1996

The effects of presentation frequency of summary and average KR in the acquisition and retention of a motor skill.

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THE EFFECTS OF PRESENTATION FREQUENCY OF SUMMARY AND AVERAGE KR IN THE ACQUISITION AND RETENTION OF A MOTOR SKILL

by

Jae Todd Patterson

A Thesis
submitted to the
Faculty of Graduate Studies and Research
through the Department of Kinesiology
in Partial Fulfilment of the
requirements of the Degree of
Master of Human Kinetics at
the University of Windsor

Windsor, Ontario, Canada

1995

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ISBN 0-612-11021-4

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Abstract

Summary KR is a feedback scheduling method of withholding feedback for a set number of trials in a block then presenting feedback for each trial via a graphical presentation. The feedback presented represents the difference between the actual movement and the goal of the task. Average KR is an average of the error values over the prescribed trials presented as a single graphical value. Summary KR research to date has produced mixed support as an effective feedback schedule. Previous summary research has examined one variable at a time (eg. summary length, presentation frequency, task, and type of feedback) to explain the summary effect. Based upon this single faceted approach to understanding the summary effect the present study examined a multifaceted approach to understanding the summary effect. Subjects received feedback after every fifth trial in acquisition for a feedback presentation of 18 %. Subjects either received information about the last 5, 10, or 15 trials presented as an average or summary presentation. Subjects completed 125 acquisition trials and 15 no-KR trials following a 10 minute retention interval, and 25

no-KR trials following 2 day retention interval.

Subjects performed a simple ball positioning task with a 1000 ms goal movement time. For the acquisition phase the group receiving KR following every trial was found to have significantly lower |CE| values compared to all the other conditions for only the first three blocks of acquisition. A block effect was also reported with groups becoming more consistent and accurate with practice. Subjects maintained significant consistency over the 10 minute and the 2 day retention intervals. Surprisingly, further ANOVA's of the independent variables excluding the group receiving KR after every trial, revealed the summary condition to be more consistent than the average condition in acquisition performance. Further ANOVA's on both retention tests yielded no significant effects of |CE| or VE. The lack of significant effects of the independent variables are discussed in terms of the effects of task, number of trials summarized/ averaged, presentation frequency, type of feedback, and the guidance hypothesis.

Dedication

The dedication of this thesis is in honour of my late father Gary W. Patterson, one of my strongest and proudest supporters.

Acknowledgements

The beginning and completion of this thesis would not be possible without the acknowledgement of the following friends and colleagues.

My most sincere thanks and appreciation are extended to Dr. Patricia Weir who played an active part in the development and completion of the following thesis. Dr. Weir also contributed a vital role in the development of my capabilities and skills as a successful graduate student.

To the following professors I extend my appreciation for fostering a positive attitude toward education and research at the graduate level at the University of Windsor, Faculty of Human Kinetics: Dr. J. Leavitt, Dr. K. Kenno, Dr. J. Corlett, Dr. W. Marino, Dr. M. Kimmerle.

The demands and stresses of graduate work would not be relieved if not for the humour and uniqueness of the following people: Gordon Todorovic, Robert Nichloson, Philip Sullivan, Aubrey Kent, Chris Uchaz, & Mary Jo Rehm.

Thanks must also be extended to the following people who offered the use of their equipment and expertise for an unlimited time in completion of this thesis: Dr. Wayne Marino, Dr. Jack Leavitt, Dr. Patricia Weir, & Wu Lee.

A special thanks is extended to the committee members of this thesis who offered their time and expertise in the formulation and completion of this thesis: Dr. Timothy Lee (Kinesiology, Mc Master University, Hamilton, Ontario), Dr. Ged Namikas (Department of Psychology, University of Windsor), Dr. Jack Leavitt and Dr. Patricia Weir.

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Introduction

The acquisition of a motor skill requires augmented feedback prior to, during, or after the completion of a movement (Newell, Morris, & Scully, 1985). Information given to a subject after the completion of a movement is termed knowledge of results (KR). KR is defined by Magill (1989) as "information provided to an individual after the completion of a response that is related to either the outcome of the response or the performance characteristics that produced that outcome (p.318)". The subject uses KR to generate new responses in successive practice trials, therefore improving performance during acquisition trials (Salmoni, Schmidt, & Walter, 1984). KR ultimately guides subjects to the goal performance over a series of acquisition trials (Schmidt, Young, Swinnen, & Shapiro, 1989). KR provided after every trial ensures accurate performance in acquisition trials without requiring subjects to engage in other cognitive processes associated with the task (eg. environmental or task cues, response produced feedback) which facilitates performance in no-KR retention tests (Lavery, 1962; Schmidt et al., 1990; Sidaway, Fairweather, Powell, & Hall, 1992).

Providing KR after every trial in acquisition prevents subjects from developing error detection and correction mechanisms. Subjects fail to develop the ability to produce stable and consistent movement patterns because they adjust their performance on each trial based on the KR provided (Schmidt et al., 1990). A factor crucial in learning a task is error detection capabilities developed during the acquisition trials of the performer (Yao, Fischman, & Wang, 1994). The guiding characteristic of KR has been termed the guidance hypothesis by Salmoni et al. (1984).

Immediate KR rapidly guides the subject's performance towards reaching the goal of the task (Lee, White, & Carnahan, 1990). However, according to the guidance hypothesis, subjects who receive KR after every trial in acquisition rely on this source of information to maintain performance, and ultimately ignore other cues inherent in the task that are important when KR is no longer available. KR is ultimately acting as a performance crutch for the subject (Salmoni et al., 1984). However, subjects who are exposed to less than 100% relative frequency of KR are faced with a situation in which they must learn aspects of the task that will carry them through the no-KR trials between presentations of KR (Salmoni et al., 1984). Examples of this comes from the research of bandwidth KR (Sherwood, 1988), trials delay procedure (Lavery & Suddon, 1962), reduced relative frequency of KR (Ho and Shea, 1978; Sparrow & Summers, 1992), and summary KR (eg. Lavery, 1962; Schmidt et al., 1989; Schmidt et al., 1990). Support for the guidance hypothesis can be found through the effects of summary KR (Lavery, 1962; Schmidt et al., 1989; Weeks and Sherwood, 1994; Wright, Snowden, & Willoughby, 1991).

A review of KR literature by Salmoni et al. (1984) revealed that earlier work on KR failed to separate the temporary effects of receiving KR, being performance effects, with relatively permanent effects considered as learning effects. The authors explain that studies which infer learning from KR without a retention test are inferring performance, not learning. Subjects after a series of acquisition KR trials should be measured by a no-KR retention test to measure the effects of KR and learning (Salmoni et al., 1984; Schmidt et al., 1989). The use of retention tests have dominated the summary KR literature yielding some very interesting results. In fact, summary KR depresses acquisition performance but facilitates learning indicated by no-KR retention tests (Gable, Shea, & Wright, 1991; Lavery, 1962; Schmidt et al., 1989; Wright et al., 1991; Yao et al., 1994).

Summary KR is a KR scheduling method of withholding KR for a set number of trials then presenting KR based on those previous trials after the last trial in the summary block has been completed (Schmidt et al., 1989). Subjects receive their error information on an assigned number of trials via a graph, not visible to the subject during the performance of these trials (eg. Schmidt et al., 1989; Schmidt et al., 1990; Yao et al., 1995., Weeks and Sherwood., 1994). Summary KR is difficult to use due to a temporal separation from a given trial and its KR which creates confusion as to the particular performance characteristics to which a given KR refers (Schmidt et al., 1989). Subjects who receive summary KR seemingly engage in other cognitive processes associated with the task, which in fact results in better performance scores on a retention test compared to subjects who receive KR after every trial (Schmidt et al., 1989; Schmidt et al., 1990; Weeks & Sherwood, 1994; Wright et al.,1990). The notion of summary KR was first introduced by Lavery (1962).

Lavery (1962) had subjects perform three novel ball tasks. He gave subjects KR after every trial, or KR after every trial that also included KR on the preceding trial(s), and a final group which received KR only once after the 20 trials, the daily total. Each group received either qualitative or quantitative KR, thereby yielding 6 conditions. The group that received KR after every trial performed significantly better than the twenty trial summary group in the acquisition phase of the experiment. When Lavery (1962) examined the retention test data, the group that received summary KR after the 20 trial block performed significantly better than all the other KR groups. Thus, subjects maximized intrinsic feedback to aid in the retention of the task. Lavery (1962) concluded that intrinsic information is crucial for the retention of a motor skill and in order to retain the motor skill, KR should be delayed for a certain number of trials. Withholding KR encourages the subject to perceive and interpret the cues inherent in the task facilitating retention performance (Lavery, 1962). The characteristic feature of summary KR is that as the summary length increases, the longer the subjects perform without receiving KR. This begins to resemble the no-KR retention phase. Thus, when the subjects participate in no-KR retention they are in a familiar situation which seemingly facilitates retention of the task (Guay et al., 1992).

Since Lavery (1962), the attention given to summary KR has focused primarily on the number of trials presented in a summary. It was hoped that determining an optimal summary length would provide insight into the number of trials needed to create a 'summary effect'. The summary effect is found when subjects receiving summary KR of a particular length exhibit less error in the retention tests of no-KR trials compared to the groups who received KR after every trial (Guay et al., 1992). The groups do a reversal of positions in the retention test, with groups receiving KR after every trial performing the best in acquisition but performing the poorest in retention. The summary effect is considered important because understanding this phenomenon may clarify the roles KR presentation plays in the learning of a skill (Guay et al., 1992).

Summary lengths between 5 and 15 trials have been the primary focus of summary KR research (Guay et al., 1992; Schmidt et al., 1989; Schmidt et al., 1990; Sidaway, Fairweather, Powell, & Hall, 1992). Summary lengths of 15 trials are at the high end of the summary scale (the summary scale being from 5 - 15 based on Schmidt et al., 1989, 1990). The problem with summary lengths that are too long is they put the performer in a situation overloaded with information that they must attend to, which in effect, is not optimal for learning (Guay et al., 1992). Based on inconclusive findings, looking for only an optimal summary length can not be the primary variable to understand the summary effect; but must be considered an important variable if the summary effect is to be understood.

A study that broke from trying to find the optimal summary length was Sidaway et al. (1991) who found that Schmidt et al. (1989) allowed their presentation frequency of KR to covary. All the groups in Schmidt et al. (1989) received 100% relative frequency but the presentation frequency of KR varied from 100% to 7%. Based on this confound Sidaway et al. (1991) hypothesized that the summary effect may not be due to the summary length, but the KR presentation frequency. The authors used a linear slide task that required subjects to complete the task in 750 msec. This particular study manipulated the number of trials presented in a 15 trial summary (summary information based on the last 15 trials, last 7 trials, last 3 trials, or the last trial) while holding the KR presentation frequency of all groups constant at 7%. Subjects in fact saw KR once every block of fifteen trials. A group which received KR after every trial was included in the study as a control group. The authors found the group that received KR after every trial had the lowest error scores in the acquisition phase of the experiment as well as the retention phase of the experiment. Sidaway et al. (1991) concluded that it was the frequency of KR presentation during the acquisition phase of the experiment rather than the number of trials in the summary length that determined retention performance, and hence the summary effect. This is an interesting conclusion since Sidaway et al. (1991) did not find a summary effect for any of their groups. However, the number of no KR trials between KR presentations may influence the summary effect.

Sidaway et al. (1992) also held their presentation frequency constant at 7 % with subjects receiving a KR summary after 15 trials. This study was a replica of Sidaway et al. (1991) with the addition that there were two movement times of 500 and 1000 milliseconds compared to 750 milliseconds in Sidaway et al. (1991). Again, no summary effect was reported. The 15 trial KR delay in both studies, due to the lack of differences between summary groups, may not be the optimal number of no-KR delay trials before the presentation of KR. According to Schmidt et al. (1989) long summary lengths encourage the processing of movement information but lack sufficient guidance in acquiring the correct performance; therefore an optimal summary length is predicted. Thus Sidaway et al.'s (1991, 1992) failure to find a summary effect due to the 15 trial KR delay being too long. A reduction in the number of KR delay trials while keeping the presentation frequency constant may be more beneficial to the learner acquiring a motor skill.

The summary KR protocol forces subjects to engage in cognitive processing strategies that are believed to maintain consistent performance in acquisition, but display learning of the task in a retention test. If KR summaries are too long, subjects may lack the minimal amount of guidance needed to learn the task. As well, they are also being overloaded with information that exceeds their working memory capacity. Sidaway et al. (1991, 1992), may have presented too much information in the summary length or the temporal delay before the presentation of KR was too long. The effects of presentation frequency and the number of trials contained in the summary could also be a result of the task being used.

Several summary KR studies have focused directly on the effects of summary KR when learning particular tasks (eg. Gable et al., 1991; Wright et al., 1990). Reviewing the tasks in summary KR research it has been found that the more complex the task, the shorter the summary lengths creating the summary effect (eg. Schmidt et al., 1990; Wright et al., 1991; Yao et al., 1994). However, when looking at the effective summary lengths for simple tasks (eg. ballistic timing task, static force production task, linear slide) the summary lengths range from a summary of twenty trials (Lavery, 1962) to as low as five trials (Schmidt et al., 1990); to finding absolutely no effects of summary KR at all (Sidaway et al., 1991, 1992). Thus, the task does play a role in the effectiveness of summary KR as well as variables such as summary length and presentation frequency which also must be taken into consideration when learning a motor task.

When looking at the number of trials contained within a summary, Weeks and Sherwood (1994) introduced an experimental group called the Average KR Group. The authors considered using this condition because of its dominant role in practical settings. Practioners view several practice attempts, then form an average characterization of the performance that is then presented to the learner (Weeks & Sherwood, 1994). The distinguishing characteristic of average KR is that it masks both the information of individual trials, and the variability of performance. Weeks and Sherwood (1994) found no significant difference between the average and summary KR group. Because there was no significant difference between these groups they reasoned that the summary effect may not be due to the summary format but to a reduction in the number of trials the subjects use in the summary KR presentation. This is very interesting because the summary groups in Weeks and Sherwood (1994) received information on each of the previous five trials whereas the average KR group received one value based on the previous five trials, one fifth the information but both these groups performed the same.

