526 496 482 505 526 543 515 529 526 539 540 525 517 505 538 524 488 459 521 517 528 573 551 540 524 450 424 504 464 467 465 456 464 432 450 414 423 462 442 452 437 463 432 447 487 450 524 535 416 426 427 482 432 538 497

1 M 10 980 955 926 813 774 679 730 657 702 677 621 681 627 651 635 618 619 618 608 556 570 559 538 582 568 548 566 552 550 542 543 557 552 576 530 556 571 579 618 627 588 599 586 584 599 569 591 585 547 585 550 563 540 564 555 603 535 553 586 563 573 584 576 553 617 590 581 567 578 549 566 561 550 552 570 570 542 576 549 572 576 559 552 557 519 579 606 606 617 571 662 654 602 603 627 608 615 597 597 615 564 583 574 550 601 550 601 604 650 614 572 621 619 600 581 605 588 591 582 574 630 600 545 604 598 587 562 611 555 568 560 585 591 564 599 557 553 577 554 611 530 533 531 524 552 535 558 541 555 532

2 M 11 1213 1190 946 942 930 808 850 817 864 965 802 813 802 805 824 703 805 741 761 852 756 768 705 716 705 886 746 691 657 739 618 591 580 640 592 634 567 580 592 571 543 559 563 549 573 530 553 504 494 529 738 764 531 602 567 551 547 517 547 531 543 548 525 574 597 548 569 546 796 614 536 609 574 576 568 608 570 595 548 583 627 582 587 592 522 664 598 624 718 624 660 579 504 529 565 526 561 626 553 601 500 525 491 493 485 547 527 483 453 506 478 495 516 556 474 481 497 458 436 443 677 721 613 621 643 545 576 587 583 608 615 568 605 680 652 697 606 564 632 633 592 615 591 624 605 637 661 619 660 573

2 F 12 1053 949 1273 968 921 823 814 761 790 797 848 681 654 653 619 609 648 597 604 581 614 581 665 581 561 531 572 509 530 532 473 519 503 507 510 516 498 531 569 477 521 588 537 560 584 546 542 535 527 544 502 498 528 524 511 550 537 559 549 496 477 506 527 504 479 492 494 510 498 546 469 468 464 490 459 458 490 492 468 505 547 590 537 562 580 560 639 662 579 586 575 592 572 586 572 588 584 587 605 598 583 592 609 591

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2 M 13 747 1004 1131 830 987 1033 1134 1440 1530 1483 641 541 472 496 463 538 530 475 443 585 566 604 557 590 642 539 575 570 538 550 557 592 568 601 513 558 666 506 468 544 519 600 560 541 544 534 483 517 492 483 532 574 579 557 516 590 592 572 554 559 617 556 506 565 567 537 557 576 575 543 618 597 622 688 611 542 592 637 556 589 501 502 552 569 526 505 615 532 493 451 593 563 507 485 466 435 480 498 485 488 459 482 489 517 506 486 437 458 494 463 494 467 456 410 461 467 512 515 535 488 568 568 545 551 501 550 539 546 478 526 530 541 534 546 529 507 527 520 532 551 545 522 520 530 521 527 503 546 522 519

2 M 14 1107 1166 1177 1224 1177 1155 1170 1190 1107 1139 835 849 895 843 844 822 834 879 820 837 652 641 674 660 644 661 605 600 573 629 614 577 570 557 576 605 547 556 511 560 618 566 561 548 566 539 521 545 541 587 555 552 532 536 558 535 535 557 540 524 578 572 577 555 562 546 562 539 536 542 510 484 522 548 505 521 506 495 519 561 567 560 583 578 571 556 589 547 560 595 724 596 607 586 597 590 558 585 568 556 586 586 566 554 560 561 521 522 513 521 521 524 539 506 524 517 569 541 538 513 482 509 520 537 512 507 544 506 498 487 508 482 471 493 486 539 461 458 445 461 483 470 475 466 501 520 493 461 462 468

2 M 15 1002 1015 1019 980 979 989 987 966 962 1044 776 769 806 774 705 717 736 711 712 714 504 558 492 514 536 486 503 516 501 547 544 646 620 591 611 587 558 641 665 515 621 613 637 572 584 553 512 543 512 587 568 543 550 589 551 611 598 541 553 586 541 573 593 588 536 545 591 536 537 548 515 548 548 533 491 528 484 550 512 526 514 494 496 514 510 524 473 498 504 514 567 521 585 571 530 516 570 525 577 597 572 540 510 484 553 587 536 568 518 544 507 512 540 523 612 582 537 538 549 569 523 506 543 484 490 544 551 582 505 498 504 565 484 513 576 551 492 508 435 487 568 572 440 489 523 541 595 536 515 517

2 M 16 715 711 858 713 751 733 746 747 898 863 722 726 727 675 680 653 683 617 715 667 643 632 687 624 730 690 693 663 799 694 653 612 653 637 670 689 654 727 675 620 660 664 643 647 641 616 619 698 590 610 712 663 694 725 673 636 646 622 618 596 608 614 570 572 584 569 573 525 522 561 540 559 573 548 550 548 549 539 565 544 565 575 563 523 546 550 498 524 526 507 576 575 598 612 576 578 534 557 549 557 546 549 608 557 558 501 542 632 559 575 600 638 574 626 531 545 601 593 613 595 565 579 576 551 541 561 542 553 535 535 586 571 585 574 584 576 553 556 543 564 523 537 512 561 541 578 584 557 564 568

2 F 17 697 858 704 665 653 650 646 601 635 598 582 590 533 604 588 562 564 600 607 588 589 564 569 584 558 556 562 571 522 577 571 538 580 539 571 574 576 549 580 555 523 573 557 557 568 567 570 518 564 556 567 562 527 552 546 551 558 554 515 574 573 598 576 570 530 561 572 540 564 565 552 566 519 567 567 591 560 529 563 546 556 577 563 585 541 586 554 569 524 558 746 591 557 550 556 564 562 572 508 548 557 533 546 588 538 549 530 548 543 538 518 523 533 543 526 526 535 531 513 568 403 408 448 466 455 465 472 481 482 460 452 468 480 466 482 487 465 481 458 457 466 458 467 454 460 480 451 497 443 416

