GENERALIZABILITY OF THE GUIDANCE HYPOTHESIS TO A BRIEF ACQUISITION PHASE

By

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A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Science

Lakehead University

April, 1992

ISBN 0-315-78963-8

MASTER OF SCIENCE
(Theory of Coaching)

LAKEHEAD UNIVERSITY
Thunder Bay, Ontario

TITLE: Generalizability of the Guidance Hypothesis to a Brief Acquisition Phase

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SUPERVISOR: Dr. D.J. Weeks

NUMBER OF PAGES: ix, 81

Abstract

Three experiments were conducted to investigate the generality of the guidance hypothesis to a brief practice (acquisition) session. Three research paradigms were studied consistent with those outlined by Schmidt (in press). Schmidt has been vocal in advocating the notion that frequent knowledge of results (KR) degrades learning. In experiment 1 the relative frequency of KR was investigated by employing four frequency conditions with a 5-trial acquisition phase. Summary-KR was studied in Experiment 2, utilizing three different summary lengths with a 15-trial acquisition phase. Finally, the trials-delay procedure was considered in Experiment 3. There were four varieties of delay, each having a total of five KR statements. In all three experiments the task involved a limb movement from left key to right key, performed in a criterion time of 500 milliseconds. All three experiments employed an immediate retention test (10 minutes later) and a delayed retention test (2 days later) to determine if the experimental conditions affected learning.

Acknowledgements

I would like to sincerely thank my advisor, Dr. Daniel Weeks, for his tremendous guidance, knowledge, and especially his patience. To Drs. Jane Crossman and Jane Taylor, I would like to extend my thanks for their guidance and support. I also would like to thank Barb Thomson and Brad Beyak for all their help in the lab.

On a more personal note, I would like to dedicate this thesis to my brother Robert, my personal computer whiz, without whom I would never have been able to type this paper. To the greatest parents in the world, who are always there for me - how can I ever thank you enough for all your financial and emotional support throughout my academic career. It's almost over! And last but certainly not least, I would like to thank Gary, the man who kept me sane throughout the last three years. THANKS FOR BELIEVING IN ME!!!

Forward

This thesis was written in the style adopted by the American Psychological Association for the preparation of manuscripts. Pages 1 to 69 represent the body of the manuscript as prepared for journal submission. The remaining pages constitute the appendices which include tables of the ANOVAs and means, and a worked example of measures of error.

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GENERAL INTRODUCTION

One of the key topics in motor behavior research concerns the issue of feedback. Feedback is one of the most important variables affecting motor skill learning, aside from actual practice (Bilodeau & Bilodeau, 1961; Reeve, Dornier, & Weeks, 1990; Schmidt, in press; Winstein & Schmidt, 1990). This information may take two forms - knowledge of performance (KP) and knowledge of results (KR) (Salmoni, Schmidt, & Walter, 1984; Schmidt, 1988).

Knowledge of performance refers to information regarding the movement, or the movement pattern, whereas KR concerns the outcome of the response (Schmidt, 1988). It is the latter that traditionally has been regarded as the most effective form for learning (Adams, 1987; Bilodeau & Bilodeau, 1958; Bilodeau & Bilodeau, 1961; Newell & Walter, 1981; Salmoni et al., 1984). Furthermore, KP has received less attention with regard to performance and learning because it is difficult to analyse movement patterns in many tasks (Schmidt, 1988).

The Performance-Learning Distinction

Knowledge of results has been defined as "verbal, terminal extrinsic feedback" (Salmoni et al., 1984; Schmidt, 1988). Essentially, KR is information (e.g., a score) representing the outcome of the movement which is presented to the performer (Newell & Walter, 1981; Schmidt, 1975a; Winstein & Schmidt, 1990). As such, research on KR is concerned with its effects on performance and learning. Tolman recognized this distinction as early as 1932 when he discussed the nature of learning (Tolman, 1932).