Yao et al. (1994) using a spatial temporal task also directly compared summary KR and average KR with a 5 trial and 15 trial average KR compared to a 5 trial and 15 trial summary KR group. These researchers found, as did Weeks and Sherwood (1994) that average and summary feedback operated similarly in learning the task, but both were superior to the group receiving KR on every trial. Further research may distinguish the effects of summary KR and average KR, if in fact a difference does exist. (A complete review of literature is located in Appendix A)

Statement of the Problem

An optimal temporal delay, the number of no - KR trials a subject is exposed to, the number of trials summarized, as well as the type of task may be factors contributing to an optimal KR summary length in acquiring a motor skill (Guay et al., 1992). Previous studies of summary KR research have focused on one variable as being the possible reason for the summary effect. This method of understanding summary KR has produced mixed results. Clearly, summary KR is a multi-faceted phenomenon (Guay et al., 1992) that cannot be explained with one single variable, it is a relationship among many variables.

In order to address these issues, this study compared acquisition and retention performance of groups receiving KR after every trial, KR as a summary, or KR presented as an average performance. All groups were presented KR after every fifth trial in acquisition resulting in a presentation frequency of 18%. It was hypothesized that the summary and average groups would have poorer acquisition scores compared to the group receiving KR after every trial (Gable et al., 1991; Schmidt et al., 1989, 1990; Sidaway et al., 1991); that the summary groups would have better retention scores compared to the average groups and every trial group (Weeks and Sherwood, 1994; Yao et al 1994); and that summary and average KR groups would have better retention scores than the KR1 group (Sidaway et al. 1991, 1992). (Formal Hypotheses are located in Appendix B).

METHODOLOGY

Subjects

Thirty five male and thirty five female (N= 70) University of Windsor right handed graduate and undergraduate students participated in the study. (mean age = 24.3 ± 5.7 years). They were randomly selected from the psychology subject pool. All participants had no prior experience with the task and were naive to the purposes of the experiment. Participants were randomly assigned to one of seven experimental conditions (n= 10). All subjects completed an informed consent form prior to their participation in the study (See Appendix C).

Experimental Design

The experiment was a mixed design, with Feedback Type x Number of trials summarized x Blocks (2 x 3 x 23), with repeated measures on the last factor. For the first factor the subjects in the experimental conditions received either KR presentations in a summary format or as an average. For factor two, there were three presentation lengths; the five trial condition containing information about the last five trials, the ten trial condition containing information about the last ten trials, and the fifteen trial condition containing information about the last 15 trials. These two factors formed 6 experimental conditions: 5 SUM, 10 SUM, 15

SUM, 5 AVE, 10 AVE, 15 AVE. All experimental groups received KR after every fifth trial beginning after trial fifteen. Presenting subjects with feedback after trial fifteen allowed the presentation frequency of all the experimental groups to be 18%. There was a control KR 1 condition that received KR after each of the 125 acquisition trials, which resulted in a KR frequency of 100 %. The last factor was practice blocks in which there was 22 blocks of five trials and one block of fifteen trials (Block One in acquisition). Each block was comprised of five trials, (except for Block One) for a total of 125 acquisition trials.

For the no-KR retention tests (10 minute and 2 day retention) there were 3 blocks of 5 trials for the ten minute retention, and 5 blocks of 5 trials for the long term retention. The dependent variables were absolute constant error |CE|, an absolute measure of the subjects accuracy; and variable error (VE) which is a measure of the subjects inconsistency in responding around their own mean response (Schmidt, 1988). Thus, measurements of both accuracy and consistency were obtained.

Apparatus

As can be seen in Figure 1, the task was a simple unidimensional ball positioning task. The apparatus had a

46.0 centimetre (cm) x 40.0 cm base with an elevated base at the rear of the apparatus. The elevated base was 15.0 cm in height and 49.4 cm long and was located 30.0 cm from the start button. The red start switch (2.3 cm x 2.3 cm) was located front and center (20.0 cm) on the lower base. Located on the elevated base were two tennis ball holders 2 cm deep, 30.0 cm apart from one another. The tennis ball holders were located at opposite ends of the elevated platform containing two normal standardized yellow tennis balls. In the middle of the elevated platform was a red light approximately eye level to the participant. The red light when illuminated signalled the subject to move when they were ready (See Figure 1). A movement time chronoscope measured the subjects movement time in milliseconds.

Measurement System

The measurement of the subjects movement time response in relation to the task movement time goal was recorded into the computerized spread sheet Quattro Pro via a 486 IBM personal computer by the experimenter. The movement times, in milliseconds, were typed into the computer after each response. The feedback provided to the subjects was the difference between their movement time and the goal movement time of the task. Seven different templates were used, a

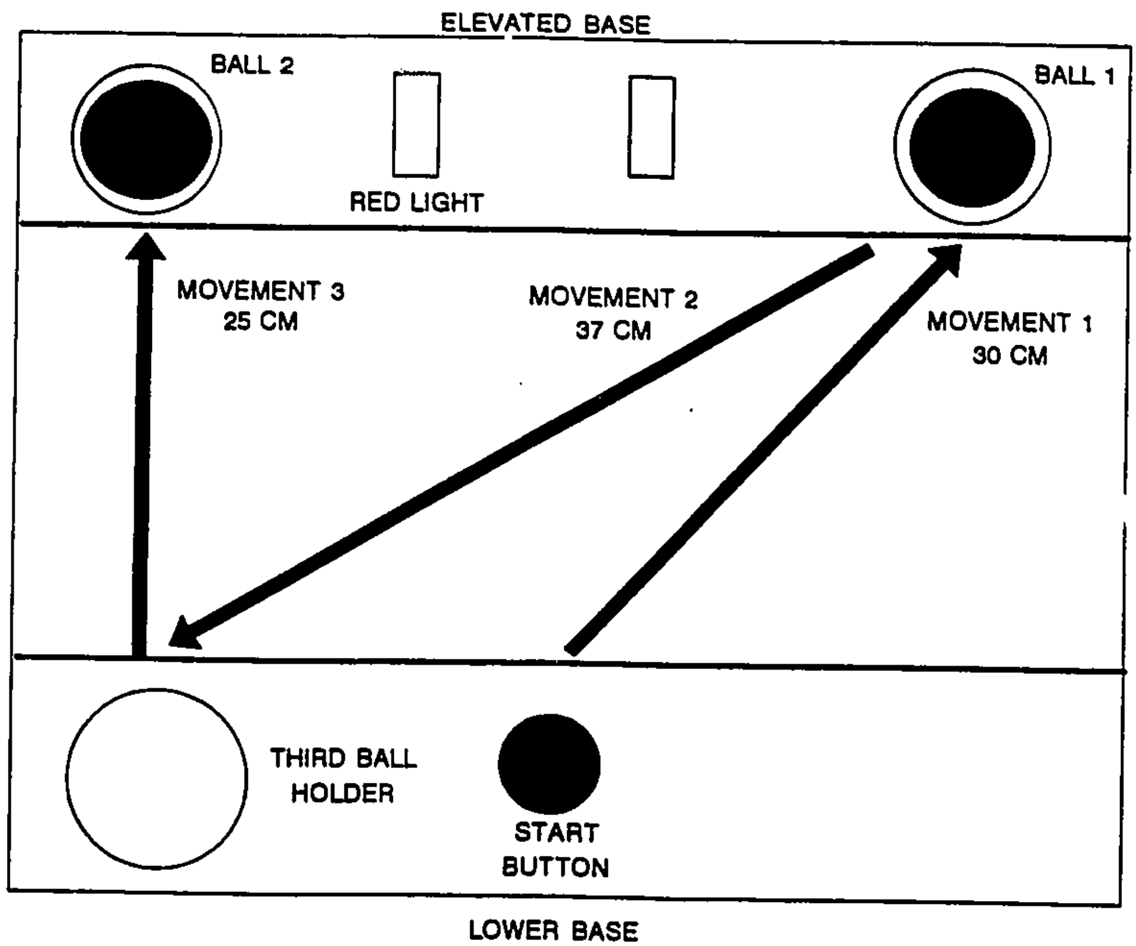

Figure 1. Simple ball positioning apparatus.

different template being used by each of the seven groups. The template allowed for the subjects movement time values to be typed into the spread sheet at which time their error value was automatically calculated. As soon as a specified block in the template reached the 5 value limit, the experimenter typed in the experimental group and the block just completed thus creating an output of a bar graph of five bars or a single average value depending on the template. The bar graph shown to the subject displayed the completed trial(s) represented on the X-axis and movement time error(s) on a positive - negative Y-axis. The Y-axis for movement error ranged from -500 milliseconds to +500 milliseconds in 50 millisecond intervals. For each graph a horizontal zero line ran through the middle of the graph. Thus, trials that were too fast appeared as bars pointing downward from the zero line (negative score) where as trials that were too slow appeared as bars pointing upward from the zero line (positive score). This is consistent with Yao et al. (1994) who had a positive - negative Y axis of -300 milliseconds and +300 milliseconds with 50 millisecond increments. Presentations of KR via a bar graph has been found to facilitate the acquisition and retention of a motor skill (Cauraugh, Chen, and Singer, 1993) and is a commonly employed method of presenting KR as a summary.

Procedure

The goal, known to the subjects, was to complete the task in 1000 msec. A simple task of this nature was chosen because of the varied and mixed results of the summary KR effect using other simple tasks (eg. Guay et al., 1992; Schmidt et al., 1989). Subjects were randomly assigned to conditions that differed in type of feedback presentation (summary vs average) and the number of trials contained within this presentation. All experimental conditions received a presentation frequency of 18%, however the relative frequency between the summary conditions varied (See Table 1).

In order to keep the presentation constant at every five trials and the number of trials contained within the summary varied amongst the groups there was an overlap of information for four of the experimental groups (15 SUM; 15 AVE; 10 SUM; 10 AVE). These groups received information after every fifth trial but the number of trials contained in the summary contained an overlap of either 5 trials or 10 trials from the last summary presentation (See Table 2).

Table 1

Presentation Frequency and Relative Frequency of Experimental Groups

Group	Receives KR after trial 15 and thereafter......	Presentation Frequency	Relative Frequency after 5th Trial (From trials 16-125)
5 SUM	every 5 th trial	18 %	100 %
10 SUM	every 5 th trial	18 %	200 %
15 SUM	every 5 th trial	18 %	300 %
5 AVE	every 5 th trial	18 %	100 %
10 AVE	every 5 th trial	18 %	200 %
15 AVE	every 5th trial	18 %	300 %
KR 1	every trial	100 %	100 %

Table 2

Number of Trials Contained within a Feedback Presentation

GROUP	BLOCK (ACQUISITION: TOTAL OF 23 BLOCKS) (Procedure after trial 15 in acquisition) F = feedback presentation
KR1	F F F F F • • • • •
5 SUM	F • • • • •
10 SUM	¦ F • • • • • • • • • •
15 SUM	¦ ¦ F • • • • • • • • • • • • • • •
5 AVE	F: TRIALS 11..15/ 5 • • • • •
10 AVE	¦ F: TRIALS 6..15/ 10 • • • • • • • • • •
15 AVE	¦ ¦ F: TRIALS 1..15/ 15 • • • • • • • • • • • • • • •

Note. ¦ = Overlapping feedback from previous block

F = Feedback presentation

• = Individual Trial

This idea of overlapping trials was first introduced by Guay et al. (1992; Experiment 2) who used a 10/5 condition which accounts for the increased relative frequency over 100%.

At the beginning of the experiment, subjects read a standardized list of instructions describing the nature of the task. Subjects then viewed a one trial demonstration of the task by the experimenter, and any questions the subject may have were answered at that time. Following this, subjects were shown a sample graph for their condition. The meaning of a positive and negative error value displayed by the graph were explained to avoid confusion during the test period.

All subjects sat one arm length from the apparatus in line with the first ball. The subjects placed the second and third digits of their right hand on the start switch keeping the movement time clock on 0. The subjects first movement was to lift their fingers from the start switch and move their right hand to grab the first ball located on the far right of the elevated base, a total movement of 30 cm (movement 1). The subject lifted and held this ball, and then transported it to the ball holder located on the lower base to the left of the start button, a total movement of 37 cm (movement 2). From this point the subject moved their right hand upward and forward to grasp and lift a second tennis ball sitting in the ball holder on the left side of the elevated base, a total movement of 25 cm (movement 3). The movement time was defined as the period between finger lift and the lifting of the second tennis ball. The total movement distance was 92 cm and was to be completed in 1000 msec. All groups completed 125 acquisition trials.

Intertrial intervals were approximately 15 seconds on trials where no feedback was presented for all experimental conditions. However, the KR1 group viewed their KR during this 15 second interval. On trials where feedback was presented to the experimental conditions, for example on trials 15, 20, 25, ..., 125 the intertrial interval was lengthened to 35 seconds which allowed for twenty seconds of viewing time of the feedback. On these trials, the KR1 group also viewed their feedback for 20 seconds. This feedback presentation time was consistent with Sidaway et al. (1991, 1992). KR delay and the intertrial interval was monitored by the experimenter via an analog clock located in front of the experimenter, hidden from the subjects view.

Following completion of the acquisition trials all groups rested for ten minutes. Following this interval all subjects participated in 15 no-KR trials. Two days later all subjects were given an additional 25 no-KR trials. Subjects were informed at the beginning of the experiment they would be required to participate in the delayed retention tests.

Statistical Analyses

Performances in acquisition, immediate, and long term retention were grouped into blocks of 5 trials for analysis. Based upon this, twenty five acquisition blocks, three immediate retention blocks, and five long term retention blocks were created. Absolute constant error (the absolute value of constant error for each subject, which is a measure of the amount of bias around the goal without respect to its direction), and variable error (subjects variability around their own bias) (Schmidt, 1988) were computed for subjects over blocks as indicators of the acquisition and learning effects of the independent variables. All phases were analyzed using a mixed analysis of variance with repeated measures on blocks: Acquisition data was analyzed in a 7 x 25 (Groups x Blocks), ten minute delayed retention data was analyzed in a 7 x 3 (Groups x Blocks), and long term retention data was analyzed in a 7 x 5 (Groups x Blocks).

All significant F-ratios were further analyzed using a Tukey HSD post hoc test. The region of rejection was $p < .05$ for all analyses. In accordance with Schmidt et al., (1990), the effects of the independent variables were based upon the performance levels of the feedback conditions in the retention tests where the temporary effects of the independent variables are theoretically equated.

Results

The data is presented by phase, and complete analysis of variance (ANOVA) summary tables are contained in Appendix D. Block and Group mean values for ¦CE¦ and VE are contained in appendices E and F respectively.