2 M 18 611 611 586 627 594 598 591 520 565 539 538 514 498 544 572 520 487 530 554 554 583 574 660 559 545 596 552 575 561 471 535 527 525 558 549 555 549 543 594 537 517 530 531 523 531 568 488 513 472 465 509 538 493 514 539 527 535 499 488 513 553 576 504 524 629 573 549 560 584 587 581 571 559 566 548 566 605 560 507 527 555 547 580 557 561 532 543 562 583 564 575 531 529 560 533 488 503 492 493 470 466 464 451 432 446 484 490 502 508 496 482 522 460 491 465 490 440 481 476 463 484 496 506 524 477 514 511 507 508 501 523 521 516 499 494 534 524 493 472 471 451 470 464 451 445 443 454 451 506 449

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2 F 20 861 765 712 750 690 621 625 572 573 607 585 518 499 498 528 548 531 490 514 516
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3 M 21 758 715 778 757 840 800 659 643 675 660 662 631 617 680 663 568 582 588 634 657
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3 F 22 734 608 541 543 567 533 559 524 554 574 528 545 567 519 531 519 516 497 486 550
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3 F 23 798 725 746 806 747 775 812 788 751 727 717 763 773 734 751 771 762 722 724 723
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3 M 24 801 888 779 726 752 839 868 734 727 775 739 810 765 751 718 707 708 761 697 730
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3 F 25 622 601 560 580 508 517 518 479 499 471 477 490 450 519 540 547 592 571 560 556
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3 M 26 648 648 570 571 571 522 567 508 504 512 509 503 529 551 529 541 502 545 556 531 566 523 518 534 542 550 553 532 539 539 548 522 520 464 565 499 482 502 481 497 504 492 549 546 512 506 547 529 538 520 535 577 551 511 553 549 568 521 557 572 575 532 544 562 563 548 512 573 550 509 547 563 582 548 554 562 556 507 583 560 563 546 531 529 521 529 584 546 579 530 590 560 552 591 596 561 620 617 575 632 600 605 580 585 600 538 568 545 556 579 568 581 594 530 551 530 543 563 559 533 611 594 605 566 596 588 597 598 605 566 577 579 612 616 612 587 612 591 567 574 580 581 585 572 588 568 562 574 636 598

3 M 27 679 615 637 621 674 669 677 764 687 527 569 605 564 584 537 544 534 540 552 528 559 537 544 512 522 553 544 553 557 574 522 588 540 587 569 610 557 552 540 528 571 532 554 562 534 588 553 609 566 585 552 583 580 525 538 523 553 536 552 564 540 536 563 554 552 543 558 610 541 552 550 566 567 554 546 557 571 534 545 574 565 551 576 534 565 542 538 548 557 554 557 511 503 477 489 504 508 488 506 499 527 494 468 508 496 517 505 493 510 512 514 508 514 495 489 498 518 499 516 513 517 484 460 470 494 477 494 501 468 467 486 487 474 502 491 491 507 518 505 535 500 520 507 492 518 511 536 510 526 497

3 M 28 766 720 697 670 749 538 491 544 548 510 453 482 469 435 465 419 456 451 454 507 498 515 473 482 522 473 492 430 446 475 484 559 507 485 497 575 557 511 497 487 503 527 532 515 489 512 558 517 526 534 528 500 514 489 556 483 522 529 548 565 557 643 565 649 613 567 562 544 547 542 514 493 490 512 491 488 520 557 555 546 563 557 565 541 538 523 556 515 544 561 575 515 477 521 531 537 514 526 504 501 501 472 503 508 509 493 511 530 543 542 558 556 556 531 532 542 551 548 522 522 599 535 540 586 590 591 571 587 597 574 618 585 616 584 617 642 623 606 594 605 602 606 618 623 623 613 577 610 629 635

3 M 29 1108 1141 1095 1185 1254 839 754 751 756 749 730 605 585 566 533 603 642 668 541 592 573 726 512 541 465 533 558 530 491 470 598 598 647 661 574 577 643 585 571 527 534 541 572 572 525 540 568 518 579 541 565 586 710 545 537 521 518 553 613 526 562 524 488 535 556 575 544 591 622 595 615 670 584 585 567 655 588 543 616 547 512 536 550 497 597 497 570 587 512 528 494 558 507 525 506 553 521 561 516 483 447 479 498 509 496 538 474 470 502 471 559 455 439 427 465 456 494 487 478 479 513 480 477 468 460 457 457 444 435 411 486 436 476 463 479 419 461 438 464 464 468 455 458 506 491 498 478 480 503 507

3 F 30 635 554 581 570 578 596 598 557 615 625 623 620 624 576 577 613 613 618 523 530 550 502 484 520 492 494 520 532 477 495 514 473 465 454 488 513 555 525 586 572 539 551 521 536 566 551 618 664 565 597 570 604 613 633 573 561 569 612 588 568 590 648 523 578 537 524 535 506 693 585 536 594 540 584 588 587 566 535 630 578 539 554 556 596 571 516 574 518 551 582 587 560 578 601 632 610 578 531 505 538 496 497 530 484 536 526 564 555 586 550 572 507 530 560 567 550 608 601 563 609 570 538 542 550 541 502 530 545 574 518 552 506 556 495 535 520 504 523 585 506 503 503 647 520 491 485 478 497 489 528

4 M 31 1453 1445 1483 1450 1445 1575 1091 1058 1095 1021 975 967 1002 919 969 672 670 788 699 676 703 733 743 796 774 813 753 702 727 620 619 689 596 616 643 701 553 669 696 706 683 543 614 632 615 616 623 635 578 670 703 675 707 645 626 612 640 649 640 634 592 563 591 588 560 663 548 615 619 618 572 604 593 574 587 632 618 652 593 621 613 619 576 617 610 609 607 591 582 602 702 605 691 623 612 601 635 614 601 610 637 635 597 595 595 661 658 610 587 618 608 600 625 670 595 599 595 611 620 622 565 507 562 555 558 538 540 586 538 547 511 529 522 596 614 553 547 483 519 494 503 529 500 560 609 550 597 597 475 523

4 F 32 772 705 757 689 674 681 697 675 615 642 667 661 679 633 630 688 662 609 634 615 552 563 596 589 547 561 514 513 563 503 612 528 531 550 493 518 498 509 515 531 549 473 497 530 526 562 494 511 522 546 530 581 577 504 531 527 518 495 511 486 544 556

530 520 568 547 527 564 578 586 557 542 578 566 559 580 550 563 555 581 555 532 499 515 505 513 509 500 480 481 464 475 450 462 474 438 454 441 442 450 483 423 429 428 451 453 472 467 447 457 454 466 444 448 479 425 433 509 395 423 525 541 562 521 560 527 518 538 534 584 590 526 537 536 549 548 575 542 534 547 531 550 525 514 573 527 529 532 522 529