Learning is frequently defined as a relatively permanent change in behavior resulting from practice or experience (Adams & Reynolds, 1954; Bilodeau & Bilodeau, 1961; Dunham, 1971; Salmoni et al., 1984; Schmidt, 1975a; Schmidt, in press; Schmidt et al., 1989). Performance, on the other hand, is the translation of learning into behavior and may be temporarily affected by many variables (Dunham, 1971; Schmidt, in press). To determine if a change in performance, following the provision of KR, is attributable to learning, or is simply a temporary performance effect, a transfer or retention test may be performed (Salmoni et al., 1984; Schmidt, 1975a; Schmidt, in press; Schmidt et al., 1989).

The transfer or retention test is designed to allow all experimental groups to operate under a common level of the independent variable; usually a no-KR transfer test is utilized. If enough time is allowed between the practice conditions and the transfer test, the temporary effects of KR will fade away, leaving the permanent effects. Thus, any change in performance would be attributable to learning (Salmoni et al., 1984; Schmidt, 1975a; Schmidt et al., 1989).

Presentation of Knowledge of Results

Temporal Locus of Delivery

Experiments concerning KR have largely been concerned with temporal locus of its delivery. The basic question surrounds what is the best time to present KR to the learner. The time period between each trial may be divided into three intervals. The intertrial interval is the total time between two consecutive trials. That interval may be further divided into the KR-delay interval (the time between the response and the presentation of KR) and the post-KR delay interval (the period between the delivery of KR and the next trial) (Adams, 1971; Bourne & Bunderson, 1963; McGuigan, 1959a; Newell & Walter, 1981; Salmoni et al., 1984; Schmidt, 1988).

R-1 ——————— KR-1 ——————— R-2

——————— Inter-trial Interval ———————

—— KR-delay Interval ——— ——— Post-KR Delay Interval ——

Figure 1 - Intervals in the KR paradigm. The R refers to the response.

(From Schmidt, 1988, pp. 534)

It is proposed that during these intervals, various types of information processing activity occurs. The individual uses the KR-delay interval to temporarily store some aspect of a movement just made (Salmoni et al., 1984). The post-KR delay interval is the time during which information processing occurs and is extremely important for learning (Adams, 1971; Newell & Walter, 1981; Salmoni et al., 1984; Schmidt, 1988).

Researchers have investigated the effects of various manipulations to each of these intervals. However, it is difficult to study each interval separately without confounding one of the other time periods (Adams, 1971; McGuigan, 1959a). Typically, studies will hold the intertrial interval constant while investigating the effect of the KR-delay and post-KR delay intervals (Adams, 1971).

Studies manipulating the intertrial interval have produced contradictory results (Salmoni et al., 1984). Some have reported that increasing this period has beneficial effects on learning (Adams, 1987; Salmoni et al., 1984) while others have concluded that there is no effect (Salmoni et al., 1984; see Table 1 for an example of some studies to which Salmoni refers.) From the available evidence, Salmoni et al. (1984) have concluded that the relation between the intertrial length and learning is a positive one.

Table 1

Intertrial Interval Studies

Author	Task	Findings
Koch & Dorfman (1979)	limb movement (200 ms)	- no learning effect (covaried intertrial & KR-delay)
Dees & Grindley (1951)	knob turning (criterion degree)	- increased interval, increased learning (covaried intertrial & post-KR)
McGuigan (1959b)	line drawing (6 in)	- increased interval, increased learning (covaried intertrial & Kr-delay)

In terms of performance, the evidence indicates that changing the length of the KR-delay period has no effect (Adams, 1971; Lavery, 1962; Lorge & Thorndike, 1935; Salmoni et al., 1984; Schmidt, 1988). However, most of the literature regarding the KR-delay interval has failed to consider learning. Studies that have investigated learning effects have concluded that there is no effect associated with increasing the KR-delay interval (McGuigan, Crockett, & Bolton, 1960; Salmoni et al., 1984). However, this conclusion may be erroneous due to the long KR-delay intervals that were utilized. Even when KR was presented "instantaneously", a delay occurred while the experimenter recorded the data and relayed it to the subject (Swinnen, Schmidt, Nicholson, & Shapiro, 1990; see Table 2 for an example of two such studies.)

Table 2

KR-Delay Interval Studies

Author	Task	Findings
McGuigan et al. (1960)	line drawing (accuracy)	- no learning effect (0 sec. vs. 20 sec. KR-delay)
Swinnen et al. (1990)	lever sliding (criterion distance)	- KR advantage for 8 sec. (relative to 0 sec.)