Acquisition

Absolute Constant Error. Figure 2 displays the effects of ¦CE¦ for all feedback conditions. The analysis of variance for ¦CE¦ revealed a significant block effect with $F(24,1512) = 33.68$, $p < 0.05$ (Critical Difference {CD} = 53.67, $p < 0.05$, See Appendix E), and a group x block interaction $F(144,1512)= 1.31$, $p < 0.05$ (CD = 141.65, $p < 0.05$). The effect of group failed to reach significance, $F(6,63)= 1.71$, $p > 0.05$ (See Appendix F). Post hoc analysis of the group x block interaction revealed that the KR1 group had lower ¦CE¦ scores than all the other feedback conditions and was significantly different from the SUM10, SUM15, AVE5, and AVE10 conditions in Block 1, all groups except SUM5 in Block 2, and SUM10, SUM15, and AVE10 in Block 3. Following Block 3, the first presentation of feedback for all feedback conditions, until the end of acquisition, the feedback conditions were not significantly different from one another. The steady improvement of the KR1 group with lower

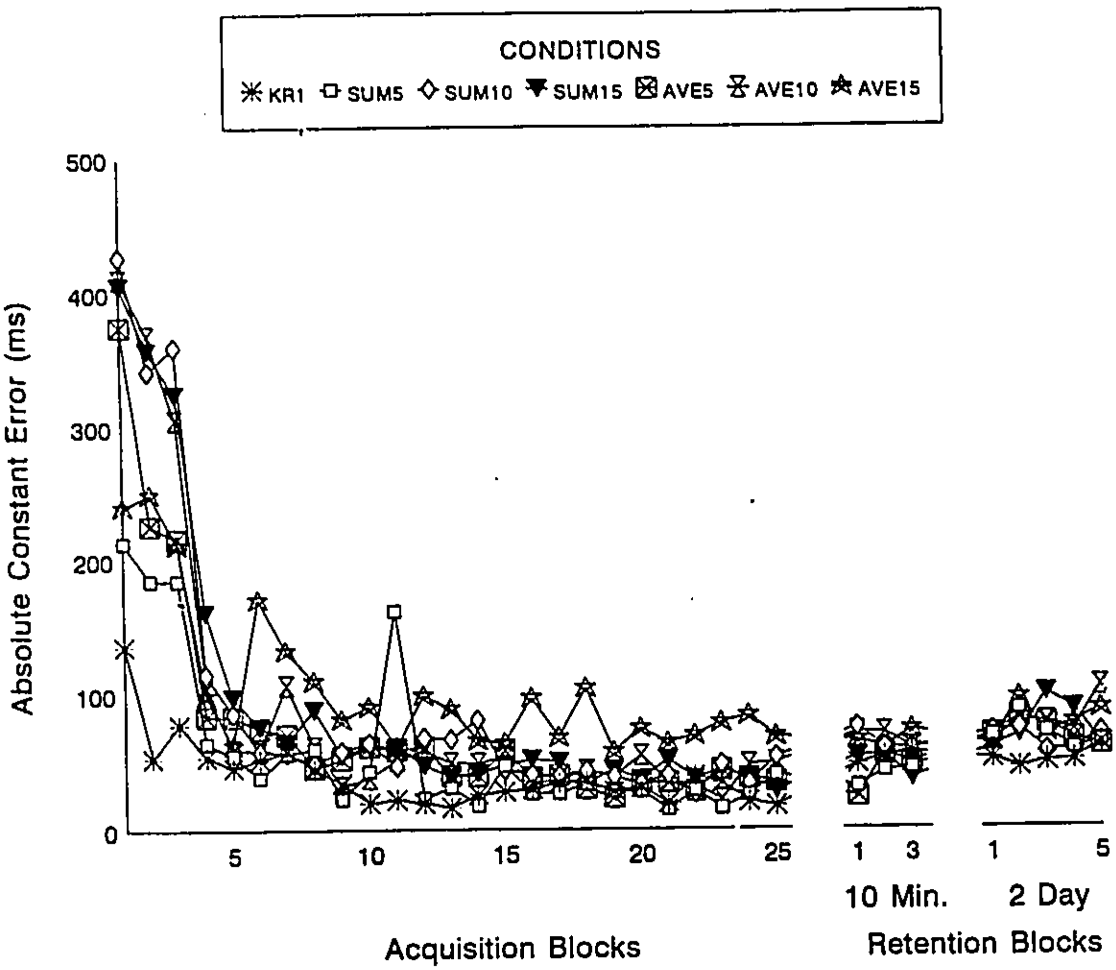

Figure 2. The effects of practice and KR type and amount on acquisition and retention accuracy.

|CE| scores in the first three blocks was expected due to this group receiving 14 trials of feedback prior to any other condition receiving feedback. Once all conditions received their first presentation of feedback (completion ofBlock 3), the conditions became statistically similar. While not significant, the AVE15 condition had the largest |CE| for 18 of the 25 acquisition blocks. The KR1 condition had the lowest |CE| values for 13 of the 25 blocks and the SUM5 group had the lowest |CE| for 10 of the 25 blocks in acquisition. Though not significant in the present study, the KR1 condition commonly has significantly lower |CE| values through out acquisition (Schmidt et al., 1989; Guay et al., 1992; Sidaway et al., 1991, 1992).

VARIABLE ERROR (VE). Variable error for feedback conditions as a result of acquisition performance are displayed in Figure 3. The main effect for group was not significant with $F(6,63) = 1.56$, $p > .05$, nor was the Group x Block interaction with $F(144,1512) = 1.03$, $p > .05$. There was however a significant block effect $F(24,1512) = 1279$, $p < 0.05$ (CD = 24.23, $p < 0.05$). Subsequent post hoc analysis revealed that Block 1 had the highest variability compared to all other blocks. Blocks 4 to 25 were not significantly different from one another indicating that again all groups became

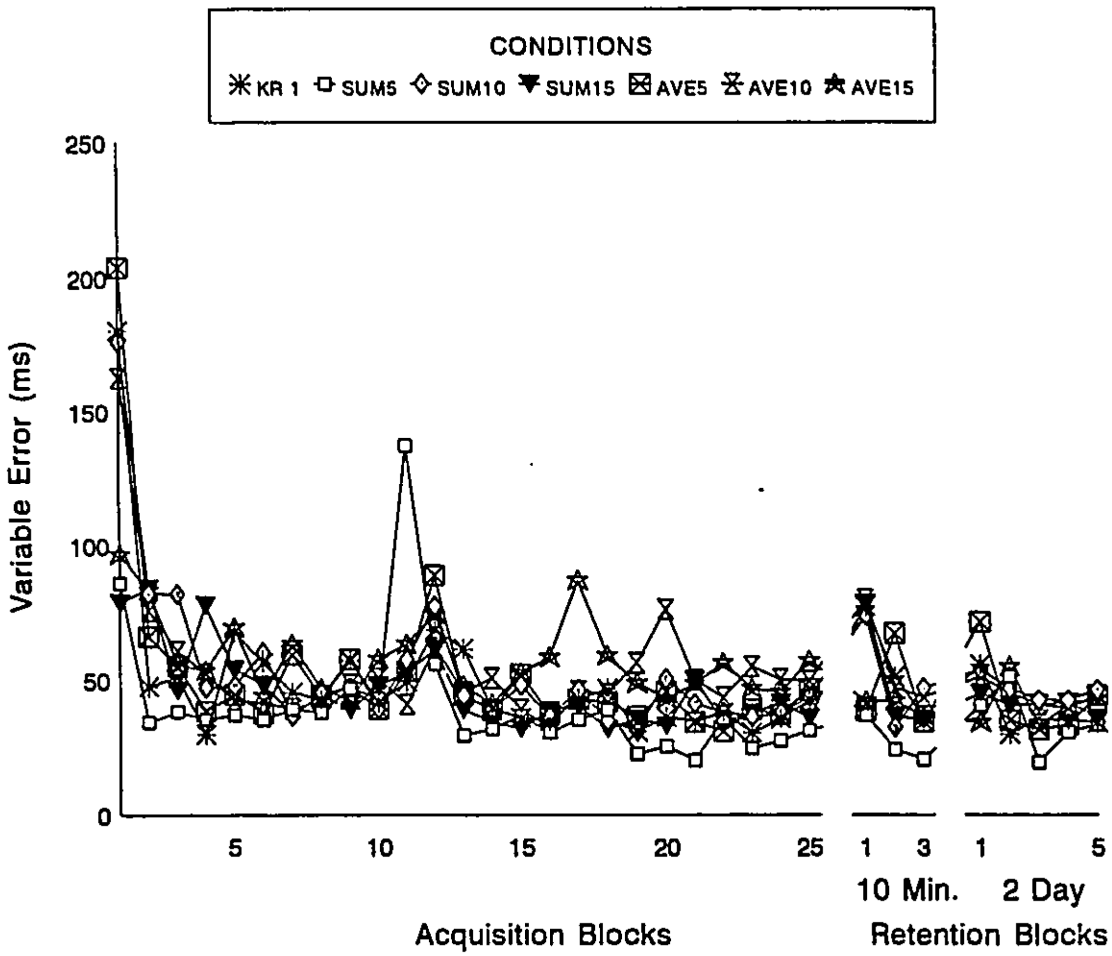

Figure 3. The effects of practice and KR type and amount on acquisition and retention consistency.

statistically similar with practice. Though not statistically significant, the SUM5 group was the most consistent throughout acquisition.

Generally, for the acquisition phase, there were no significant effects of type or the number of trials summarized. The most interesting finding of the acquisition phase was after all the experimental groups received feedback they became statistically similar.

10 Minute Delayed Retention

Absolute constant error |CE|. |CE| for feedback conditions is displayed on the right hand side of Figure 2. The main effects of condition and block failed to reach statistical significance with, $F(6,63) = 0.75$, $p > 0.05$, and $F(2,126) = 0.22$, $p > 0.05$ respectively. The group x block interaction was also not significant $F(12,126) = 3.40$, $p > 0.05$.

Variable error (VE). VE for feedback conditions is presented to the right hand side of Figure 3. The effect of group failed to reach significance $F(6,63) = 0.95$, $p > 0.05$. Though not significant, the SUM5 group had the lowest VE scores compared to the other 6 conditions in all three of the 10 minute retention blocks (See Figure 3). The effect of block

$F(2,126)=3.40$, $p < 0.05$ (CD = 23.22, $p < 0.05$) was significant with subsequent post hoc tests revealing Block 1 to be more variable than Block 3 (see Appendix E). The group x block interaction $F(12,126)= 0.56$, $p > 0.05$ failed to reach statistical significance.

2 Day Retention

Absolute Constant Error ¦CE¦. ¦CE¦ for the 2 day retention is displayed to the far right of Figure 2. There was no significant effect of group with $F(6,63)= 0.32$, $p > 0.05$. Though not significant, the KR1 group had the lowest ¦CE¦ in four of five long term retention blocks (See Figure 2). The effect of block $F(4,252)=1.27$, $p > 0.05$, and the group x block interaction $F(24,252)= 1.15$, $p > 0.05$ also failed to reach statistical significance.

Variable Error. VE for the 2 day retention test is displayed on the far right of Figure 3. The effect of group, and the group x block interaction failed to reach statistical significance with $F(6,63)=0.66$, $p > 0.05$, and $F(24,252)=0.79$, $p > 0.05$ respectfully . However, the effect of block $F(4,252)=2.95$, $p < 0.05$ (CD = 14.43, $p < 0.05$) was significant and the post hoc analysis revealed that Block 1 had greater response variability than Block 3 (See Appendix

E).

Generally, the retention data yielded no statistically significant effects for summary/average KR, presentation frequency, or the number of trials contained in the presentation, in either retention test. Though not significant, the SUM5 condition produced the lowest VE group mean in all aspects of the study including both retention tests.

When comparing the acquisition and retention means of the feedback conditions (See Table 3) *all* groups had a lower group mean VE score in the 2 day delayed retention test compared to their acquisition group mean. This is an indication that all groups became more consistent over the retention interval in the absence of KR. For |CE|, all groups except for the SUM5 and KR1 group reduced their |CE| mean over the retention test (See Appendix F for complete list of group means).

Table 3

Group VE and ¦CE¦ Values for Acquisition, 10 minute, and 2 day retention test.

GROUP	ACQUISITION	IMMEDIATE RETENTION	2 DAY RETENTION
KR 1	VE: 48.97 ¦CE¦: 38.60	VE: 54.90 ¦CE¦: 51.86	VE: 37.95 ¦CE¦: 50.64
SUM 5	VE: 40.64 ¦CE¦: 58.40	VE: 27.10 ¦CE¦: 38.96	VE: 35.01 ¦CE¦: 69.06
SUM 10	VE: 53.02 ¦CE¦: 92.32	VE: 51.13 ¦CE¦: 64.10	VE: 46.37 ¦CE¦: 65.18
SUM 15	VE: 46.20 ¦CE¦: 93.38	VE: 50.03 ¦CE¦: 47.52	VE: 40.86 ¦CE¦: 74.95
AVE 5	VE: 52.60 ¦CE¦: 75.55	VE: 46.71 ¦CE¦: 42.01	VE: 43.02 ¦CE¦: 70.15
AVE 10	VE: 54.30 ¦CE¦: 87.53	VE: 56.83 ¦CE¦: 66.43	VE: 44.19 ¦CE¦: 78.69
AVE 15	VE: 57.68 ¦CE¦: 103.3	VE: 40.22 ¦CE¦: 65.35	VE: 41.02 ¦CE¦ 78.11

Effects of the Independent Variables: Type of feedback and number of trials in feedback presentation.

In the previous analyses, the KR1 group did not differ from the other feedback conditions. To analyze the independent effects of the number of trials summarized and type of feedback, further analyses were performed on the remaining six groups. All additional phases were analyzed using a mixed analysis of variance with repeated measures on blocks: For acquisition a 2 x 3 x 25 (Type x Number of Trials in Feedback Presentation x Blocks); a 2 x 3 x 3 (Type x Number of Trials in Feedback Presentation x Blocks) for the ten minute retention; and a 2 x 3 x 5 (Type x Number of Trials in Feedback Presentation x Blocks) for the long term retention.The acquisition data revealed a significant block effect for |CE|, $F(24,1296)= 31.73$, $p < 0.05$ (CD = 59.64, $p < 0.05$) with groups improving over blocks with practice (See Appendix E). There were main effects for both KR Type and Block for VE with $F(1,54)= 4.52$, $p < 0.05$, and $F(24,1296)= 9.40$, $p <0.05$ (CD = 25.91, $p < 0.05$) respectively. Post hoc analyses revealed that Summary KR had lower response variability than the average feedback condition, and that Block 1 was the most variable for the experimental conditions compared to Blocks 2 to 25

(See Figure 4).