4 F 33 989 884 905 826 849 967 895 917 919 962 854 752 779 850 862 887 920 948 1077 971 709 747 789 650 812 774 753 793 714 693 624 600 772 665 613 649 623 616 654 559 704 658 575 577 537 612 532 547 532 575 735 594 589 690 610 601 643 659 600 675 621 731 734 670 606 582 599 638 712 644 502 615 581 532 555 637 678 701 545 582 507 516 516 522 543 618 618 648 589 523 640 627 596 575 585 583 543 552 622 579 641 575 684 670 600 557 559 611 534 588 536 509 517 652 579 611 690 644 580 543 662 610 614 568 567 577 515 450 546 549 486 518 524 541 534 554 516 565 583 599 555 615 579 541 605 550 603 589 599 599

4 M 34 1345 1233 1297 1239 1249 1208 1291 1221 1215 1279 1268 1143 1081 1061 1063 1058 1119 1188 1144 1103 1088 1097 971 953 985 966 952 1005 1001 1047 1049 1035 965 878 901 924 888 924 890 837 880 822 851 852 865 869 891 831 886 821 830 845 781 862 797 751 740 759 722 795 712 749 758 769 835 756 758 781 766 685 709 776 718 709 682 748 748 778 825 772 742 807 779 730 768 824 809 756 710 780 773 676 680 741 693 712 729 674 621 623 648 687 730 730 697 662 657 738 707 712 707 694 706 654 699 739 702 677 662 651 841 751 732 803 759 792 813 707 734 672 695 718 754 735 728 746 725 742 704 698 718 754 707 787 731 714 743 727 752 761

4 M 35 849 842 887 786 642 606 594 531 602 555 538 616 593 567 536 529 522 502 505 500 505 532 549 475 484 505 486 551 529 582 622 564 557 508 635 512 619 612 591 650 632 722 656 654 640 643 564 560 640 537 545 563 523 570 534 515 544 546 501 554 528 542 594 500 619 531 541 535 497 496 508 512 463 455 492 536 544 557 558 537 564 519 530 535 497 515 524 549 568 530 541 507 542 511 488 550 519 524 493 519 493 515 477 467 476 458 484 506 504 491 511 448 538 519 525 465 462 494 542 487 525 517 491 520 487 505 516 521 541 543 527 487 503 468 505 506 507 504 515 490 507 548 494 493 484 491 517 461 493 492

4 F 36 823 776 788 725 791 740 816 679 658 711 644 658 653 668 724 622 656 616 581 635 609 613 618 609 671 617 642 666 689 644 595 653 702 672 664 617 654 672 682 706 605 672 665 651 708 648 668 669 648 635 657 621 657 630 654 616 666 671 649 584 601 569 635 588 635 639 620 561 560 614 583 544 567 630 578 509 513 542 566 564 589 594 617 584 595 640 573 590 543 594 537 549 579 585 563 572 548 558 561 582 579 557 560 541 539 566 620 536 533 533 520 523 508 544 501 584 511 544 558 519 650 581 553 514 532 539 553 595 541 599 527 535 502 556 540 563 541 566 535 568 606 586 534 526 543 546 561 500 543 506

4 M 37 857 739 664 550 512 480 486 487 487 507 521 517 526 548 550 535 521 578 598 549 539 538 496 562 571 556 584 574 609 576 607 597 595 628 541 544 611 619 645 583 559 613 585 611 611 609 621 621 589 614 617 607 634 561 527 528 530 527 507 504 567 537 548 530 527 541 551 523 521 543 548 540 568 545 577 610 567 585 584 594 589 548 554 602 579 562 588 579 590 572 518 508 519 499 473 536 513 528 527 499 499 528 526 520 534 519 526 546 532 538 523 549 538 549 571 549 518 589 558 563 616 633 612 576 583 594 546 563 625 630 576 589 595 594 575 566 564 580 581 586 577 586 576 599 575 575 582 615 614 589

4 M 38 1524 1012 1018 1047 973 848 809 781 899 831 858 860 835 692 757 730 733 721 690 704 717 746 751 751 749 768 770 724 880 785 890 813 800 755 825 806 865 599 624 640 693 646 640 648 651 677 661 646 604 631 616 634 698 670 671 645 611 657 653 621 596 634 643 651 697 638 606 638 655 777 621 683 707 684 678 619 623 621 672 634 600 630 593 572 574 559 570 599 596 576 564 631 578 594 585 576 591 575 586 562 554 585 564 561 543 616 571 604 576 563 548 531 582 557 542 559 601 566 569 549 596 650 615 616 587 596 621 565 572 547 581 602 603 628 601 591 557 566 566 544 553 590 585 569 552 580 550 549 598 557

4 M 39 858 806 821 757 812 753 704 687 666 666 660 634 622 581 552 563 580 584 562 638 593 654 641 604 642 555 591 589 555 584 625 585 544 582 625 559 629 600 529 608 560 550 582 574 601 548 588 526 543 574 516 575 515 526 578 555 505 604 562 585 559 619 601 661 647 638 600 620 579 586 569 607 605 645 603 616 635 628 575 585 630 581 587 591 630 633 525 515 611 569 598 621 547 583 644 590 581 534 566 570 537 522 576 492 519 497 489 492 501 553 549 529 579 530 526 505 549 494 512 494 571 581 542 629 525 531 500 533 582 505 492 549 483 487 476 493 520 489 486 479 543 487 481 481 481 481 475 469 478 470

4 F 40 557 539 516 522 525 576 597 650 563 624 569 590 587 518 593 579 653 575 560 580 581 570 536 545 551 567 557 561 572 604 559 532 566 565 545 585 604 623 611 583 550 562 561 596 540 532 516 565 530 532 521 519 563 542 531 525 541 554 561 574 589 565 583 561 502 563 563 527 539 547 575 548 542 592 586 600 588 638 566 598 584 513 555 543 535 573 577 587 560 584 540 569 526 515 547 559 534 568 551 539 525 538 552 546 524 582 513 497 513 538 534 523 493 501 507 491 527 497 518 515 512 529 504 499 495 490 492 468 468 493 511 482 507 497 484 465 487 541 497 501 466 499 483 477 483 488 498 485 493 466

Summary KR Experiment Two

The data are stored according to the following format:

The code left of the subject data refers to group number, gender and subject number.