Swinnen and his colleagues (1990) attempted to provide truly "instantaneous" KR by having the subject read his/her score on the clock as soon as the movement was completed. The delay groups waited the prescribed time before being able to read their score. Swinnen et al. (1990) found a short KR-delay interval to produce enhanced learning compared to instantaneous feedback. Furthermore, the beneficial effects of delayed KR were noticeable in long retention periods, rather than in an immediate retention test.

The general conclusion from the various studies is that the post-KR interval must be of a minimum length to allow information processing to occur (Adams, 1971; Newell &

Walter, 1981; Salmoni et al., 1984; Schmidt, 1988), yet; it should not be too long (Salmoni et al., 1984). It is held that a post-KR delay interval that is too long may result in performance and learning decrements due to forgetting (Salmoni et al., 1984). No studies have been performed, however, where a long enough post-KR delay has been utilized to produce learning decrements. Furthermore, studies employing very short post-KR delay intervals have failed to use retention tests (see Table 3 for examples of the studies performed). In sum the optimal length for this interval remains to be specified.

Table 3

Post-KR Delay Interval Studies

Author	Task	Findings
Dees & Grindley (1951)	knob turning (criterion degree)	- increased interval, increased learning (intervals unknown; covaried with intertrial interval)
Schmidt et al. (1975)	recognition memory task	- increased interval, increased learning (10-30 sec. intervals)
	rapid timing	- no effect on learning (12-32 sec. intervals)

Interpolation

A number of experiments have been conducted that consider the effect of interpolated activities on the KR-delay interval and the post-KR delay interval (Adams, 1971; Lee & Magill, 1983; Salmoni et al., 1984; Schmidt, 1988; Shea & Upton, 1976). These activities may be either, unrelated or related to the experimental task. In general, filling the KR-delay interval with any type of activity interferes with learning. Presumably this result is because the activity blocks information processing activities. In contrast, filling the post-KR delay period decreases performance but the effects on learning are not as clear (Adams, 1971; Salmoni et al., 1984; Schmidt, 1988).

Shea and Upton (1976) found that filling the KR-delay interval with a similar movement with a different criterion interfered with performance and learning as measured by a retention test. Presumably interpolated activities interfere with the stored feedback representation resulting in forgetting of the original movement. Interpolated activities also may interfere with information processing. Lee and Magill (1983) found that interpolated activities (both a related motor activity and an unrelated non-motor activity) during the KR-delay interval decreased performance but had no effect on learning. Alternatively, Salmoni et al. (1984), argued that a delay during this interval appears to facilitate learning.

Precision of KR

Research into the effect of KR on learning has also investigated the precision of the KR statement (Salmoni et al., 1984). The information provided by KR may be divided into two broad categories - qualitative and quantitative. According to Reeve et al. (1990):

> A qualitative KR statement typically provides information about the quality of the response (i.e., whether the response is correct) but not precise information related to the outcome of the response, whereas a quantitative KR statement provides precise information about the magnitude and direction of the response error (p. 284).

Table 4 summarizes some findings regarding the influence of precision of KR.

Generally, quantitative KR facilitates performance more than qualitative (Lavery, 1964; Newell & Walter, 1981; Reeve et al., 1990; Salmoni et al., 1984; Schmidt, 1988; Trowbridge & Cason, 1932). Salmoni et al. (1984) suggest that KR should be less precise early in practice and progressively increase in detail with the proficiency of the subject. If information becomes too precise it may hinder performance thus, an optimal level must be reached (Newell & Walter, 1981; Reeve et al., 1990; Rogers, 1974; Salmoni et al., 1984; Schmidt, 1988). Further, adults are capable of receiving more precise KR than children (Salmoni et al., 1984; Schmidt, 1988).