For the immediate and long term retention analyses none of the effects were significant at the $p < 0.05$ level for |CE| or VE.

In summary, the most important and interesting finding of these further analyses was the significant superiority of the summary KR condition compared to the average KR condition for VE scores in acquisition but the effect was temporary because it did not persist over the 10 minute and 2 day retention interval.

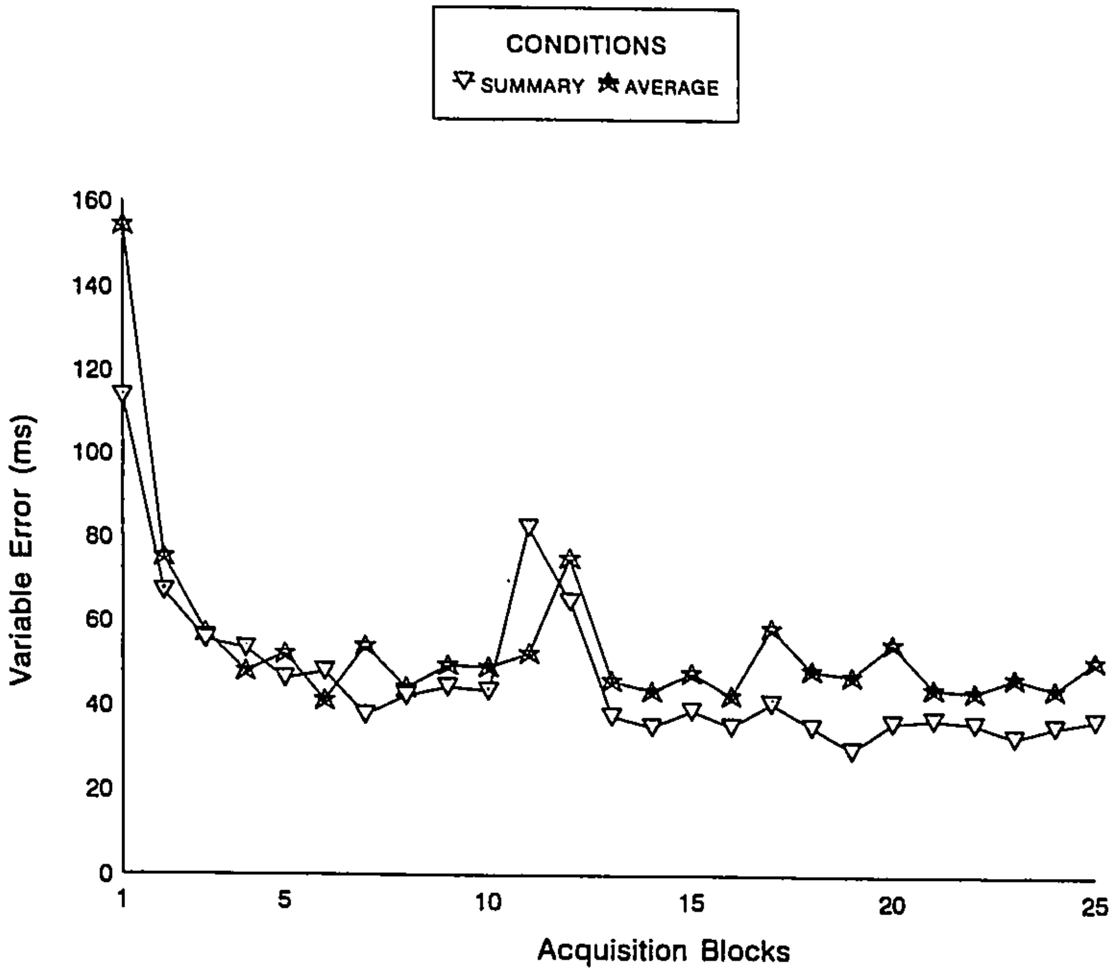

Figure 4. The effects of summary versus average KR on VE during acquisition.

Discussion

The purpose of the present study was to examine a multi faceted approach to further understand the summary effect. Type of information, and Number of Trials Summarized were factorially combined with a 18% presentation frequency to examine this phenomenon. Contrary to the findings of Weeks and Sherwood (1994), and Yao et al. (1995), the present study found no effects of summary or average KR on the acquisition or retention of a motor skill therefore not supporting Hypothesis 1 stating that summary and average KR groups would have poorer acquisition scores than the KR1 group. However, a significant difference was found between average and summary KR in acquisition contrary to previous findings by Weeks and Sherwood (1994) and Yao et al. (1995). Hypothesis 2 stating the summary KR groups would have better retention scores than all the average groups and the KR1 group, was not supported. Even though this trend was present throughout the retention period, it was not statistically significant. Sidaway et al. (1991; 1992) found no significant effects of a 7% presentation frequency in their summary conditions. The present study found no significant effects of an 18% presentation frequency in acquisition or either retention test. Thus, Hypothesis 3 stating that summary KR and average KR groups would have better retention scores than the KR1 group in the 10 minute and 2 day retention was not supported. As well, group error scores were unaffected by the number trials presented as a summary or average. Despite the lack of significant effects for the independent variables, a number of factors may have contributed to the present findings and will be discussed.

Task

When a subject is presented with a novel task, the KR paradigm assumes that learning can not occur without the receipt of feedback regarding performance (Schmidt, 1988). Although there is no operational definition distinguishing a simple task from a complex task, an *explanation* of such a distinction is presented based upon previous empirical literature. A simple task is unidimensional in nature, meaning that there is only one dimension the performer must control for, either space or time (Newell and Walter, 1981; Schmidt et al., 1990; Swinnen et al., 1990). In a simple task, KR is provided to inform the subject of the change required so that the next response more closely approximates the goal (Newell and Walter, 1981). The task used in the present study is unidimensional in that subjects had to resolve only the time needed to complete the task. In contrast a complex task has the goal specified for the subject but, the subject must resolve both the spatial and temporal components in order to reach the goal. For example, the goal of a coincident anticipation timing task, which requires the interception of an LED display, can be achieved through a number of different movement patterns (spatial) varying in distance and velocity (temporal). Typically the feedback provided to the subjects is response related and does not provide any information regarding how to change the movement pattern on the upcoming trials. Subjects in a coincident timing task have no spatial goal assigned, but have many separate dimensions that can be adjusted simultaneously such as the time of the backswing, the speed of the backswing, the location of the end of the backswing, the time of the forward swing, and the speed of the forward swing (Schmidt et al., 1990; Young & Schmidt, 1992). In the coincident timing task there is no one goal movement pattern, but rather the subject's goal is the discovery of some pattern of action that would result in a maximum score (Schmidt et al. 1990). Unlike the coincident timing task, the present study had the movement pattern defined and the subjects needed to resolve only the temporal dimension. The success of the subject in intercepting the LED display in the coincident timing task requires very low spatial error accompanied with a high velocity. Thus, the subjects are controlling a spatial as well as a velocity dimension for successful performance. As well, Yao et al. (1994) used a ballistic timing task in which the subjects had to achieve a spatial as well as a temporal goal. The authors of this study concluded that there task was complex based on the fact that the subjects had to solve for two dimensions, which is also consistent with our discussion. The present study along with other studies that have used simple tasks have found summary effects for a 15 trial delay (Schmidt et al., 1989) to finding no effect at all (Sidaway et al., 1991, 1992). All groups in the present study learned the task quickly. After receiving their first block of feedback, all groups performed the task similarly for the remaining blocks in acquisition and retention. The experimental conditions in the present study needed only the one block of feedback (block 3) to learn the task and for the subsequent blocks KR was used to maintain the subjects performance at or around the goal time. The most concrete findings in the previous research has been the superiority of using lower summary lengths to learn a complex task.

The task used in the present study may have been too easy for the subjects to benefit from any effects of the experimental manipulation.

There appears to be a differentiation between simple and complex tasks on the dependent variables used in summary KR research. Though this statement is not entirely supported, the empirical evidence does offer some suggestions (eg. Schmidt et al., 1990; Weeks and Sherwood, 1994). With simple tasks, the most pervasive effect is on VE scores, where subjects become remarkably consistent at performing the task (Sidaway et al., 1991). This consistency is achievable because most of the tasks involve generating a specified movement time. Thus, subjects may not accurately achieve the goal movement time, but perform consistently. Though not significant, an interesting trend was displayed by the summary 5 condition who had the lowest group VE mean for acquisition and both retention tests. Although this finding was not significant it is supported by Weeks and Sherwood (1994) and Yao et al. (1995) who also found the summary 5 condition to have the lowest VE scores in acquisition. However, complex tasks exert their primary effects on |CE| values (Schmidt et al., 1990; Wright et al. 1991). Complex tasks seemingly require a high degree of accuracy to reach the goal of the task. The coincident timing task involves numerous potential movement patterns and the subject has to discover the trade offs among these movement patterns in order to come to an accurate solution to the motor problem (Schmidt et al., 1990). Feedback is given as a score, not necessarily an error score, but a score which must be increased over trials. The only method of increasing this score is a result of moving very accurately.

A second task dimension to be considered is the goal movement time. The movement time, of 1000 ms, employed in the present study may have placed the subjects in a comfortable and easily attainable situation. Sidaway et al. (1992) examined the effects of summary KR with two different movement times. The authors found that subjects who are faced with a slower movement time as opposed to a time which makes the subject move as fast as possible seem to have more room for error on a fast or slow side. The authors believed that the subjects involved in the 1000 msec condition as opposed to the 500 msec condition had to remember a speed that was not close to their maximum which resulted in substantial increase in |CE| on the 2 day retention test. The subjects involved in the 500 msec group had to ultimately move close to their maximum speed which therefore resulted in movement consistency in this group. Separate pre-test pilot subjects were told to move as fast as possible and the movement time was developed based on this data. Perhaps a slower movement time may have placed the subjects in a more challenging situation. However, Sidaway et al. (1992) found a significant difference between the movement times but not the experimental conditions.

Summary Length (Number of Trials in Feedback Presentation)

Summary length refers to the number of trials contained within the KR presentation. The commonly employed method of delivering summary KR is through a graphical presentation. Carraugh, Chen and Singer (1993) examined the effects of verbal numerical KR and KR presented as a bar graph in a timing task, similar to the present study. The authors found subjects in a graphical KR condition were more consistent than subjects in a verbal KR condition. The method of KR presentation in the present study may have been an optimal method of providing feedback as the goal of the task was easily attained by subjects receiving the informative KR presentation. According to Carraugh et al. (1993) graphical KR allows for direct comparisons, spatial relatedness and is easier for subjects to comprehend when compared with verbal KR. Graphical KR is a method of KR presentation that should be continued as a feedback presentation method.

Early summary KR research examined the number of trials contained within a summary presentation to explain the summary effect. Studies directly examining the summary length found learning effects for a summary 15 condition (Schmidt et al., 1989), to a summary 5 condition (Schmidt et al., 1990) to finding no effect at all (Sidaway et al., 1991; 1992). The summary length in the present study ranged from 1, 5, 10, or 15 trials. The result of this information manipulation had no effect on the acquisition or retention of the motor skill. This finding is consistent with Sidaway et al. (1991, 1992) who also found that their summary groups were unaffected by the number of trials in the summary length. However, a notable difference exists between the Sidaway et al. (1991; 1992) studies and the present study in that the subjects in the Sidaway et al. (1991; 1992) studies were not given feedback about each trial in acquisition unless they were in the summary 15 condition. In the present study, subjects received feedback about all trials. Despite this difference between the two studies, the outcomes were the same. However, while not significant, the groups receiving 5 trials of information had the lowest error scores for VE and |CE| for acquisition and both retention tests. This trend was not surprising because the feedback this group was receiving was not being influenced by previous trials as it was with the 10 and 15 trial conditions who received an overlap of information of 200% and 300% relative frequency. This overlap of information especially for the average condition clearly influenced acquisition and retention performance. This trend offers the suggestion that 5 trials may have been optimal for this task. If the number of trials summarized and presented to the subjects was a factor influencing the acquisition and retention of the task, there would have been a significant difference between the experimental conditions. This was not the case.

While discussing summary length, research comparing summary and average KR have reasoned that since there has been no notable difference to date between summary and average KR, the summary effect may result from the reduction in the number of trials the subject pays attention to or with which the subject is presented (Weeks and Sherwood, 1994). An interesting limitation is present in summary KR research in that subjects involved in a summary condition varying in different numbers of trials summarized, could all essentially be attending to only the last trial in the summary, the most recent trial. The researcher once the summary has been presented essentially has no control over the number of trials the subject attends to. Thus, all groups could essentially be performing as the same group since all the subjects could be attending to the last trial in the summary, resulting in little or no differences among the groups. Finding no differences among groups which vary in the number of trials summarized is a common trend in studies examining presentation frequency. Sidaway et al (1991, 1992) found no difference between a group receiving a summary of the final trial in the block to a group receiving information about all the trials in the completed block. The present study found no significant differences between a group receiving a five trial summary to a group receiving a fifteen trial summary. A limit exists in the human learner concerning the number of trials they can attend to and process when learning a motor skill. However, summary KR research has not yet reached an answer to this limit which ultimately may depend upon the experience of the learner, the task, and the method of feedback presentation.

Presentation Frequency

When using KR, the guidance hypothesis predicts an inverted U relationship in which the beneficial guidance effects of KR and the detrimental effects of overreliance are balanced (Schmidt et al., 1989). Along with an optimal summary length, the guidance hypothesis would also predict an optimal temporal delay which would reflect the point at which KR should be presented to enhance learning. This temporal delay is referred to as presentation frequency, or the number of intervening trials between KR presentations as a function of the total number of trials. Sidaway et al. (1991) examined a 7% presentation frequency (15 trial delay) of summary KR based on the success of the summary 15 group in retention in Schmidt et al. (1989) who had a 7% presentation frequency. Sidaway et al. (1991) did not support the superiority of this group. Given this finding and the previous success of summary 5 conditions, the present study examined a delay of five trials before all groups received feedback (Schmidt et al., 1990; Weeks and Sherwood 1994; Yao et al., 1995). A five trial delay in the present study resulted in a presentation frequency of 20% for all experimental conditions. This is significantly greater than the Sidaway et al. (1991; 1992) studies. The use of a 18% presentation frequency was hoped to be optimal in the acquisition of the novel task. However, the twenty percent presentation frequency had no effect on the acquisition or retention of the employed task. The present study found no difference between a 18% and a 100% presentation frequency. Perhaps the optimal presentation frequency of KR lies between 5 and 15 trials. However, like the optimal number of trials in the presentation, the optimal presentation frequency is probably task dependent.