The codes are:

1 = Control; 2 = Summary KR; 3 = Strategy. M = Male; F = Female.

1 M 01 695 643 643 643 593 560 569 539 533 486 501 488 517 512 525 485 457 476 497 453 443 472 424 449 598 576 595 570 562 569 588 578 518 534 529 569 533 557 539 539 549 539 599 540 574 553 525 539 533 550 529 548 594 509 563 538 560 565 524 525 565 512 606 515 551 561 507 554 569 560 571 562 564 536 535 539 519 517 574 553 558 527 556 520 589 558 542 555 547 555 616 690 622 669 632 630 597 661 649 621 618 615 640 615 608 625 617 627 644 642 663 646 640 655 637 606 637 648 617 615

1 M 02 615 606 576 591 532 553 538 564 596 594 614 600 609 562 498 554 539 491 547 443 576 525 498 605 549 583 520 503 519 547 556 580 539 518 572 534 557 584 594 540 562 562 524 585 553 539 516 545 577 553 554 549 550 549 599 629 569 539 529 575 582 527 541 569 528 557 546 527 558 596 558 530 527 508 578 550 561 580 601 511 520 586 522 564 560 600 558 490 604 578 826 871 829 887 880 760 884 766 759 836 833 795 876 843 924 910 739 612 754 772 743 704 810 706 634 713 682 634 634 751

1 M 03 1285 1002 829 731 604 509 661 584 590 601 529 544 516 582 538 530 577 575 581 485 598 518 504 562 534 513 554 584 566 507 571 586 588 508 534 534 556 538 538 517 571 572 548 557 637 524 637 597 599 521 636 521 572 572 622 603 591 507 573 561 592 544 525 557 584 499 525 529 574 547 547 538 561 577 529 549 573 600 590 531 571 548 484 578 604 550 570 600 576 580 884 834 850 769 827 741 804 800 806 786 770 889 777 823 749 774 728 747 818 757 768 789 762 789 740 743 704 775 761 784

1 M 04 717 486 627 565 620 580 525 548 536 508 544 585 546 555 612 587 557 588 516 542 561 553 556 573 550 540 574 574 535 592 617 541 579 565 555 547 558 588 522 534 585 543 529 613 544 601 585 587 588 592 538 533 529 529 549 559 554 557 586 564 580 505 575 557 547 539 555 598 623 510 566 508 563 501 613 586 554 550 555 531 567 554 560 552 541 534 558 537 543 530 534 521 533 529 493 471 510 500 572 525 546 479 493 510 513 524 494 482 504 540 516 530 474 496 502 500 511 521 509 500

1 M 05 1256 1076 811 712 598 555 555 593 528 530 559 492 535 576 539 512 502 559 564 566 589 594 546 604 603 554 566 525 607 537 624 632 652 624 621 606 619 601 566 589 564 588 589 686 523 537 575 568 562 676 627 543 555 600 591 548 607 577 602 612 569 599 593 599 536 553 594 566 596 543 624 631 617 578 588 570 602 663 589 580 634 632 560 629 553 580 533 545 566 592 639 595 591 614 578 613 599 586 576 594 614 651 611 590 597 594 568 497 584 623 580 614 647 633 597 603 654 584 601 653

1 M 06 1540 1184 1019 979 901 891 796 789 750 686 709 697 609 701 678 608 576 649 650 666 620 641 652 676 562 599 584 577 587 569 564 542 575 568 620 529 572 591 635 576 591 537 553 591 573 553 556 542 550 621 523 554 532 550 579 579 520 498 538 563 579 592 589 581 578 522 577 498 558 565 596 594 572 545 532 516 578 540 539 576 590 524 523 594 552 554 565 566 541 558 500 493 486 487 504 492 476 506 522 496 496 562 528 528 516 485 509 559 528 487 554 527 521 510 564 541 537 510 531 507

1 M 07 831 598 613 621 556 565 560 527 539 502 531 526 518 550 526 497 495 510 489 481 471 456 476 463 475 457 468 471 534 547 547 519 539 533 526 551 550 566 521 524 544 530 556 545 560 569 525 570 571 594 545 563 581 532 525 525 542 535 557 540 549 524 523 489 517 514 536 516 496 547 546 516 523 534 540 527 537 531 541 543 589 588 542 555 513 533 574 550 567 565 650 689 690 645 602 624 582 565 573 594 577 583 525 525 554 595 572 557 586 546 542 538 523 517 522 562 523 522 536 517

1 M 08 780 565 569 625 555 523 537 509 485 489 473 498 481 492 485 500 514 468 511 492 620 621 570 555 636 555 657 728 613 641 704 700 684 675 695 636 610 648 603 584 639 583 637 623 633 683 734 829 573 522 474 659 559 609 511 450 467 658 564 499 485 542 480 467 479 590 512 598 599 656 583 593 548 528 458 557 454 533 423 536 431 483 515 604 418 499 476 502 524 600 626 674 753 676 682 691 697 716 668 734 779 774 814 759 676 774 636 715 867 798 733 753 777 841 743 766 859 771 768 807

1 M 09 1139 871 714 746 603 563 534 555 687 500 461 495 518 514 487 461 501 504 469 542 511 492 453 491 466 512 495 517 531 512 641 501 534 520 553 511 566 611 476 491 658 553 508 503 522 521 560 596 531 526 513 540 565 529 524 509 506 492 593 540 537 538 587 593 541 504 536 544 554 589 567 546 587 538 509 499 556 534 557 558 546 515 550 527 531 528 541 566 564 607 548 527 505 551 492 478 498 534 496 592 569 501 498 523 521 604 529 522 541 465 483 475 480 450 444 476 503 516 505 474

1 F 10 1020 826 723 655 717 569 553 595 591 595 605 532 595 581 596 577 546 568 585 576 571 582 565 594 589 553 550 570 578 553 583 580 585 607 640 591 599 608 582 595 543 571 581 633 588 551 570 589 586 665 595 577 609 651 608 557 638 564 598 650 566 588 585 596 634 562 573 569 564 569 617 621 596 590 585 572 573 618 567 564 635 624 565 597 559 593 576 541 550 561 591 584 600 602 605 582 591 609 608 635 639 665 645 644 666 659 636 584 627 646 634 663 647 689 654 637 671 669 672 691