Table 4

Precision of KR Studies

Author/Subjects	Tasks	Findings
Lavery (1964) -male (30-60 yrs)	throwing (accuracy)	- quantitative (magnitude & direction) better on retention than qualitative
Reeve et at. (1990) - undergraduates	time movement (criterion)	- quantitative better on retention than qualitative
Trowbridge & Cason (1932) - undergraduates	line drawing (criterion)	- error score better than right/wrong - no retention rest
Thomas et al. (1979) - grade 2 & 4	lever sliding (criterion)	- grade 4 - quantitative better on retention than direction - grade 2 - direction better than quantitative

As the level of precision increases, it may be necessary to initially lengthen the post-KR delay interval to allow more information processing time (Newell & Walter, 1981; Salmoni et al., 1984). In general, the literature shows that enhancing the precision of KR leads to increased learning, however; the findings are inconsistent (Reeve et al., 1990; Salmoni et al., 1984). The equivocal findings may be due to the different tasks and characteristics of the subjects involved in the various studies.

KR and Learning

According to Schmidt's (1975b) schema theory a performer develops a schema (internal representation) for a given skill as a function of practice. Following a movement attempt, the individual briefly stores information regarding: a) the initial conditions; b) the response specifications; c) the sensory consequences of the response produced; and d) the outcome of that movement. With each successive movement, the individual formulates a schema, that outlines the relations among these four sources of information (Schmidt, 1975b).

For example, the task in the present experiments involves the subject making a limb movement from the left key to the right key in a criterion time of 500 milliseconds. Thus, the initial conditions consisted of the apparatus and the subject's body position in relation to the apparatus. The response specifications would be the task and the criterion time. Once the subject has completed the movement, he/she would store the sensory consequences of the task (i.e., kinesthetic sensations). Finally, on those trials where the subject receives KR, it would be classified as movement outcome information. The subject then would use these four sources of information to formulate/update the schema for this particular task.

Information pertaining to error is needed to allow a comparison of each movement to the schema. Each time KR is given, the individual can update the schema and prepare a corrected response for the next practice trial (Ho & Shea, 1978; Rubin, 1978; Schmidt, 1975b). Continued practice allows the individual to detect his/her own errors through an error detection mechanism (Adams, 1987; Schmidt, 1975a; Schmidt, 1975b; Schmidt, in press; Swinnen et al., 1990).

Scheduling of KR

Frequency of KR

Numerous researchers have attempted to determine the optimal scheduling (i.e., amount) and delivery of KR for learning. The traditional view on KR is that more is better - the more KR that is given, the more the subject will learn (Adams, 1971; McGuigan, 1959b; Salmoni et al., 1984; Schmidt, 1975a; Taylor & Noble, 1962; Trowbridge & Cason, 1932; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Although, the amount of KR given may be varied according to many different schedules, the scheduling of KR typically is categorized in terms of absolute and relative frequency.

Absolute frequency of KR is the total number of times that KR is presented to the learner during a practice sequence (Salmoni et al., 1984; Schmidt, 1975a; Schmidt, 1988; Schmidt, in press; Winstein & Schmidt, 1990). Relative frequency refers to the percentage of trials on which KR is presented. Specifically, the absolute frequency of KR divided by the total number of practice trials (Salmoni et al., 1984; Schmidt, 1975a; Schmidt, 1988; Schmidt, in press; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). For example, if there are 50 trials, and KR is presented on half of them (e.g., 25 KR trials), the absolute frequency of KR is 25 and the relative frequency of KR is 50% (25/50) (Salmoni et al., 1984).

Earlier investigators held that there was a positive relation between absolute frequency and initial performance (Bilodeau & Bilodeau, 1958; Bilodeau, Bilodeau & Schumsky, 1959; McGuigan, 1959b; Salmoni et al., 1984; Schmidt, 1975a). Basically, any variation that increases the amount of KR during acquisition trials (i.e., practice trials) will improve performance (Winstein & Schmidt, 1990). The improvement, however, does not necessarily remain during transfer or retention tests, which are generally accepted as true tests of learning (Schmidt, 1988; Winstein & Schmidt, 1990).

An emerging viewpoint is that learning may actually be degraded by frequent feedback; a view contradictory to the traditional belief (Black, 1970; Salmoni et al., 1984;

Schmidt, 1975a; Schmidt, 1988; Schmidt, in press; Sherwood, 1988; Taylor & Noble, 1962; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). However, it must be remembered that the traditional viewpoint was based on studies that did not include transfer or retention tests. Thus, in many cases, the conclusions with regard to learning were really only performance effects.