Average and Summary KR

Researchers have developed an interest in average KR reasoning that the summary effect was not due to the summary length but possibly the number of trials presented to the subjects (Weeks and Sherwood, 1994; Yao et al., 1995). Thus, rather than presenting a summary of previous trials, the average KR paradigm presents a single value representing an average performance. The studies to date which have examined the effects of average KR and summary KR have not found a significant difference between the two in the acquisition or the retention of a motor skill. The present study found a significant difference between average and summary KR with summary KR resulting in more consistent acquisition performance. Finding summary KR to be more consistent than average KR is contrary to the previous studies (Sidaway et al. 1991,1992; Weeks and Sherwood, 1994; Yao et al., 1995). The quantity of feedback was not important to the subjects but the type of feedback was important. This finding is not surprising given the fact that in the summary KR conditions subjects are able to view the variability of their performance after the completion of a set number of trials. Groups in the present study were able to see how well they did on the last 5, 10, or 15 trials after every fifth trial. Subjects after viewing their summary feedback presentation seemingly extract an overall trend of how well they are performing (Yao et al., 1995). Subjects in the average conditions accumulate an average 'feeling' of a particular block of trials, which is very different than viewing past performances where a sense of variability is present. The 'feeling' generated from the average condition was not as beneficial as the summary presentation as evidenced by their higher VE scores.

A second possible reason for high variability in the average conditions is that subjects were receiving an overlap of information from previous practice attempts. Subjects assigned to the AVE10 or AVE15 condition received an average based on the previous five or ten practice attempts. Thus, changes in performance were masked by a large number of preceding trials. The present study was the first to actually use an overlap of information in an average presentation. Subjects in the summary and average 10 and 15 conditions were receiving a 200% and 300% relative frequency. This was a result of keeping the presentation frequency constant for all groups. The study by Weeks and Sherwood (1994) and Yao et al. (1995) had their average based on just completed trials.

A third reason for the superior consistency of the summary KR condition may be the result of being able to view a perfect practice attempt. When subjects were able to view this perfect trial they were able to compare this movement with their previous five or ten movements just completed. In almost all cases, subjects in the summary condition were very consistent within the block. Subjects either had five trials that were too fast or five trials that were too slow. Very seldom did a subject in the summary condition have a summary feedback presentation of graphs being too fast and too slow. The average group seemingly tried to remove the representation of feedback on their next set of trials. Subjects in this group would view their feedback graph and change their movement on the next set of trials based upon this possibly misleading feedback presentation. It seems that summary and average KR promote different informational strategies when reaching the goal of the task. Average presentations based on multiple trials (10 -15) ultimately place the subject in a situation in which they have very little direction in which to change their movement on the upcoming trials (Yao et al., 1995).

Summary KR provides essential information about the subject's variability which is crucial information if the subject is going to develop an accurate memory representation of the task. Summary KR fosters the development of the subjects error detection mechanism. Weeks and Sherwood (1994) question the importance of providing variability information for free in a summary KR presentation. There is evidence that groups receiving feedback in a summary manner about the last trial in a block perform just as well as subjects receiving information about all the trials in the block. This calls into question whether or not the summary effect is due to the number of trials within the presentation. The problem with this idea is the fact that the group receiving information about the last trial in the block are receiving their actual error score with this trial being the freshest in motor memory, therefore it is the easiest to correct. An average score is a computed value based on a series of trials with the last trial not always being most representative of the previous attempts. The last trial studies (eg. Sidaway et al ., 1991, 1992) are giving actual error information. The number of trials summarized may be an issue but the type of feedback given is an area which needs continued research. The present study provides important empirical evidence that average and summary KR do not operate similarly in the acquisition of a motor skill contrary to the findings of Weeks and Sherwood (1994) and Yao et al. (1995).

Guidance Hypothesis

The guidance hypothesis for KR research suggests that subjects use frequent KR presentations to "guide" their upcoming performances. It is generally believed that a sufficient amount of KR is needed in the acquisition period for the subject to accurately reach the goal of the task (Salmoni et al., 1984). However, the negative consequence of providing too frequent KR is that subjects come to rely on this source of information to guide performance thus failing to learn other aspects of the task that are important for movement learning (Salmoni et al., 1984). The attractive characteristic of summary KR is that there is a temporal delay between feedback presentations which allows the learner to engage in intrinsic assessment of task related cues to support performance when KR is removed (Weeks and Sherwood, 1994). The guidance hypothesis makes three predictions based upon the present study: first, the KR1 group would rely on KR during acquisition thus developing an inconsistent movement pattern in acquisition and both retention tests; second, there would be an optimal number of trials that could be summarized/ averaged enhancing learning of the task; and third, there would be an optimal temporal delay before the presentation of feedback enhancing learning of the task.

Prediction one of guidance hypothesis predicts that in contrast to the experimental conditions the KR1 group would rely on KR during acquisition thus, developing an inconsistent movement pattern in acquisition and both retention tests. This prediction was based on the premise that the condition receiving feedback after every trial would come to rely on KR over practice trials. This reliance would cause the KR1 condition to have degraded performance in both retention periods due to the removal of KR. This overreliance on KR would prevent the subjects from engaging in various information processing strategies that would provide effective capabilities in responding when KR was withdrawn in a retention test (Wulf and Schmidt, 1989). The experimental conditions on the other hand had a five trial temporal delay before the presentation of any KR. This delay of feedback was hoped to have the beneficial effects of guiding the subjects to the goal time, but in the same sense it wasn't provided so frequently subjects would become dependent on it based on the prediction of the guidance hypothesis that there is an optimal temporal delay before the presentation of feedback. It was hoped that the delay of feedback would aid the development of error detection capabilities during the no KR trials in which the subjects must process their own response produced feedback and determine the accuracy of their response (Winstein and Schmidt, 1989). Despite this reasoning, the data failed to support this prediction with the KR 1 group performing with no more error than the experimental conditions in which none were significantly different from one another. This finding is additional support for the findings of Sidaway et al., (1991,1992) who also found the KR1 condition to have no detrimental effects on retention of a motor skill.

The second prediction of the guidance hypothesis is that there is an optimal number of trials that can be summarized or averaged to effectively enhance learning. Though the present study found very few effects of the independent variables, the summary 5 condition, though not significant, was the most consistent group throughout the acquisition, and retention tests. However, a statistically significant summary or average length was not found. Thus, the present study failed to support the second prediction as no optimal summary or average length was found.

The third prediction of the guidance hypothesis, is that there is an optimal temporal delay before the presentation of feedback which enhances learning of the task. Subjects who experience a temporal delay before receiving feedback develop a consistent movement pattern and are able to effectively asses their intrinsic feedback (Schmidt et al., 1989). There is an optimal point in the acquisition period in which the beneficial aspects of KR and the detrimental effects of overreliance of KR are balanced (Schmidt et al., 1989). The SUM 5 condition as well as all the other experimental conditions experienced a temporal delay of five trials before the presentation of feedback. Because of this temporal delay , subjects in these conditions were not forced change their movements on each subsequent trial. Subjects in these conditions had very little reason to change their movements from trial to trial due to infrequent feedback presentations. Trial to trial instability of subjects is known to be detrimental to the development of a memory representation of the task (Weeks and Sherwood, 1994). Learning of a task involves heightened sensitivity to detect and correct ones errors in the absence of KR. The KR1 group who received feedback after every practice trial appeared not to experience trial to trial instability. Although this effect was not significant, the KR1 group did not perform any more poorly than the other conditions therefore failing to support the third prediction of the guidance hypothesis. The guidance hypothesis emphasizes that frequent KR creates frequent movement changes which develops inconsistent movement patterns (Schmidt et al., 1989). This is not supported in the present study.

The guidance hypothesis has developed renewed interest in the KR paradigm, however it lacks answers to the questions behind the benefits of receiving KR in a delayed schedule or after every trial (Gable et al., 1992). As well, The guidance hypothesis places considerable emphasis on the no-KR trials and the processes that they generate, thus being very vague in what is being learned differently during the no-KR trials (Schmidt et al., 1989). The guidance hypothesis is not explicit as to whether the dependence on KR is produced, quickly or requires several trials (Guay et al., 1992). The processes involved in this delay period which underlie changes in retention performance are not understood or known. The underlying idea of the guidance of hypothesis is the notion that during these delays the subject is developing error detection capabilities over time due to the early stages of practice, KR dominates the information processing strategies of the learner (Swinnen et al., 1990). Based on the guidance hypothesis, a conclusion about why none of the conditions in the present study differed significantly is not possible. The most effective scheduling method, and the task parameters such as closed or open skills, discrete versus continuous, are issues which need continued research to extend the guidance hypothesis (Salmoni et al., 1984).

Conclusion

Summary KR has a hypothetical underpinning which makes it an effective feedback schedule manipulation. However, when this hypothetical underpinning, the guidance hypothesis, is applied to the laboratory setting summary KR seems to produce equivocal findings as an effective feedback schedule. It seems obvious that many factors contribute to the summary effect. Factors such as type of feedback, number of trials summarized, presentation frequency, and task all interact with each other in developing a summary effect. Though the present study found very few effects of the independent variables, it is evident that the task used in the present study may have had an influence on the effectiveness of the independent variables. The summary effect may have its most prevalent effects in tasks which require a considerable amount of practice and feedback before the goal of the task is reached. The emphasis on feedback for successful performance may result on an overreliance of feedback for the condition receiving feedback after every trial, a prediction of the guidance hypothesis. Once again, the human learner in the summary KR research continues to leave many questions unanswered as to why and when this feedback schedule manipulation is effective and optimal.

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Appendix A: Review of Literature

Optimal Summary Length Research

In 1962, Lavery studied the effects of three conditions and two degrees of KR on the acquisition and retention of three novel single kinematic ball projection tasks. Subjects were provided KR after every trial (KR1), after twenty trials (SUM 20), or about all preceding trials as well as the current one (CUM 20) , a form of cumulative KR. The SUM 20 and the CUM 20 groups were presented their KR graphically, displaying the deviation of their response from the goal of the task. Information given was either qualitative, based upon the direction of the error being either too far, too short, or perfect, or quantitative containing the magnitude of the error. Each subject performed each task under a different KR condition but remained within their given level of information being either qualitative or quantitative. By doing this method of task assignment the researcher allowed for comparisons between the subjects (Ss) and a between Ss comparison of the two levels of information.

On day 1 all subjects practised 20 no - KR trials in each task. For the next five days subjects performed with KR, followed by four consecutive days of no-KR, followed by a long term retention test of 37 and 93 days from the first day of the experiment. Each task was practised for 20 trials daily. Lavery (1962) could not perform a Task (3) x Condition (6) analysis because this interaction was confounded by subjects.

The data was analyzed by the use of an orthogonal polynomial analysis of trends for repeated measures of the same subject for the five acquisition days and the first four retention days. The 18 subjects performing on the three tasks each under a different condition improved linerally from day to day. The combined mean scores of the KR1 and the CUM 20 condition was better than the SUM 20 condition after 5 days of practice with KR. The differences in mean scores due to qualitative or quantitative information was not significant nor was the interaction between the KR condition and the level of information.

In retention, the mean score for the SUM 20 condition was significantly better than the KR1 condition and CUM 20 condition over the four consecutive days of no-KR retention. This was interesting because Lavery (1962) predicted that the SUM 20 would equal CUM 20, and both would have better scores than the KR 1 condition. What Lavery found was that the SUM 20 condition had significantly better scores than the KR 1 and the CUM 20 condition. This finding motivated Experiment Two by Lavery (1962) who believed that receiving KR after every trial may have interfered with the summary presentation, and any beneficial effect that this summary method would of had was lost somehow in the CUM 20 group.

In Experiment Two, Lavery (1962) compared the KR 1 condition to the SUM 20 condition to test the hypothesis that KR after every trial blocks inherent cues of the task which are ultimately useful in retention. Quantitative KR was withheld from subjects for 10 seconds during which time they were told to focus on inherent cues of the task which could aid them in the retention of the task. Lavery (1962) increased the KR delay for the KR 1 condition from 4 to 10 seconds for this reason. Subjects practised 20 trials a day on two of the three tasks, the first day with no feedback, the next five days with KR, and the final four consecutive days without KR.

The acquisition data for Experiment Two revealed that the acquisition scores for the SUM 20 and the KR 1 condition were identical to Experiment 1 with the KR 1 condition performing significantly better than the SUM 20 condition. The analysis of the retention data yielded no significant difference in overall performance or in trend due to KR conditions, apparatus, or subjects. The KR 1 condition seemingly improved in the Experiment Two retention test because of the reinforced importance of the inherent cues of the task.

It should be mentioned that the main difference between Experiment One and Experiment Two is subjects knew about the upcoming no KR trials and were told literally to 'prepare' themselves for the no-KR trials. In Experiment One however, the subjects were unaware of the upcoming no KR trials. As was noted above, the KR delay interval was increased from 4 seconds to 10 seconds for the KR 1 condition to provide enough time to attend to the inherent task cues. Focusing the subjects attention to these cues were possibly the reason for their improved retention results in Experiment Two. Lavery (1962) concluded that any method that encourages subjects to attend to and interpret the inherent cues in the task will ultimately favour retention.

Schmidt, Young, Swinnen, and Shapiro (1989) in their study of summary KR attempted to find an optimal summary length of either 1, 5 (5/5), 10 (10/10), or 15 (15/15) trials for a ballistic timing task. The authors, motivated by Lavery (1962)'s study wanted to further investigate the role of summary KR in learning a motor skill. It was hypothesized that short summary lengths provide too much information to the subjects, and long summary lengths cause the subjects not to learn the movement pattern but allow for the processing of movement information besides that of KR. Schmidt et al. (1989) explain that according to the guidance hypothesis there should be a balance point where the beneficial aspects of guidance and the detrimental effects of overreliance are balanced. The feedback provided to the subjects was a graphical presentation of absolute constant error. Subjects were randomly assigned to one of four conditions and completed 90 acquisition trials along with a 10 minute and 2 day NO KR 25 trial retention tests. The design of the experiment was a Condition (4) x Blocks (6) x Gender (2) design in acquisition and a Condition (4) x Blocks (5) x Gender (2) in retention.