1 F 11 973 808 837 794 795 784 750 757 624 613 608 615 635 551 589 592 558 566 593 600 543 611 571 589 540 541 526 542 551 612 520 533 554 506 495 501 522 521 504 541 502 507 540 509 517 574 539 585 566 576 581 549 592 521 549 531 546 545 563 559 597 551 541 522 538 581 503 453 468 469 510 537 548 584 555 518 547 515 532 517 498 500 553 548 542 489 535 521 505 539 501 511 534 551 504 535 552 529 535 519 562 536 525 512 498 514 559 589 506 540 526 536 531 499 516 569 509 489 532 484

1 F 12 1030 869 632 586 528 555 483 462 481 488 444 450 429 432 451 479 467 447 435 406 420 393 499 479 589 541 554 562 614 542 692 569 535 578 611 525 547 547 560 533 605 567 559 564 545 497 605 513 513 505 540 530 520 524 529 546 529 587 572 487 629 543 571 508 562 595 509 521 554 518 516 514 528 516 567 529 515 675 505 556 579 555 551 510 527 531 567 569 535 517 487 487 465 462 488 515 473 445 481 438 478 465 476 470 463 498 524 515 508 501 475 504 492 474 492 485 475 530 519 492

1 F 13 1275 1056 973 902 782 855 751 725 683 666 655 635 639 638 620 559 576 614 567 584 591 568 577 572 625 576 591 601 639 594 575 564 587 590 566 587 556 552 605 584 568 577 563 567 578 575 569 584 623 563 553 531 555 549 583 569 589 554 549 523 565 566 616 594 561 568 533 520 574 557 571 551 570 528 577 586 599 565 557 582 549 530 543 537 622 570 527 556 535 523 568 578 604 597 618 567 587 620 625 656 652 672 662 672 701 691 670 627 649 658 662 687 648 717 682 654 680 712 708 710

1 F 14 453 474 440 430 432 440 445 517 622 615 587 611 595 595 656 801 631 603 634 573 629 600 626 551 646 550 632 639 562 568 596 608 582 583 687 587 518 628 640 545 517 526 597 576 593 532 559 689 541 557 517 550 467 543 557 551 511 521 523 548 564 546 546 508 672 621 486 538 551 587 561 595 490 514 523 578 548 597 493 649 507 555 545 551 579 541 569 523 546 543 639 669 619 617 601 553 606 664 665 652 615 664 678 637 625 651 642 558 580 596 595 570 584 607 551 542 615 635 593 530

1 F 15 784 576 636 599 836 583 551 597 655 660 651 573 655 587 654 642 590 578 607 586 553 571 585 585 576 552 534 615 550 570 543 529 519 591 660 577 580 615 599 601 522 555 573 580 653 565 565 610 611 655 564 611 664 703 625 566 670 551 594 689 563 577 578 593 732 571 552 572 533 595 610 611 576 603 582 574 544 573 546 548 636 617 570 566 566 607 620 538 534 531 544 573 609 591 632 552 583 632 641 677 665 679 679 699 736 724 704 671 671 670 689 712 648 745 711 671 689 755 744 729

1 F 16 737 614 581 572 553 504 508 523 500 498 499 487 508 477 489 503 502 524 526 502 513 516 501 479 572 555 551 557 550 580 545 578 570 560 595 554 566 562 572 534 541 572 562 561 633 510 588 589 534 580 599 561 618 580 568 527 632 551 536 594 572 577 553 568 538 552 554 565 564 577 515 563 542 544 569 558 516 573 634 535 570 564 555

521 614 556 566 545 541 554 817 665 722 694 687 723 660 660 724 672 652 623 632 598 665 634 585 583 606 609 587 634 585 609 598 649 584 601 636 734

1 F 17 762 621 618 479 590 583 524 592 558 523 673 572 569 590 585 580 556 596 576 559 543 528 565 573 530 588 512 538 556 565 543 555 500 604 600 552 566 536 526 562 527 566 528 552 534 575 540 512 574 611 534 577 541 539 553 539 556 528 577 542 563 584 510 574 530 527 558 521 550 521 571 530 563 537 564 531 563 513 572 540 542 510 554 496 538 516 550 543 498 594 498 501 516 553 499 532 511 508 556 510 516 479 518 525 484 509 511 488 518 546 599 563 514 510 513 553 517 525 528 495

1 F 18 1508 1077 1006 870 866 845 764 819 922 800 683 756 724 713 717 685 682 673 662 665 728 680 752 642 592 579 608 575 588 584 600 566 521 591 660 566 603 581 558 566 564 705 575 584 636 505 562 569 527 596 555 575 556 509 731 555 532 588 661 616 770 517 544 519 575 570 535 617 614 610 582 563 554 552 558 518 545 575 555 574 579 565 571 533 573 582 525 563 562 522 533 581 729 509 523 532 566 542 513 500 507 410 491 488 484 470 557 522 466 460 780 713 528 525 523 602 528 475 474 506

2 M 19 826 831 747 823 736 753 751 786 829 670 672 672 656 649 668 529 457 462 500 443 424 426 426 454 442 413 424 452 483 457 548 546 512 486 522 457 444 463 459 487 531 470 509 560 506 482 509 499 490 523 538 551 554 526 540 584 544 545 556 573 537 545 534 558 572 563 604 578 568 553 545 594 563 592 638 674 678 676 684 637 648 624 616 652 704 645 672 690 666 644 604 614 584 581 516 539 584 540 499 530 523 549 586 580 555 567 613 587 587 622 642 585 564 576 574 534 570 617 551 570

2 M 20 535 506 544 538 523 533 560 518 549 526 537 530 512 524 485 554 573 600 587 563 571 558 545 592 588 565 592 560 598 562 534 616 555 576 576 566 564 548 555 584 570 564 559 592 562 562 550 574 595 599 579 594 596 583 555 581 600 616 608 600 572 560 548 574 608 579 583 597 557 601 638 631 594 614 581 533 577 567 574 589 556 553 528 547 543 532 543 573 556 552 510 500 527 548 567 530 520 531 547 522 532 514 502 522 530 547 538 525 528 558 578 552 547 545 529 540 533 547 554 560

2 M 21 817 889 809 839 761 871 915 706 680 680 743 627 614 516 597 501 507 519 542 481 492 502 475 461 434 430 417 460 519 471 478 412 377 419 446 453 450 548 685 654 651 633 568 757 648 593 633 598 605 683 682 748 680 703 749 637 677 725 730 660 585 615 636 737 730 586 762 724 702 773 725 607 812 807 808 688 754 680 692 874 620 678 837 961 750 726 578 714 750 565 494 531 500 485 513 530 542 566 521 509 523 542 528 534 560 573 560 534 555 595 550 514 588 534 574 536 634 582 558 561