Schmidt (in press) has outlined three research paradigms that lend support to the idea that frequent feedback degrades learning - relative frequency, trials-delay procedure, and summary-KR.

Relative Frequency

The early studies on relative frequency indicated that a higher percentage of KR was best for learning (McGuigan, 1959b; Schmidt, in press). However, these studies tended to confound absolute frequency and relative frequency of KR. For example, McGuigan (1959b) held the total number of trials constant while manipulating the relative frequency of KR, consequently varying the absolute frequencies for the experimental groups. Thus, the better performance of McGuigan's high relative frequency group may have been due to an increase in absolute frequency. This interpretation is supported by Bilodeau and Bilodeau (1958) who concluded that absolute frequency is positively related to learning. However, they too did not perform a retention test, thus, the observed results can only be regarded as a performance effect.

Other research regarding the relative frequency of KR investigated the effect of an intermittent reinforcement schedule, as opposed to the traditional continuous reinforcement schedule (Adams, 1987; Black, 1970; Schmidt, 1988; Schulz & Runquist, 1960; Taylor & Noble, 1962; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Reinforcement was similar to KR except that the individual simply received some reward for responding correctly. According to the principles of reinforcement, an individual has many responses available in his/her repertoire (Skinner, 1938). The individual will select different responses until one results in a reward which strengthens that response and increases the probability of it occurring again.

An intermittent reinforcement schedule refers to the fact that subjects will not be rewarded for every correct response (Schmidt, 1988). Extinction corresponds to withdrawal of KR (Adams, 1987). "The expectation for it was that motor performance would decline, which it did" (Adams, 1987, p. 49). According to Adams (1987), "resistance to extinction is a function of the schedule of reinforcement in acquisition" (p. 49).

Schulz and Runquist (1960) found that intermittently reinforced responses were better than continuously reinforced responses in terms of resistance to extinction.

Once the reinforcement was removed, those subjects receiving the intermittent schedule were more resistant to extinction. These findings support the idea that intermittently reinforced responses are more resistant to extinction than continuously reinforced responses (Schulz & Runquist, 1960).

The traditional viewpoint regarding KR frequency was further challenged when studies were performed with retention tests in order to assess learning. It was shown that performance during acquisition trials did improve with a higher relative frequency of KR, but, increased performance was not found on subsequent retention tests (Sherwood, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

Subsequent investigators have supported the findings of Schulz and Runquist (1960). That is, lower relative frequencies of KR were more resistant to extinction than higher relative frequencies (Black, 1970; Taylor & Noble, 1962). Furthermore, studies employing retention tests found that subjects who experienced a lower relative frequency performed better than those who received a high relative frequency which indicates that learning is actually enhanced with reduced KR frequency (Salmoni et al., 1984; Schmidt, 1988; Sherwood, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

According to Salmoni and his colleagues (1984), "with the total number of KR trials (absolute frequency) fixed, decreased relative frequency improves performance on a no-KR transfer test" (p. 363). Thus, although the groups with a higher relative frequency of KR performed better during the acquisition phase than the lower relative frequency groups, the reverse was true on the no-KR retention tests (Salmoni et al., 1984). When the total number of trials is held constant and the relative frequency is manipulated (thus, varying the absolute frequency), there is still a tendency for increased learning with a lower relative frequency of KR (Schmidt, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

Trials-Delay Procedure

A number of studies have investigated the issue of feedback frequency through the trials-delay procedure. With this procedure additional responses occur between a given trial and its KR (Bilodeau, 1956; Bilodeau, 1966; Bilodeau, 1969; Lavery, 1962; Lavery, 1964; Salmoni et al., 1984; Schmidt, 1975a). The trials-delay procedure was utilized as early as 1935 by Lorge and Thorndike when they investigated the influence of delay in the "after-effect of a connection" (pp. 186). Utilizing a ball-throwing accuracy task, Lorge and Thorndike manipulated the time that KR was delayed. One of their conditions involved delaying KR until after the next throw, basically a 1-trial delay. The results indicated that there was no gain in accuracy for the 1-trial delay condition relative to immediate KR.