Performance in acquisition was grouped into blocks of 15 trials for analysis, whereas the 25 trials in retention tests were analyzed in blocks of 5 trials. |CE| and VE were the dependent measures computed over these blocks. The average |CE| over all blocks in acquisition was significantly different between all the groups in a Conditions x Blocks x Gender analysis. A Tukey post hoc test revealed that across all blocks both the 10/10 and 15/15 conditions had significantly greater |CE| values than the 1/1 and 5/5. As with Lavery (1962), the authors found that summary KR depressed performance during acquisition relative to immediate KR for the first two thirds of the practice phase. The data from the acquisition phase extends those findings of Lavery (1962) in that performance in acquisition was inversely related to the summary length. For the VE acquisition scores, neither the group effect nor the group x blocks interaction, was significant.

When looking at the true effects of summary KR, retention tests reveal learning of a task. In the immediate retention test (10 minutes), there were no important effects of summary KR length. The |CE| values for the 1/1 group had slightly higher values than the other groups. The VE data revealed that the KR 1 condition increased VE scores across blocks while the summary condition were actually decreasing their VE scores. For the delayed retention test (2 days), the |CE| values decreased as the summary length increased

Thus, the authors failed to find a learning effect in the immediate retention test but did find a learning effect in the two day retention test. The two day retention test revealed that the 15/15 condition had the lowest |CE| values compared to the 1/1 condition. The authors predicted that an optimal summary length may lie beyond 15 trials closer to the 20 trial summary that Lavery (1962) found.

Schmidt, Lange, and Young (1990) examined the effects of different summary KR lengths on a task more complex than Lavery (1962), and Schmidt et al. (1989). The task was a coincident timing task (similar to a bat hitting a ball) which had no set movement goal pattern.

The subjects task was to discover a movement pattern that would maximize their score. Subjects were assigned to one of four experimental conditions, KR after every trial (KR 1), KR after every fifth trial (SUM 5), KR after every tenth trial (SUM 10), or KR after every fifteenth trial (SUM 15). All subjects completed 90 acquisition trials with an immediate (10 minutes) and a delayed (2 days) retention test both consisting of 30 trials each.

A computer hooked up to the task measured the instaneous velocity of the lever as it crossed the coincident point, and the absolute spatial error which was defined as the distance between the levers position and the coincident point at the moment the LED arrived there. The subjects score was the product of the instaneous velocity and a weighting coefficient. The design of this experiment was a Groups (4) x Blocks (6) ANOVA in acquisition and a Groups (4) x Blocks (3) ANOVA in retention.

The results of the acquisition phase revealed that the effects of conditions was significant. The acquisition data revealed that there was a strong tendency for performance scores to decrease as the summary lengths increased. The larger summary conditions clearly depressed performance in acquisition. In the immediate retention test (10 minutes, 30 no-KR trials) there was no significant block effect and there was no blocks X group interaction. The main finding of the immediate transfer test was the SUM 5 group who performed slightly more effectively than those in the KR 1 condition, both of which performed more effectively than the SUM 10 and SUM 15 trial summary groups. A Tukey's HSD post hoc revealed that the SUM 5 trial condition had better scores than the SUM 10 and SUM 15 trial conditions. However, the KR 1 and SUM 5 conditions were not significantly different from one another. In the delayed retention test there was a significant groups effect with the SUM 10 and SUM 15 conditions not statistically different from eachother. The KR 1 and SUM 5 condition were different from each other and significantly different from the SUM 10 and SUM 15 condition with the SUM 5 condition having better scores than the KR1, SUM10, and SUM 15 condition.

Schmidt et al. (1990) found that the SUM 5 condition performed significantly better than all the other conditions in both retention tests. This is a different finding than Schmidt et al. (1989) who found that the SUM 15 condition had better scores than the other conditions on the two day delayed retention test. Schmidt et al. (1990) propose that as the task complexity increases the summary length should decrease and that possibly a 5 trial summary is the most effective summary in learning a motor skill. Based upon the task being more difficult than Schmidt et al. (1989), and Lavery (1962), the authors concluded that the SUM 10 and SUM 15 trial summary condition were not supplied with enough guidance in this task to actually learn the task. The authors however do suggest that this optimal summary length of 5 trials may be task dependent. The results of this study however suggest that the most effective performance conditions for learning based on a 2 day retention are not necessarily those which produce the most effective performance during practice.

Guay, Salmoni, and McIlwain (1992) attempted to replicate the summary effect found by Lavery (1962), and Schmidt et al. (1989) in hopes of finding an optimal summary length. The underlying notion of the first experiment was that groups in the summary conditions would display greater error in the acquisition phase , but would display superior performance in the retention phase. Understanding the summary effect was deemed important by the authors to help clarify the roles KR may play in the skill learning setting. The task in this study was a ballistic timing task which involved angular positioning. The goal was to complete the task in 1000 msec. The feedback provided to the subjects was in relation to the movement time, the constant error. KR was either presented after every trial (1/1), after every fifth trial (5/5), after every tenth trial (10/10), or after every fifteenth trial (15/15). Subjects completed 90 acquisition trials as well a 30 no-KR retention test 10 minutes after, 2 days after and 6 months after the completion of the study. Subjects were unaware of these retention tests until the acquisition trials were completed. The data for acquisition and retention trials were grouped into blocks of ten trials for analyses. The dependent measures were |CE|, and VE. Summary KR groups x Blocks x Gender analyses were run for each independent variable. Because there was no significant effects, gender was not further mentioned.

The |CE| acquisition data revealed that all groups improved over practice producing a block effect. There was also a groups main effect with the 10/10 and 15/15 trial conditions producing significantly higher |CE| scores than the 1/1 condition. The groups x blocks interaction was also significant. However, there were only significant group differences for blocks 2, 3, 4, 5, and 8. The VE data revealed that there was a group x blocks interaction. There were group differences for blocks 1 and 2 only, the subjects in the 1/1 condition were more variable over the first two blocks than the other groups, however this dissipated quickly.

For the immediate transfer, a one way analyses of variance was run for each of the three blocks. A significant group difference existed for block one only, with the 5/5 condition producing less error than the other three conditions. For VE, there was a significant decrease in within subject variability during the immediate transfer for all groups. For the 2 day retention and the 6 month retention of |CE|, there were no significant group differences. The VE for the 2 month retention revealed a groups x blocks interaction which was not interpretable by the authors. The VE in the 6 month retention revealed that the first block was more variable than the other two blocks.

The authors did not find a summary effect like Lavery (1962) and Schmidt et al. (1989). Guay et al. (1992) however did find that as the summary lengths increased the movement errors also increased. The results of this study are inconclusive as to the optimal summary length due to the temporary superiority of the 5/5 condition in the first trial block of the immediate transfer only, which was followed by no group differences for the remaining immediate transfer trials or retention trials. The authors conclude that the studies thus far (Schmidt et al. 1989, 1990) are inconclusive as to whether or not there is an optimal summary length.

In Experiment Two, Guay et al. (1992) further attempted to unravel the mysteries of the summary effect by adding a 10/5 group. This group received a summary of the last ten trials after every fifth acquisition trial. The rationale behind this group was that if the number of trials in the summary is important than this group should perform the same as the 10/10 group. If however, the temporal delay is important, emphasized by the Sidaway, Fairweather, Powell, & Hall (1991) study, than the 10/5 group should perform as well as the 5/5 trial summary group. The same task was used in this study as in Experiment one. The experimental conditions were 1/1, 5/5, 10/10, and 10/5. The dependent measures was |CE| and VE. Groups x Blocks x Gender was run for each dependent variable and since there was no significant effects of gender it was not mentioned any further.

During the acquisition phase, the |CE| scores revealed a groups main effect with the 10/10 and 10/5 conditions producing significantly more error than the 1/1 group. There was also a groups x blocks interaction, indicating that the group receiving KR on every trial was more accurate than the other groups on blocks 1, 2, and 3 only. For VE, there was a group by blocks interaction. The groups receiving KR more frequently (1/1 and 5/5 trial condition) were more variable over the first ten trials, but this order was reversed for trials 11 - 30.

For the immediate transfer test, the groups x blocks interaction was significant. Simple group effects existed for blocks 2 and 3. In block two the 1/1 condition produced lower error scores than the other three conditions. In block three, the 10/10 and 10/5 trial produced less error than the other two groups. For the retention test, there was a groups x blocks interaction. For blocks 1 and 2, the 10/5 trial condition produced less error than the 1/1 , 10/10, and 5/5 trial conditions for |CE|.

The results of this study did not reveal an optimal summary length, nor did it reveal a summary effect. The most interesting finding of this study was the 10/5 group who had the same temporal delay as the 5/5 group but the same information as the 10/10 group. The results revealed by this group prove that summary KR is a multiple rather than a single factor phenomenon. The authors concluded that an optimal summary length would result from an optimal temporal delay (eg. Sidaway et al., 1991), the number of no KR trials, and the number of trials displayed in which all may have different effects for different types of tasks. The authors emphasize that after fifty years of providing error information to a learner we still do not know how this information works.

Optimal summary length has been the primary variable of interest in the aforementioned studies. However, looking for an optimal summary length can not be the primary variable of understanding the summary effect; but it is an important variable if the summary effect is to be understood.

Presentation Frequency

Sidaway, Moore, & Schoenfelder - Zhodi (1991) conducted an experiment that examined keeping the summary KR presentation frequency constant. The motivation behind this experiment was the fact that Schmidt et al. (1989) allowed their frequencies to covary. The groups in Schmidt et al. (1989) study had summary groups of 1, 5, 10, and 15 trial summaries which resulted in KR frequency presentations of 100%, 20%, 10%, and & 7% respectively. The KR presentation frequency of the groups may have led to the differences in the amount learned and not the number of trials presented in the summary. Sidaway et al. (1991) manipulated the number of trials summarized while holding KR presentation frequency constant. All the groups received KR after a block of 15 trials. Subjects either received KR about the last 15 (15/15), 7 (15/7), 3 (15/3), or last trial (15/1). All the groups had a KR presentation frequency of 7%. The task used in this study was the same as Schmidt et al. (1989) except a longer movement time was used because subjects had a difficult time attaining a time of 550 msec on the apparatus, so a slower time of 750 msec was used in the study. All subjects completed 90 acquisition trials along with a 10 minute and two day 25 no KR trial retention tests. Subjects were given their temporal accuracy graphically. The dependent variables for this study were |CE| and VE.

The data of the acquisition trials were grouped into blocks of 15 trials and the retention data was grouped in to blocks of 5 trials. The acquisition data was analyzed by a Groups (5) x Blocks (6) ANOVA with repeated measures on the last factor. The retention data was analyzed by a Groups (5) x Retention Test (2) x Blocks (5) ANOVA with repeated measures on the last factor.

In the acquisition phase there was a main effect for groups with a Newman Keuls post hoc revealing significant lower |CE| scores for the 1/1 group, and no differences between the summary groups. Error scores tended to increase as the summary lengths increased. However all the groups improved significantly after the first block at relatively the same level. The VE scores revealed a main effect for blocks with only the first and last block being significantly different. There was a trend with the KR1 and the SUM 15 condition to have lower VE scores but this was not significant.

For the retention tests there was a main effect for groups, with the 1/1 group having lower |CE| scores than all the other summary groups which were not different from one another. The main effect for retention was significant with the 10 minute retention having lower error scores than the 2 day retention. There were no significant results for VE.

Sidaway et al. (1991) concluded that the summary KR effect is not due to the number of trials in the summary because the SUM 1 condition learned the task equally as well as the SUM 15 condition. The authors data and Schmidt et al. (1989)'s data suggests that the frequency of presentation or perhaps the temporal delay of KR is an important factor in learning. Sidaway et al. (1991) reject the notion that the number of trials in the summary is crucial for learning. It is the frequency of KR presentation during acquisition rather than the number of trials in the summary that possibly determines retention performance.

Sidaway, Fairweather, Powell, and Hall (1992) further examined presentation frequency and whether movement time influences the summary KR effect. This may explain the differences between the results of the immediate group of Schmidt et al. (1989), and Sidaway et al. (1991) studies. The procedures for this study replicated those of Sidaway et al. (1991) except for the total movement time. Experimental groups were either placed in the 500 msec or 1000 msec condition. Subjects received feedback after a fifteen trial block displaying the last 15 trials (15/15), or the last 3 trials (15/3), or the last trial (15/1), and a group which received KR about the last trial as well as a summary of all the 15 trials performed following the completion of the 15 trial acquisition block (BOTH). There was also a group which received KR after every trial (1/1). |CE|, CE, VE were calculated for every block of fifteen trials. The acquisition data was analyzed by a 2 x 5 x 6 (MT goal x KR condition x blocks) mixed ANOVA with repeated measures on blocks. Retention data was analyzed by a 2 x 5 x 2 (MT goal x KR condition x retention test) mixed ANOVA with repeated measures on the last factor. The task used in the study was a linear slide task with subjects receiving graphical KR based upon their CE values from the movement time goal (500 or 1000 msec).

Based on the 3 way ANOVA for the acquisition scores there was a significant main effect for KR condition revealing that the 1/1 condition and the BOTH condition had consistently lower |CE| scores than all the other groups. There was no significant difference between the 1/1 group and the BOTH KR group conditions There was a significant interaction between KR condition and blocks. There was stable performance by block 3 for the 1/1 and BOTH condition, while summary groups exhibited a more gradual decline in error scores. Groups that were required to complete the task in 1000 msec had significantly less bias than those groups whose movement time goal was 500 msec.

The retention data revealed that the groups in the 500msec group had equivalent performance |CE| in both retention tests. The 1000 msec groups had markedly poorer performance in the 2 day retention test than in the 10 minute retention test. There was a main effect for movement time goal with lower variability in the retention tests for 500 msec groups than the 1000 msec groups. The effects of KR condition did not reach significance.

Sidaway et al. (1992) did not find a summary effect for their summary conditions. The difference between Sidaway et al. (1991) and Schmidt et al. (1989) cannot be explained by the different movement times because there was no effect of the KR condition on movement time goals. As with Sidaway et al. (1991), learning was unaffected by the number of trials in the summary display because subjects in the 1/1 condition did not perform more poorly in retention than the summary groups. There was only partial support for the presentation frequency of 7 % because all the summary groups (15/15, 15/3, 15/1) performed equal to the 1/1 and the BOTH group who received a relative KR frequency of 100 %. The results of this study simply display the resourcefulness of the human learner according to Sidaway et al. (1992) because the 15/1 condition was equal to the 1/1 in retention. The authors point out that much is still left to be learned about the effects of summary KR in motor skill learning.