2 M 22 1808 1769 1719 1720 1507 1381 1300 1328 1405 1477 1457 1398 1418 1347 1399 1096 1048 1038 1041 1053 1135 1136 1161 1097 1101 1097 1022 979 982 962 807 749 763 778 828 811 798 787 784 793 773 774 777 792 844 733 711 683 714 730 700 695 750 704 715 681 678 734 674 675 644 606 638 612 642 614 644 627 634 651 638 589 599 591 571 600 591 568 589 586 574 592 609 605 592 603 580 560 592 566 680 637 633 607 628 581 605 605 601 597 592 580 572 590 599 580 618 615 611 583 603 572 585 602 572 564 626 599 613 619

2 M 23 519 425 646 437 401 419 438 414 417 390 426 425 410 475 376 389 394 360 436 419 405 427 410 436 442 437 468 475 450 453 510 543 512 528 577 575 556 544 560 564 527 564 583 594 610 575 563 557 577 562 598 566 593 596 566 602 585 572 573 558 520 504 507 511 499 501 547 505 535 519 547 538 539 537 538 565 560 556 567 559 550 568 536 539 553 534 572 555 611 560 567 606 571 637 594 625 581 603 595 577 566 572 605 582 633 610 554 545 560 563 604 591 541 564 592 569 568 586 614 603

2 M 24 577 587 707 551 578 499 487 564 551 527 552 531 554 523 480 526 522 457 442 481 487 447 460 459 475 558 490 492 490 497 426 436 402 494 501 482 488 515 561 518 475 489 519 446 420 484 492 431 506 492 456 522 480 499 473 446 462 456 442 439 579 550 571 585 537 570 565 628 590 612 607 662 607 734 637 674 647 821 672 749 735 616 691 709 679 667 729 668 645 691 654 639 579 586 610 632 571 607 608 587 574 578 561 606 554 590 635 647 573 603 590 605 565 604 667 504 529 557 624 580

2 M 25 1604 1465 1382 1395 1465 1379 1403 1384 1268 1290 1194 1284 1231 1175 1116 853
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2 M 26 521 522 502 490 444 499 503 512 499 500 498 457 487 498 501 534 540 516 519 523
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2 M 27 1056 892 862 1080 782 784 814 758 766 743 742 764 800 762 704 607 551 608 551
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2 F 30 903 1065 741 739 784 718 730 725 841 793 757 728 839 815 781 745 662 656 579 855
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2 F 31 1099 1080 1076 1131 1140 1193 1141 1097 1110 1175 1191 1122 1159 1106 1109 889
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721 772 745 744 760 807 769 734 758 720 706 718 750 715 688 760 703 733 669 643 671
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2 F 32 1360 1138 1173 1164 1005 1008 1027 1030 1047 1012 1010 939 927 950 937 910 945
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899 831 794 754 732 793 813 784 706 660 641 679 634 628 652 627 661 645 631 650 703
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2 F 33 643 580 600 564 560 585 559 524 553 566 539 547 532 523 555 565 536 543 521 501
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2 F 34 829 701 620 618 681 623 576 587 618 593 731 710 739 655 650 572 577 557 617 599 591 557 596 563 580 595 557 538 539 587 551 492 584 587 535 550 528 533 528 530 542 531 517 494 497 484 488 518 512 498 461 478 471 494 504 496 490 503 503 482 453 440 427 440 468 481 483 473 450 446 463 477 471 439 429 542 594 563 572 562 611 623 610 643 634 591 632 604 611 730 587 571 553 531 546 635 550 521 552 519 534 578 573 562 512 502 593 520 535 540 540 538 543 533 567 561 562 544 487 515

2 F 35 676 646 667 740 709 716 769 775 753 747 697 640 605 684 705 575 582 545 558 556 624 615 606 629 640 601 552 685 681 590 574 570 578 630 615 604 615 619 559 574 569 578 577 543 636 576 626 619 570 543 565 606 612 679 644 611 591 587 644 594 552 559 545 593 552 542 555 581 565 566 550 550 597 596 606 535 547 569 571 561 509 543 552 528 587 516 536 548 547 561 553 525 553 543 556 569 563 606 581 557 600 541 562 549 581 572 576 597 541 531 535 565 533 519 583 576 545 531 497 575

2 F 36 1176 1296 1018 1224 1000 1175 1121 1233 1176 1140 1029 955 958 886 860 772 849 928 874 860 930 850 1000 908 835 854 850 771 773 717 740 633 656 622 715 639 581 565 610 532 566 558 598 589 553 479 456 450 630 625 546 578 563 636 570 569 653 567 620 549 589 536 524 607 558 634 565 613 583 593 618 599 630 632 555 571 588 575 618 582 609 697 598 574 585 556 554 501 534 505 522 577 526 597 597 519 522 519 547 562 498 510 522 538 523 523 520 524 500 588 540 559 522 514 541 545 518 544 534 566

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APPENDIX D

INSTRUCTIONS TO SUBJECTS

Subject Instructions used in Relative Frequency Experiment Two

For the Control and the Strategy Groups

Please read the following instruction very carefully and fell free to ask any question if it is not clear.

As a subjects you are asked to move your right arm to left from the micro switch to knock over the first barrier and then to move right to knock over the second barrier in 1000 ms.

You will receive feedback after every trial on a 12 inch monitor in front of you. The total movement time (feedback) will only be given for the first 60 trials and for the rest it will be withdrawn.

Then (right after that) there will be ten more trials without feedback on the screen. Five minutes later 20 trails will be performed without feedback in the same manner as before.

For Relative Frequency Group

Please read the following instruction very carefully and fell free to ask any question if it is not clear.

As a subjects you are asked to move your right arm to left from the micro switch to knock over the first barrier and then to move right to knock over the second barrier in 1000 ms.

You will receive feedback on the first and than on every fifth trial (i.e. 5^{th}, 10^{th}, 15^{th} and so on) until the 60^{th} trial on a 12 inch monitor in front of you. The total movement time (feedback) will only be given for the first 60 trials and for the rest it will be withdrawn.

Then (right after that) there will be ten more trials without feedback on the screen. Five minutes later 20 trails will be performed without feedback in the same manner as before.

Subject Instructions used in Summary KR Experiment Two

For the Control Group

The aim of this experiment is to investigate the effect of various feedback manipulations upon the learning of a simple motor skill.