Bilodeau (1956) reinvestigated the effects of KR delay on performance in two experiments employing a linear positioning task. The first experiment included four groups: 0, 1, 2, and 3-trials delay. Each group received 16 KR trials resulting in 17, 18, 19, and 20 total trials, respectively. In the second experiment, Bilodeau (1956) included three groups, 0, 2, and 5-trials delay. Again, the number of KR trials was held constant (30 trials) while the number of responses (31, 33, and 36, respectively) was confounded. After the acquisition trials in both experiments (including a one minute rest) the subjects were given a 4-trials test under 0-trial delay conditions. Bilodeau found that decrements in acquisition performance were a function of the number of trials by which KR was delayed. However, the retention test indicated that there were no significant differences among the experimental groups.

Lavery and Suddon (1962) also investigated the trials-delay procedure in two experiments. The first experiment involved three simple instruments - manual lever, force gauge, and dynamometer. The manual lever task involved moving a lever a criterion distance. Both the force gauge and the dynamometer tasks required the subject to exert a criterion force; the difference was that the latter task was designed to allow the subjects to exert forces substantially greater than normal. Three trials-delay conditions (0-, 2-, and 5-trials delay) were employed. Each subject performed each task under each condition, with the order of the tasks and conditions varying. The no-KR retention tests favoured the 5-trials delay condition.

The second Lavery and Suddon (1962) experiment was designed "to determine the effect of the level of accuracy reached during acquisition on the level maintained during retention" (p. 234). Using the results from their first experiment the investigators postulated that a 0-trial delay group and a 5-trials delay group could be trained to the same level of accuracy at the conclusion of the acquisition phase if the total number of trials for each group was different. Specifically, the 5-trials delay group must be given more acquisition trials than the 0-trial delay group in order to reach the same level of accuracy at the end of the acquisition phase. The results of this experiment indicated that the 5-trials delay group retained their level of accuracy better than the 0-trial delay group. In other words, the 0-trial delay group demonstrated a greater decrease in accuracy during retention, as compared to their final acquisition accuracy level, than the 5-trials delay group. Lavery and Suddon (1962) concluded that "The data lend support to the generalization that a method of KR which enhances the cues inherent in the task yields better retention" (p. 235).

Lavery (1964) utilized a throwing accuracy task to investigate the effects of 0- and 1-trial delay. Lavery found that acquisition occurred at a slower rate for the trials-delay groups as compared to a 0-trial delay group. Retention, however, improved with a 1-trial delay as compared to a 0-trial delay. According to Bilodeau (1966), the retention effect in the Lavery studies favours the trials-delay procedure over immediate KR.

In their extensive review, Salmoni et al., (1984) stated that the emerging view on the trials-delay procedure is that, although it has a negative effect on performance during the acquisition trials, the procedure has a positive effect on learning. Essentially, in studies that have incorporated retention tests it has been concluded that trials-delay groups demonstrate superior performance during these tests (Lavery, 1964; Lavery & Suddon, 1962; Salmoni et al., 1984).

Summary-KR

Recently, researchers have investigated a procedure similar to the trials-delay procedure, termed summary-KR. The summary-KR procedure involves providing KR only after the completion of the last trial in a set (e.g., showing a graph at the end indicating the results for all trials in that set) (Schmidt, in press; Schmidt et al., 1989). According to Schmidt (in press) "Summary feedback is somewhat like reduced relative frequency, at least in terms of the learner's capability to use information after a trial" (Schmidt, in press, p. 5).

The summary-KR technique is not new. Lavery (1962) found that a 20-trial summary was detrimental to performance during the acquisition stage but beneficial to performance during a no-KR retention test. According to Lavery, "any training method that encourages the subject to perceive and interpret the cues inherent in the task, will favor retention" (p. 309).

Schmidt et al. (1989) systematically studied the effect of summary lengths on performance and learning. The four summary length variations that were utilized were a 1-, 5-, 10-, and 15-trial summary. Knowledge of results was presented via a graph indicating the subject's constant error. The results indicated that summary-KR was detrimental for performance during acquisition, but, the reverse was true for performance on retention tests. Subjects who experienced the longest summary conditions produced the greatest number of errors during the 90 acquisition trials while demonstrating the most accurate movements during the 25 trial no-KR retention test. Schmidt (1989) pointed out that the beneficial effects of summary-KR were not evident on the immediate retention test (i.e., 10 minutes after the acquisition trials), but became apparent on a delayed test (i.e., 2 days later).