According to Schmidt et al. (1989) long summary lengths encourage the processing of movement information but lack sufficient guidance in acquiring the correct performance; therefore an optimal summary length is predicted. Sidaway et al. (1991, 1992) possibly failed to find a summary effect due to the 15 trial summary being too long. A possible reduction in the summary length but keeping the presentation frequency constant could be more beneficial to the learner acquiring a motor skill.

Task Oriented Summary Research

Wright, Snowden, and Willoughby (1990) examined the effectiveness of learning a golf putt. The task was deemed relevant because it was open loop in nature which has been proposed to be the type of task which is most subseptible to summary manipulations (Sidaway et al. 1991). The golf putt also allowed the study of summary KR in a practical setting. The subject was to putt the ball a particular distance with accuracy not being important. The researchers did not allow their presentation trials in acquisition to covary. Subjects either received KR after every trial (KR 1) or once after a five trial block of either the last trial (5/1) or the last five trials (5/5). The subjects were provided summary feedback verbally by the experimenter being the subjects constant error. The data for the acquisition and retention trials were analyzed in blocks of five trials. |CE| and VE being computed for each of the four acquisition blocks and the one retention block. Analyses of both the |CE| and VE during acquisition consisted of a 3 (group) x 4 (trial block) ANOVA with repeated measures on the last factor. The retention data was analyzed by a one way ANOVA. All subjects completed 20 acquisition trials followed by a five minute rest which they then performed 5 no-KR retention trials.

Data from the acquisition trials revealed a group x trial block interaction and post hoc testing revealed that the 1/1 condition had lower |CE| than both the 5/5 and 5/1 conditions, these groups not being significantly different from one another. For the VE scores, the groups differed on the first block but not on the second to fourth block with the 5/1 condition having lower VE than the 1/1 and the 5/5 condition.

The retention data for |CE| revealed there was a group effect with the post hoc testing revealing the KR 1 condition having significantly greater |CE| than the 5/5 and the 5/1 KR condition during the retention trial block. The summary conditions were not different from one another. The VE scores revealed no significant effect of group.

Wright et al. (1990) concluded that withholding KR in a summary format benefitted the retention of the complex task. The authors also found a summary effect. A summary effect being the groups reversed positions in the retention test compared to the acquisition trials. The summary KR effect in this study was not a relative frequency effect because the 5/1 group was comparably equal to the 5/5 group. The conditions which had the same presentation frequency had enhanced retention performance. Summary KR was a useful teaching technique in the long term retention of a complex movement skill such as a golf putt.

Gable, Shea, and Wright (1991) examined the role of summary KR on an isometric impulse force production task. This task was chosen because it has few sources of extrinsic feedback other than KR. Subjects had to produce 50 % of their maximal force output. Subjects were provided KR after every trial (1/1), once after eight trials about the preceding eight trials (8/8), or KR once after 16 trials with a summary of information about the preceding sixteen trials (16/16). The error information given to the subjects was their deviation from the target force. The dependent variables were total error, |CE|, and VE. All the dependent variables were analyzed in KR conditions x Gender x Blocks MANOVA.

The results of the acquisition data revealed that there was an interaction of KR condition and block. The authors conducted a simple main effect analysis and found that the 16/16 and 8/8 condition had greater response bias |CE| than the 1/1 condition on blocks 1 and 2, but this difference was rapidly reduced in the later trials. For the VE scores, there was no significant interaction between the KR condition and block.

For the retention data, there was a main effect of KR condition. The 16/16 condition resulted in smaller |CE| than the 1/1 condition. There was no main effect of KR condition for VE scores. For the total error, the 1/1 condition resulted in larger error scores than the 16/16 condition, and the 8/8 condition was not significantly different than either the 1/1 or 16/16 condition.

Gable et al. (1991) also found that as the summary length increased the acquisition performance decreased. However the 16/16 condition was superior in retention to the 1/1 and the 8/8 condition in an isometric force production task. The authors are in agreement with Schmidt et al. (1990) that the optimal summary length increases as the complexity of the task decreases. Task complexity might be a variable in producing the phenomenon of a summary effect.

Reviewing the tasks in summary KR research it has been found that the more complex the task, the shorter the summary lengths creating the summary effect (eg. Schmidt et al. 1990; Wright et al. 1991; Yao, Fischman, & Wang 1994). However, when looking at the effective summary lengths for simple tasks (eg. ballistic timing task, static force production task, linear slide) the summary lengths range from a summary of twenty trials (Lavery, 1962) to as low as five trials (Schmidt et al.

1990); to finding absolutely no effects of summary KR at all (Sidaway et al. 1991). The task does play a role in the effectiveness of summary KR but other variables such as summary length and presentation frequency are also important variables which must be taken into consideration when learning a motor task.

Average versus Summary Knowledge of Results (KR)

Weeks and Sherwood (1994) introduced a group which contained only one value based upon the previous five trials, this condition was introduced as the average KR condition. An average KR condition reduces the amount of information relating to individual trials, and as a result, information about variability of performance. Based on the fact that there is mixed support for the summary effect between summary groups and the 1/1 group, the average group was introduced to directly compare this group to the summary KR group which could further give an understanding of the optimal scheduling of KR. The purpose of the study was to directly compare an average and summary KR condition. The subjects participated in a force producing task in which they had to produce 30% of their own maximal force. Subjects completed 75 acquisition trials with 20 immediate and 2 day no KR retention trials. Subjects were randomly assigned to feedback after every trial (1/1), feedback after every fifth trial in a summary (SUM 5), or feedback after every fifth trial as an average (AVE 5). The design of the study was a Group (3) x Trial Block (15) ANOVA in acquisition and a Group (3) x Trial Block (4) design for immediate and long term retention with repeated measures on the last factor. The dependent variables were |CE| and VE. Subjects were given their goal force along with their actual force produced on a particular trial.

For the acquisition data, there was no significant group main effect nor a group by block interaction. For the VE scores, there was a significant group by block interaction. The 1/1 group had significantly greater VE in all but two of the fifteen acquisition blocks. A Student Neuman -Keuls test revealed that the 1/1 group differed significantly from the summary and average group.

For the immediate retention data, there was a group main effect for |CE| scores. A Student - Newman-Keuls analysis indicated the SUM 5 group differed from the every 1/1 group, whereas the AVE 5 group did not differ from the SUM 5 group or 1/1 group. There was no main effect for group or interaction for VE scores.

For the long term retention test, the |CE| failed to reveal significant main effects or an interaction. The group performances were statistically equivalent. For the VE scores there was a significant group main effect. A Student - Newman - Keuls analysis indicated that the SUM 5 group differed from the 1/1 group, whereas the AVE 5 group did not differ from the SUM 5 or 1/1 group.

Weeks and Sherwood (1994) found no differences between the average and summary groups which further supports the idea that the summary effect may be a result of the number of trials the subject pays attention to or to which the subject is presented. Average KR could possibly be a promising technique as an instructional tool.

Yao, Fischman, & Wang (1994) also directly compared summary KR to average KR. The conditions in this study were an average 15 (AVE 15) and summary 15 (SUM 15) condition and an average 5 (AVE 5) and summary 5 condition (SUM 5). There was also a condition which received KR after every trial (1/1). Subjects performed

60 acquisition trials along with a 10 minute and 2 day retention test on a spatial and temporal positioning task. The task in this study was an aiming task in which the subjects had to move a total of 40 cm in 500 msec. The task contained a spatial and temporal component in which subjects were given both as feedback. The dependent variables in this study were absolute error (AE), and variable error (VE). The design for acquisition was a 5 (feedback) x 4 (Trial Block) with repeated measures on the last factor ANOVA and for retention it was a 5 (feedback condition) x 2 (retention test) ANOVA with repeated measures on the last factor

For the temporal component mean AE scores, there was a main effect for trial block meaning that errors decreased across practice blocks for all groups. There was also a main effect for feedback condition. A Tukey test revealed that the every trial condition had less error than the longer average and summary KR conditions (15 SUM and 15 AVE) and that the 5 SUM was significantly different than the 15 SUM. In general, the more often feedback was provided the more accurate the acquisition performance. There was a significant overall decrease in VE with practice. The variability among the five feedback conditions were quite similar. In the spatial component like the temporal component, there was a main effect for trial block with all groups showing a reduction in AE with practice. There was an overall significant decrease in VE scores with practice, with variability among the five feedback conditions being quite similar.

For the retention tests of AE scores, there was a substantial decrement in performance of the 1/1 condition across the two retention tests, whereas the summary and average KR conditions declined relatively little across the two tests. The 5 SUM and 5 AVE feedback conditions had significantly lower VE than the 1/1 group. For the spatial component of the task, there was a significant difference between the 1/1 condition and the 5 AVE condition, no other pair wise comparisons were significant. For the VE scores, there was a main effect for feedback conditions with slightly lower VE for the 5 SUM and 5 AVE conditions.

The researchers found, as did Weeks and Sherwood (1994) that average and summary feedback operated similarly in learning the task. SUM 5 and AVE 5 were more effective in learning the task than the 1/1 condition and some what more effective than the 15 trial conditions, however as like Weeks and Sherwood (1994), there was no difference between the 5 AVE and 5 SUM conditions. Further research is needed to distinguish the effects of summary KR and average KR on learning a motor skill if in fact a difference does exist.

Appendix B: Formal Hypotheses

Acquisition Hypothesis

Null (H_o): There will be no difference in performance scores (¦CE¦, VE) between the experimental groups and the KR1 condition.

H_{a1}: The KR1 group will have better performance scores than all the experimental conditions (Schmidt et al. 1989; Schmidt et al., 1990; Weeks and Sherwood, 1994; Yao et al., 1994).

RETENTION HYPOTHESES (10 minute, 2 Day)

Null (H_o): There will be no difference in performance scores between average KR and summary KR conditions.

H_{a1}: Summary KR conditions will have better performance scores than average KR conditions (Weeks and Sherwood, 1994; Yao et al 1994).

Null (H_o): There will be no difference in performance scores among groups differing in the number of trials summarized contained within the feedback presentation.

H_{a1}: The 5 trial group will have better performance scores than the 10 trial group.

H_{a2}: The 5 trial group will have better performance scores than the 15 trial group.

H_{a3}: The 10 trial group will have better performance scores than the 15 trial group.

Null (H_o): There will be no difference in performance scores among groups differing in the type of feedback presentation and the number of trials contained in the feedback presentation.

H_{a1}: The 5 SUM condition will have better performance scores than the 5 AVE condition.

H_{a2}: The 5 SUM condition will have better performance scores than the 10 AVE condition.

H_{a3}: The 10 SUM condition will have better performance scores than the 15 AVE condition.

H_{a4}: The 10 SUM condition will have better performance scores than the 15 AVE condition.

H_{a5}: The 5 SUM condition will have significantly better performance scores than the 15 AVE condition.

Null (H_o): There will be no difference between the experimental conditions and the KR1 condition performance scores in the ten minute retention.

H_{a1}: The experimental conditions will have better performance scores than the KR1 condition in the 10 minute retention test (Schmidt et al 1989; Schmidt et al., 1990; Weeks and Sherwood, 1994; Yao et al., 1994).

Null (H_o): There will be no difference in performance scores between the experimental conditions and the KR 1 condition in the 2 day retention test.

H_{a1}: The experimental conditions will have better performance scores than the KR1 condition in the 2 day retention test (Schmidt et al 1989; Schmidt et al., 1990; Weeks and Sherwood, 1994; Yao et al., 1994).

APPENDIX C: Informed - Consent Letter

Information - Consent Letter

The present study examines the acquisition and retention of a simple ball positioning task. This study is being conducted by J. Patterson and is supervised by Dr. Patricia Weir of the Department of Kinesiology.

Subjects will be asked to relocate two tennis balls into two separate holders in a set amount of time. Completion of the study should take approximately 45 minutes on day one. Subjects will be asked to return two days after the first testing trial for additional practice trials which should take approximately 15 minutes. Participation in these tests will be performed on a volunteer basis.

There are no anticipated risks associated with participation in this study. All data collected as a result of your participation in the study will be used for publication purposes. Your anonymity will be guaranteed, and your consent to participate, or for the use of the data you provided, may be withdrawn at any time by indicating this to the researcher.

This study has been reviewed by, and has received clearance through the Department of Kinesiology at the University of Windsor. Dr. Weir of the Department of Kinesiology will receive any complaints or concerns with regard to your involvement in this study at (519) 253-4232, extension 2443.

Consent to Participate

I have read the information letter describing the purposes and the tasks involved in participation in a study on the motor learning processes underlying the acquisition and retention of a motor skill which is being conducted by J. Patterson and supervised by Dr. Patricia Weir of the Department of Kinesiology. I further understand that should information I provide be used in publications or for teaching purposes, my identity will be protected. I acknowledge that I may withdraw my consent to participate at any time.

This study has been reviewed by, and has received clearance through the Department of Kinesiology at the University of Windsor. Dr. Weir of the Department of Kinesiology will receive any complaints or concerns with regard to your involvement in this study at (519) 253-4232, extension 2443.