General explanation of the task: The motor task you are about to perform involves moving the handle in front of you from the start line to the finish line, reversing direction at Zones 2 and 1 respectively. So you will have to reverse movement direction 2 times before reaching the finish line. For this first day you will be required to complete 90 trials and on the second day you will perform 30 more trials.

1. Grasp the handle, which is positioned at the at the start line,
2. Move the slide leftward to 'Zone Two', then reverse right to 'Zone One',
3. Reverse direction again to move to past the finish line.
4. Your goal is to pass the finish line in as close to 550 ms as possible in **every** trial.
5. You will receive feedback from a graph which will show your error, in milliseconds, from the target time. You should seek to reduce this error to zero. There will be one point on the graph for every attempt at the movement you make.
   a) You will perform 90 trials today and you will receive feedback after every trial.

6. An early reversal of the movement will be considered as an incomplete movement and will be repeated with a subsequent correct trial.
7. Once you complete one trial, bring the slide to the start line with your other arm and be prepared for the next trial (or the feedback).

8. You should begin the next trial when the experimenter says “ready”. Make sure that you are fully prepared before you start each trial.

If you have an questions, please do not hesitate to ask! Good Luck.

Subject Instructions used in Summary KR Experiment Two

For Summary KR Group

The aim of this experiment is to investigate the effect of various feedback manipulations upon the learning of a simple motor skill.

General explanation of the task: The motor task you are about to perform involves moving the handle in front of you from the start line to the finish line, reversing direction at Zones 2 and 1 respectively. So you will have to reverse movement direction 2 times before reaching the finish line. For this first day you will be required to complete 90 trials and on the second day you will perform 30 more trials.

1. Grasp the handle, which is positioned at the at the start line,
2. Move the slide leftward to 'Zone Two', then reverse right to 'Zone One',
3. Reverse direction again to move to past the finish line.
4. Your goal is to pass the finish line in as close to 550 ms as possible in **every** trial.
5. You will receive feedback from a graph which will show your error, in milliseconds, from the target time. You should seek to reduce this error to zero. There will be one point on the graph for every attempt at the movement you make.
   a) You will perform 90 trials today. You will receive feedback only six times out of these 90 trials. You will be shown a graph of your timing errors once after every 15 trials you perform.

6. An early reversal of the movement will be considered as an incomplete movement and will be repeated with a subsequent correct trial.
7. Once you complete one trial, bring the slide to the start line with your other arm and be prepared for the next trial (or the feedback).

8. You should begin the next trial when the experimenter says "ready". Make sure that you are fully prepared before you start each trial.

If you have an questions, please do not hesitate to ask! Good Luck!

Subject Instructions used in Summary KR Experiment Two

For Strategy Group

The aim of this experiment is to investigate the effect of various feedback manipulations upon the learning of a simple motor skill.

General explanation of the task: The motor task you are about to perform involves moving the handle in front of you from the start line to the finish line, reversing direction at Zones 2 and 1 respectively. So you will have to reverse movement direction 2 times before reaching the finish line. For this first day you will be required to complete 90 trials and on the second day you will perform 30 more trials.

1. Grasp the handle, which is positioned at the at the start line,
2. Move the slide leftward to 'Zone Two', then reverse right to 'Zone One',
3. Reverse direction again to move to past the finish line.
4. Your goal is to pass the finish line in as close to 550 ms as possible in **every** trial.
5. You will receive feedback from a graph which will show your error, in milliseconds, from the target time. You should seek to reduce this error to zero. There will be one point on the graph for every attempt at the movement you make.

   a) You will perform 90 trials today but you can only ask for feedback on your performance accuracy. You must decide when it is best to ask for feedback. Tomorrow you will have to perform this task without feedback, so you should try to learn to perform this task without feedback today. Please make sure you don't ask to see the 6 graphs too soon, because you don't have any feedback for the rest of the session, and your accuracy will suffer as a result. Remember you can only ask to see your results **6** times.

6. An early reversal of the movement will be considered as an incomplete movement and will be repeated with a subsequent correct trial.

7. Once you complete one trial, bring the slide to the start line with your other arm and be prepared for the next trial (or the feedback).

8. You should begin the next trial when the experimenter says "ready". Make sure that you are fully prepared before you start each trial.

If you have an questions, please do not hesitate to ask! Good Luck

APPENDIX E

SCORING TABLE AND POST TEST QUESTIONS

Point Scale used in Summary KR Experiment Two

POINT SCALE

Through out the 90 trials you will be shown the following point scale. Your total points will be compared to those of other subjects, and the subject with the best points will win a small prize. The scale awards an increasing number of points the closer you get to the target time of < 50 ms.

The small faces at the right hand side will also indicate the mood of the experimenter while you are performing!

TIME (ms)		POINTS	
± 0 ms	5	* * * * *	☺
± 10 ms	4	* * * *	
± 25 ms	3	* * *	😐
± 50 ms	2	* *	
± 100 ms	1	*	☹
± 100 + ms	0		

Post Test Questions used in Relative Frequency Experiment Two

Let's assume that as a subject you were instructed to ignore the feedback give to you if it was outside the square at the end of the screen.

Would you be able to **ignore** the feedback that were outside the square and use **only the ones** given in the square if you were instructed to do so?

Please comment on this question!

Thank you for answering the question and participating to the experiment.

Post Test Questions used in Summary KR Experiment Two

For Control and Summary KR Groups

1. What were you trying to do in the test?
   a) What was the target time?
   b) What sequence of movements were you trying to reproduce?
   c) Did you use the feedback?
2. What kind of technique did you use to perform the task?
3. Did you use the experimenter's instructions to help you perform the task?
4. In what percentage of trials do you think you applied the above technique or instructions?

For Strategy Group

1. What were you trying to do in the test?
   a) What was the target time?
   b) What sequence of movements were you trying to reproduce?
   c) Did you use the feedback?
2. What strategy did you use in choosing when to see your graphs?
3. Did you find your strategy useful?
4. Did you estimate your errors in trials on which you got no feedback? If yes, on what percentage of trials did you estimate your error?

APPENDIX F

Conference Communications

Conference Communication at the 1994 annual conference of the British Association of Sport and Exercise Sciences, Aberdeen, UK.