Theoretical Interpretations

Functions of KR

In order to determine how KR operates to improve performance and learning it is important to consider the various functions of KR. The main functions of KR are to provide: 1) guidance; 2) motivation; and 3) association between the movement outcome and the goal (Adams, 1987; Salmoni et al., 1984; Schmidt, 1988). Presenting KR to the learner provides information that may guide the person toward the correct response (Adams, 1987; Goldstein & Rittenhouse, 1954; Salmoni et al., 1984; Schmidt, 1988; Schmidt, in press; Schmidt et al., 1989; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Such information also may motivate the subject to continue concentrating on the task at hand, although, this function of KR apparently does not have a strong effect on performance when the individual has to learn a difficult skill (Adams, 1987; Goldstein & Rittenhouse, 1954; Salmoni et al., 1984; Schmidt, 1988; Winstein & Schmidt, 1990). Finally, KR helps the learner to develop a relation between the actual outcome and the target goal (Salmoni et al., 1984; Schmidt, 1988).

Of the various functions of KR there is much controversy surrounding the guidance function. Guiding the subject toward the correct response is beneficial for performance (Adams, 1971; Salmoni et al., 1984; Schmidt, 1988; Schmidt et al., 1989; Winstein & Schmidt, 1990; Wulf &

Schmidt, 1989). However, studies incorporating retention tests have indicated that providing too much guidance may be detrimental to learning. Researchers have put forth at least two hypotheses that may account for the degraded learning associated with frequent feedback; the guidance hypothesis and the over-correction response (Annett, 1959; Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1987; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

Guidance Hypothesis. The presentation of KR may establish a response pattern distinct from the one being sought as subjects rely too much on the external information presented (Goldstein & Rittenhouse, 1954; Schmidt, in press; Swinnen et al., 1990). This over-reliance on KR has been captured in terms of a guidance hypothesis. The guidance hypothesis states that a reliance on KR can develop when it is given too often, thereby interfering in the learning of task-relevant cues (Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1989; Swinnen et al., 1990). This interference by KR prevents the subject from developing the error detection mechanism that is so important for long-term performance (Schmidt, in press; Swinnen et al., 1990). When KR is subsequently removed in a retention test, the subject is unable to process relevant cues in the task because there is no information substitute for the withdrawn KR (Salmoni et al., 1984; Schmidt et al., 1989;

Swinnen et al., 1990; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). The interference of task relevant cues was a concept understood by Lavery as early as 1962. As mentioned earlier, Lavery (1962) stated that it was important for the individual to learn the cues inherent in the task if retention was to occur.

Recent results support the idea that the guidance function of KR is merely a temporary effect. Groups of subjects who receive a higher percentage of relative KR show a higher level of performance during acquisition trials but a lower level of performance on a retention test compared to subjects who receive a lower percentage of KR trials. This evidence indicates that a smaller relative KR level serves to enhance learning (Salmoni et al., 1984; Schmidt, 1988; Sherwood, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Lavery (1962) recognized the potential negative effect of KR and stated that "minimizing extrinsic feedback maximizes intrinsic feedback and better retention result" (p. 308). In other words, giving less KR (extrinsic feedback) forces the individual to rely on his/her own error detection mechanism (intrinsic feedback) to detect and correct error. This reliance on the error detection mechanism, in turn, leads to superior retention.

Basically, in Schmidt's terms, reducing the guidance function of KR benefits learning. Initially, some KR must be present to guide the person towards the correct response.

However, in order to maximize learning, or long-term retention, a smaller percentage of KR is most effective (Salmoni et al., 1984; Sherwood, 1988). It appears that the condition which makes learning difficult during the acquisition trials (i.e., reduced frequency of KR) is best for learning (Wulf & Schmidt, 1989). Schmidt (1988) argues that a reduced relative frequency is better because it allows the learner to pay attention to relevant cues in the task thereby enhancing learning.