Participants Name:

(PLEASE PRINT)__________________________________AGE:__

Signature:______________________________D___M___Y_____

Experimenters
Signature:______________________________D___M___Y_____

APPENDIX D: ANOVA Tables

Table 1D
ANOVA table for acquisition VE

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	724258.9	24	30177	12.79	0.0000
GROUP	48212.0	6	8035	1.56	0.1735
SUBJECT (GROUP)	324352.2	63	5148		
GROUP X BLOCK	350550.3	144	2434	1.03	0.3866
SUBJECTS X BLOCK X (GROUP)	3567290.4	1512	2359		

Table 2D
ANOVA table for acquisition ¦CE¦

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	9329584	24	388733	33.68	0.0000
GROUP	777571	6	129595	1.71	0.1335
SUBJECTS (GROUP)	4776608	63	75819		
GROUP X BLOCK	2180042	144	15139	1.31	0.0103
SUBJECTS X BLOCK (GROUP)	17451585	1512	11542		

Table 3D
ANOVA table for 10 minute retention VE

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	22783.0	2	11391	3.40	0.0363
GROUP	18790.9	6	3132	0.95	0.4645
SUBJECTS (GROUP)	207108.8	63	3287		
GROUP X BLOCK	22590.9	12	1883	0.56	0.8684
SUBJECTS X BLOCK (GROUP)	421589.8	126	3346		

Table 4D
ANOVA table for 10 minute retention ¦CE¦

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	600.98	2	300.49	0.22	0.8046
GROUP	24040.52	6	4006.75	0.75	0.6132
SUBJECTS (GROUP)	337463.45	63	5356.56		
GROUP X BLOCK	11530.89	12	960.91	0.70	0.7523
SUBJECTS X BLOCKS (GROUP)	173808.11	126	1379.43		

Table 5D
ANOVA table for 2 day retention VE

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	9890.40	4	2472.6	2.95	0.0207
GROUP	4401.66	6	733.6	0.66	0.6834
SUBJECT (GROUP)	70213.55	63	1114.5		
GROUP X BLOCK	15915.70	24	663.2	0.79	0.7461
SUBJECT X BLOCK (GROUP)	211052.44	252	837.5		

Table 6D
ANOVA table for 2 day retention ¦CE¦

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
BLOCK	6122.5	4	1530.6	1.27	0.2815
GROUP	28163.9	6	4694.0	0.32	0.9231
SUBJECT (GROUP)	918173.0	63	14574.2		
GROUP X BLOCK	33187.5	24	1382.8	1.15	0.2909
SUBJECT X BLOCK (GROUP)	303255.8	252	1203.4		

Table 7D
ANOVA table for acquisition VE (exclusion of KR1 group)

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	25461.1	1	25461.1	4.52	0.0382
AMOUNT	13494.3	2	6747.2	1.20	0.3101
BLOCKS	560241.4	24	23343.4	9.40	0.0000
TYPE X AMOUNT	9094.1	2	4547.1	0.81	0.4518
TYPE X BLOCK	52423.0	24	2184.3	0.88	0.6321
AMOUNT X BLOCK	155717.9	48	3244.1	1.31	0.0804
SUBJECTS (TYPE X AMOUNT)	304480.8	54	5638.5		
TYPE X AMOUNT X BLOCKS	100533.9	48	2094.5	0.84	0.7684
SUBJECT X BLOCKS (TYPE X AMOUNT)	3219036.1	1296	2483.8		

Table 8D
ANOVA table for acquisition |CE| (exclusion of KR1 group)

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	20775.5	1	20775.5	0.24	0.6252
AMOUNT	263251.5	2	131626	1.53	0.2260
BLOCKS	10012189.5	24	417175	31.73	0.0000
TYPE X AMOUNT	30964.4	2	15482	0.18	0.8359
TYPE X BLOCKS	152072.2	24	6336	0.48	0.9839
AMOUNT X BLOCKS	632940.7	48	13186	1.00	0.4688
SUBJECT (TYPE X AMOUNT)	4648883.8	54	86090		
TYPE X AMOUNT X BLOCKS	559186.8	48	11650	0.89	0.6936
SUBJECTS X BLOCKS (TYPE X AMOUNT)	17039735.1	1296	13148		

Table 9D
ANOVA table for ten minute retention VE (exclusion of KR1 group)

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	1197.65	1	1197.6	0.42	0.5218
AMOUNT	8746.46	2	4373.2	1.52	0.2283
BLOCKS	15792.29	2	7896.1	2.69	0.0723
TYPE X AMOUNT	6496.01	2	3248.0	1.13	0.3313
TYPE X BLOCK	7111.80	2	3555.9	1.21	0.3016
AMOUNT X BLOCK	10453.63	4	2613.4	0.89	0.4722
SUBJECTS (TYPE X AMOUNT)	155541.33	54	2880.4		
TYPE X AMOUNT X BLOCK	3518.53	4	879.6	0.30	0.8775
SUBJECTS X BLOCKS (TYPE X AMOUNT)	316884.02	108	2934.1		

Table 10D
ANOVA table for ten minute retention |CE| (exclusion of the KR1 group)

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	2694.29	1	2694.29	0.46	0.5026
AMOUNT	18927.45	2	9463.72	1.60	0.2113
BLOCK	542.13	2	271.06	0.18	0.8333
TYPE X AMOUNT	2294.07	2	1147.03	0.19	0.8243
TYPE X BLOCK	1384.77	2	692.38	0.47	0.6283
AMOUNT X BLOCK	7083.50	4	1770.88	1.19	0.3178
SUBJECTS (TYPE X AMOUNT)	319399.97	54	5914.81		
TYPE X AMOUNT X BLOCK	2748.09	4	687.02	0.46	0.7627
SUBJECTS X BLOCKS (TYPE X AMOUNT)	160221.03	108	1483.53		

Table 11D
ANOVA table for 2 day retention VE (exclusion of the KR1 group)

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	299.16	1	299.16	0.25	0.6183
AMOUNT	2059.54	2	1029.77	0.86	0.4270
BLOCKS	8210.51	4	2052.63	2.23	0.0671
TYPE X AMOUNT	1427.51	2	713.75	0.60	0.5529
TYPE X BLOCK	658.88	4	164.72	0.18	0.9492
AMOUNT X BLOCK	5496.28	8	687.04	0.75	0.6511
SUBJECTS (TYPE X AMOUNT)	64326.63	54	1191.23		
TYPE X AMOUNT X BLOCK	7428.74	8	928.59	1.01	0.4311
SUBJECTS X BLOCKS (TYPE X AMOUNT)	199024.67	216	921.41		

Table 12D
<u>ANOVA table for 2 day retention ¦CE¦ (exclusion of the KR1 group)</u>

MEAN	SUM OF SQUARES	D.F.	MEAN SQUARE	F	PROB.
TYPE	2626.11	1	2626.1	0.16	0.6894
AMOUNT	2482.22	2	1241.1	0.08	0.9266
BLOCK	7597.45	4	1899.4	1.45	0.2200
TYPE X AMOUNT	2212.07	2	1106.0	0.07	0.9343
TYPE X BLOCK	3976.50	4	994.1	0.76	0.5546
AMOUNT X BLOCK	12943.91	8	1618.0	1.23	0.2818
SUBJECTS (TYPE X AMOUNT)	878189.69	54	16262.8		
TYPE X AMOUNT X BLOCK	13098.93	8	1637.4	1.25	0.2735
SUBJECTS X BLOCKS (TYPE X AMOUNT)	283793.75	216	1313.9		

Appendix E: Block means and critical difference values.

Table 1E

Block means for |CE| and VE for acquisition, 10 minute, and 2 day retention tests collapsed across all experimental conditions with the exclusion of the KR1 group.

	Acquisition		10 Minute Retention		2 Day Retention	
Block	|CE| CD=59.64	VE CD=25.91	|CE|	VE	|CE|	VE
1	345.01	133.96	52.68	58.23	65.45	49.33
2	287.59	70.96	56.51	41.53	80.21	45.58
3	266.77	56.30	52.99	36.25	74.68	34.68
4	104.14	50.70			69.21	37.94
5	73.75	49.20			73.90	41.19
6	79.14	44.51				
7	82.28	45.86				
8	68.75	43.25				
9	49.81	46.98				
10	59.45	46.33				
11	73.00	67.44				
12	58.93	69.96				
13	52.03	41.77				
14	48.60	39.32				
15	51.91	43.39				
16	47.56	38.84				
17	42.88	49.64				
18	47.78	41.92				
19	38.03	38.45				
20	43.17	45.60				
21	39.46	40.67				
22	36.33	39.77				
23	41.53	39.87				
24	43.69	39.80				
25	44.95	44.00				

Note. CD represents the critical difference in the Tukey Post Hoc test for statistical significance.

Table 2E
Block means for |CE| and VE for acquisition, 10 minute, and 2 day retention tests collapsed across all experimental conditions.

	Acquisition		10 Minute Retention		2 Day Retention	
Block	|CE| CD=53.67	VE CD=24.23	|CE|	VE CD=23.22	|CE|	VE CD=14.43
1	315.06	140.58	51.89	60.93	63.31	50.20
2	254.05	67.62	55.98	42.92	75.03	43.33
3	239.71	55.57	53.37	36.27	70.88	34.79
4	96.92	47.72			66.37	37.51
5	69.78	51.82			72.11	40.18
6	75.24	46.19				
7	78.71	45.79				
8	65.27	43.18				
9	47.55	48.43				
10	53.73	45.67				
11	65.70	64.86				
12	53.24	69.77				
13	46.91	44.59				
14	45.27	39.33				
15	48.42	42.32				
16	44.96	38.28				
17	41.63	48.66				
18	45.89	42.60				
19	36.52	37.36				
20	41.31	44.26				
21	36.54	39.83				
22	36.63	39.48				
23	40.43	38.50				
24	40.27	39.20				
25	40.89	43.79				

Note. CD represents the critical difference in the Tukey Post Hoc test for statistical significance.

Appendix F: Group means for acquisition, 10 minute, and 2 day retention

Table 1F

Absolute Constant Error scores for acquisition, 10 minute, and 2 day retention test for all blocks.

				ABSOLUTE CONSTANT ERROR			
BLK	KR1	SUM5	SUM10	SUM15	AVE5	AVE10	AVE15
				ACQUISITION			
1	135.36	212.96	226.58	405.36	374.84	410.22	240.12
2	52.78	184.34	341.28	356.86	225.58	368.12	249.36
3	77.32	184.38	359.36	324.52	215.78	305.20	211.38
4	53.60	63.60	114.50	160.52	83.42	103.76	99.06
5	45.94	54.72	85.46	97.56	83.30	59.22	62.24
6	51.84	38.20	57.64	76.18	74.56	58.00	170.24
7	57.32	56.08	56.26	64.08	70.06	106.36	131.82
8	44.40	59.58	48.42	88.42	45.62	61.08	109.36
9	34.04	22.46	57.72	54.58	51.56	31.50	81.02
10	19.42	42.64	63.52	61.74	60.84	37.68	90.28
11	21.86	161.20	46.20	60.48	58.38	51.08	60.68
12	19.06	22.64	67.62	47.04	60.62	57.28	98.40
13	16.16	30.48	66.24	38.34	39.36	48.94	88.82
14	25.26	17.46	80.38	41.26	38.82	48.40	65.28
15	27.48	46.60	43.40	47.00	57.74	53.16	63.54
16	29.38	26.16	40.30	51.34	37.52	33.48	96.54
17	34.14	26.30	38.74	49.56	39.48	35.86	67.34
18	34.52	33.10	42.90	33.98	29.52	43.22	103.98
19	27.46	27.52	38.34	43.60	22.98	38.80	56.96
20	30.18	27.80	32.80	36.44	33.70	54.10	74.18
21	19.00	14.48	39.58	51.04	34.18	33.96	63.54
22	38.40	28.00	25.70	36.60	27.26	31.72	68.70
23	33.82	15.20	47.44	43.72	43.28	21.38	78.16
24	19.74	24.68	33.00	37.06	37.06	47.02	83.34
25	16.52	39.46	52.44	27.38	34.18	48.62	67.62
$\bar{X}$	38.60	58.40	92.32	93.38	75.55	87.53	103.30
				10 MINUTE RETENTION			
1	47.14	30.68	74.22	52.92	23.24	70.38	64.66
2	52.82	41.94	59.56	53.34	54.82	70.22	59.18
3	55.62	44.26	58.52	36.30	47.98	58.70	72.20
$\bar{X}$	51.86	38.96	64.10	47.52	42.01	66.43	65.35
				2 DAY RETENTION			
1	50.46	67.48	70.66	59.54	68.64	63.72	62.64
2	43.92	87.04	72.74	68.08	80.76	77.48	95.18
3	48.06	70.08	55.96	98.62	76.48	77.54	69.40
4	49.34	57.64	57.58	87.06	64.80	71.42	76.74
5	61.40	63.06	68.98	61.44	60.06	103.28	86.58
$\bar{X}$	50.64	69.06	65.18	74.95	70.15	78.69	78.11

Table 2F
Variable Error scores for acquisition, 10 minute, and 2 day retention test for all blocks.

			VARIABLE ERROR				
BLK	KR1	SUM5	SUM10	SUM15	AVE5	AVE10	AVE15
			ACQUISITION				
1	180.24	85.59	176.04	78.76	203.82	162.65	96.62
2	47.59	34.40	82.13	84.07	66.10	75.75	83.32
3	51.19	38.25	81.96	46.08	55.16	60.62	55.73
4	29.82	35.36	47.09	77.71	38.38	52.31	53.35
5	67.53	37.05	47.88	53.83	44.68	42.43	69.33
6	56.31	35.25	60.14	48.34	37.65	41.50	44.16
7	45.36	39.16	36.73	37.19	59.39	39.46	63.22
8	42.74	37.89	44.77	44.19	43.79	42.18	46.67
9	57.15	46.98	47.22	39.00	57.67	48.38	42.64
10	41.70	43.16	39.33	47.97	39.30	50.56	57.65
11	49.36	137.26	57.62	52.48	53.15	40.91	63.23
12	68.61	55.85	77.33	61.36	88.85	62.00	74.38
13	61.46	29.42	44.23	38.92	44.52	45.59	47.95
14	39.39	31.79	39.13	34.45	38.77	50.68	41.14
15	35.87	36.69	48.10	31.98	51.99	39.07	52.51
16	34.92	30.53	36.34	38.74	37.05	31.99	58.39
17	42.83	35.32	46.41	40.39	42.80	45.91	86.98
18	46.69	38.90	35.00	31.81	41.91	44.86	59.02
19	30.79	22.50	31.04	35.59	36.42	56.27	48.89
20	36.19	25.35	50.41	32.99	45.63	76.22	43.01
21	34.82	20.07	41.14	49.90	34.22	50.08	48.58
22	37.77	35.61	37.99	34.43	30.91	43.46	56.23
23	30.28	24.64	36.21	37.64	39.00	54.95	46.78
24	35.59	27.37	37.46	41.38	37.10	50.17	45.35
25	42.52	31.20	43.82	35.82	46.63	49.59	56.93
$\bar{X}$	49.87	40.64	53.02	46.20	52.60	54.30	57.68
			10 MINUTE RETENTION				
1	77.11	36.81	73.93	78.34	38.49	79.74	42.07
2	51.21	24.05	32.42	36.44	67.20	46.98	42.12
3	36.38	20.46	47.05	35.34	34.44	43.77	36.48
$\bar{X}$	54.90	27.10	51.13	50.03	46.71	56.83	40.22
			2 DAY RETENTION				
1	55.43	40.46	53.70	45.09	71.38	51.09	34.24
2	29.85	51.25	46.77	40.62	34.80	45.26	54.77
3	35.44	19.41	42.61	41.07	31.47	40.90	32.63
4	34.88	30.48	42.45	41.60	33.28	39.49	40.63
5	34.17	33.43	46.32	35.90	44.18	44.20	43.08
$\bar{X}$	37.95	35.01	46.37	40.86	43.02	44.19	41.02

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