Journal of Sports Sciences, 13 (1), 62-63

COGNITIVE STRATEGIES UNDERLYING OPTIMAL USE OF FEEDBACK SCHEDULING

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The present study investigates the effect of summary knowledge of results (summary-KR) in conjunction with a supporting strategy on the acquisition and retention of a simple ballistic motor timing task, in comparison to a control group (1 trial summary-KR). Some recent studies (Schmidt *et al.*, 1985, *Journal of Experimental Psychology,* **15**, 352-359; Sidaway *et al.,* 1991, *Research Quarterly for Exercise and Sport,* **62**, 27-32) have indicated that a summary-KR condition seemed to facilitate performance in retention tests but was detrimental to acquisition performance. On-going studies in the Human Performance Laboratory at University of Wales, Bangor indicate that use of a strategy has the same effect as the summary-KR conditions over the transfer trials (Kirazci and Fazey, 1992, *Journal of Sports Sciences*, **10**, 601-602). The strategy group received instructions stating that they would receive feedback only on 10% of their trials (9 trials out of 90) and that their strategy was to decide at which intervals to receive the feedback during acquisition trials. In this study the effect of 10-trial summary-KR (in effect KR presentation frequency of 10% over 90 trials) was compared with 10% summary-KR supported strategy condition, a 10% yoked summary-KR strategy condition, and a 1 trial summary-KR control group (100% KR) across acquisition and retention. The hypothesis of the experiment was that the strategy groups would perform as well as the 10% summary-KR group in Delayed Retention trials, and all 3 would perform better than the control group.

The ballistic-timing task and the apparatus used in this experiment was an adaptation of that used by Schmidt *et al.*, (1985, *Journal of Experimental Psychology,* **15**, 352-359). Four groups of ten right-handed subjects were randomly assigned to four different KR conditions. In each condition the subjects were asked to move the slide left 30 cm from the starting position then right 15 cm, and then left again until the slide passed finish line 40 cm left of the starting position. They were instructed to complete the whole movement in a target time of 550 ms. KR was only given for the first 90 trials. For the remaining 30 trails in Immediate Retention (10 minutes) and Delayed Retention (2 days later) KR was withdrawn. Each subject in the control group received feedback after every trial and the 10 trial summary-KR group after every 10 trials on a 36-cm monitor in front of them. The subjects in 10% yoked summary-KR strategy group received feedback on the same trial and intervals as their counter-parts in 10% supporting strategy group. After each trial temporal accuracy at the 40-cm line was recorded and subjects' constant error for that trial or block was presented on a graph of accuracy against trial.

The 4 x 1 (Groups by Block) ANOVA of the variable error (VE) scores in the Delayed Retention test showed a significant interaction ($F_{3,36}=3.5537$, $P<0.05$). The follow up Tukey test showed this as a significant loss of consistency for the control group when the KR was withheld. The strategy group suffered no loss of consistency in their performance whilst the control, 10 trial summary-KR and 10% yoked strategy groups' performance became significantly more variable than during acquisition. The means of each group in Delayed Retention were M=21.6, SD=6.08; M=38.4, SD=16.63; M=31.0, SD=11.52 and M=29.2, SD=9.53 respectively. The order of the block means in Delayed Retention trials support the use of self-governed strategic use of feedback as an aid to motor learning. Because this difference was obtained despite keeping the nature of trials and feedback intervals constant, it was hypothesised that merely giving control to the subjects over their own feedback requirements was sufficient to facilitate consistency. This result therefore supports the idea that cognitive styles and cognitive strategies influence optimum learning of motor skills.

Conference Communication at the 1995 annual conference of the British Association of Sport and Exercise Sciences, Belfast, UK.

SUBJECTS' MANIPULATION OF KR CAN MIMIC THE SUMMARY KR EFFECT

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Providing information feedback in summary form facilitates learning for a simple ballistic motor task relative to feedback after every trial (Schmidt, Young, Swinnen and Shapiro, 1989, *Journal of Experimental Psychology: Learning, Memory, & Cognition,* **15**, 352-359). Preliminary research has suggested a supporting strategy has the same effect as the summary-KR conditions over the transfer trials (Kirazci, Smith, and Fazey, 1995, *Journal of Sports Sciences*, **13, 1**, 62-63), but several methodological weaknesses prevented an accurate comparison being drawn to previous KR research. The present study was designed to overcome these problems through major changes in the number of subjects, the homogeneity of the subject pool and their level of motivation. The strategy group in this experiment were instructed they would receive feedback 6 times out of 90 trials (7% of trials). They were to decide at which intervals to receive feedback during acquisition. The effect of 15-trial summary-KR (a KR frequency of 7% over 90 trials) was compared with a supported strategy and a 1-trial summary-KR control group (100% KR). It was hypothesised that the strategy group would perform at least as well as the summary-KR group in retention, owing to their involvement in similar problem solving activity during the no-KR trials, and that both would perform better than the control group.

Three groups of 18 subjects (30 male and 24 female) were randomly assigned to the three KR conditions. The ballistic-timing task and the apparatus used in this experiment was adapted from Schmidt et al. (1989). In each condition the subjects were asked to perform a linear slide task in as close to 550 ms as possible. KR was given for the first 90 trials; for the remaining 30 retention trials (2 days later) KR was withdrawn. Temporal accuracy was recorded on an IBM compatible PC and subjects' constant error for the trial or block of trials was presented on a graph on a 36-cm monitor. Retention data were analysed using absolute constant error (|CE|) and variable error (VE) to provide direct comparison with previous research. The one-way ANOVA for |CE| elicited a significant effect for groups, $F_{2,51} = 6.6$, $p < 0.01$. Follow-up Tukey's tests revealed the control group had significantly higher |CE| than both the summary-KR and strategy groups (M=85.1, SD±68.7; M=41.4, SD±29.4; M=36.9, SD±26.7, respectively). The one-way ANOVA among groups for VE was also significant, $F_{2,51} = 5.4$, $p < 0.01$. The follow-up Tukey's test revealed that the control group's VE score was significantly higher than both summary-KR and strategy groups (M=35.6, SD±15.9; M=26.8, SD±6.74; M=24.2, SD±7.4, respectively). The summary KR result supports other studies (e.g. Schmidt et al., 1989) which conclude that summary-KR promotes consistency in retention performance. Furthermore findings support the use of self-governed use of feedback as an aid to motor learning.

This findings provide evidence that informing subjects of the importance of the problem solving process during practice can reduce the need for supervision of feedback provision, without risking impaired retention. This research is a first step towards demonstrating that cognitive factors involved in learning motor skills can be incorporated in the learning session to increase the autonomy of the subject.