Over-correction. Another possibility is that frequent KR encourages the subject to frequently change his/her behavior in an attempt to eliminate errors. Although some of these corrections would be necessary to reduce large errors, others would simply be an attempt to eliminate small errors due to inherent "noise" processes associated with neuromuscular variability. These constant short-term corrections prevent the subject from acquiring response stability that is crucial for retention performance (Schmidt, in press; Swinnen et al., 1990).

Schmidt (in press) has outlined another explanation why frequent feedback degrades learning. In short, receiving feedback becomes an integral part of the task when presented frequently. As a consequence, problems arise when the learner has to perform without it. However, such a hypothesis has been discredited by relative frequency studies that use a 100% KR retention test. For the group who performed under the 100% KR condition during the acquisition session, the retention condition was exactly the same (i.e., the task included KR). Yet results indicated that the lower relative frequency groups out performed the 100% KR group despite the fact that their acquisition conditions differed from their retention condition.

Schmidt (in press) feels that each of these hypotheses "are not mutually exclusive, and two or more of these negative processes could be operating at the same time" (Schmidt, in press, p. 15). In other words, these negative processes may contribute to the detrimental performance in retention, but, are not able to stand alone as explanations.

Faded Feedback

In applying the notions of the guidance hypothesis to relative frequency experiments, several researchers began utilizing a faded feedback schedule. This procedure entails providing more KR in the initial acquisition trials, subsequently reducing the frequency of KR through the practice session (Ho & Shea, 1978; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). In most simple tasks, performance during the acquisition trials reaches an asymptote after only minimal practice (Ho & Shea, 1978). Furthermore, information regarding errors is especially important early in practice because it guides the learner toward the correct response (Winstein & Schmidt, 1990).

Ho & Shea (1978) utilized a faded feedback schedule in which KR was provided on each of the first 20 trials and then after every 6th trial. The task involved 50 trials on a linear positioning apparatus. Two additional experimental groups were employed that received KR on every trial for 25 or 50 trials. At the conclusion of the acquisition phase, there were no significant differences between the groups. However, following a no-KR retention test, the group that experienced the faded feedback schedule demonstrated the least amount of error (Ho & Shea, 1978).

Wulf & Schmidt (1989) also employed the faded feedback schedule to investigate the effects of a reduced relative frequency of KR. Using a task that involved performing a movement sequence in a criterion time, they employed relative frequencies of 100% and 67%. Across the acquisition session KR for the faded feedback group was gradually reduced from 83% to 50%, for an average of 67%. The immediate no-KR retention test revealed no significant differences between the two groups. However, results of the delayed retention test indicated that the 67% group performed more accurately (Wulf & Schmidt, 1989).

Recently, Winstein & Schmidt (1990) performed two experiments employing the faded feedback schedule with a linear positioning task. In the first experiment, a 50%-faded relative frequency was employed. This group started at 100% KR with a gradual reduction in the percentage of KR across trial blocks as the acquisition phase progressed yielding an average relative frequency of 50%. An immediate no-KR retention test demonstrated no significant differences between the 50%-faded group and a group that received 100% KR. A delayed retention test, however, indicated that the 50% relative frequency group performed better than the 100% group (Winstein & Schmidt, 1990).

The second experiment performed by Winstein and Schmidt (1990) utilized the same groups but with a delayed KR retention test. The results from this experiment were similar to the first; the 50% relative frequency group displayed fewer errors on the retention test (Winstein & Schmidt, 1990).

Purpose of the Present Study

The current position is that a reduced amount of KR is best for motor skill acquisition. In support of this notion several researchers have proposed a guidance hypothesis to explain the beneficial effect of a reduced frequency of KR on learning (Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1989; Swinnen et al., 1990). Studies investigating relative frequency (Black, 1970; Taylor & Noble, 1962; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989), the trials-delay procedure (Bilodeau, 1956; Lavery, 1964; Lavery & Suddon, 1962), and summary-KR (Lavery, 1962; Schmidt et al., 1989) have generally been interpreted as supportive of the guidance hypothesis. All of these experiments, however, have incorporated lengthy acquisition periods.

According to the guidance hypothesis, the guidance function of KR increases as the acquisition phase proceeds; with more trials, more KR is provided, thus, allowing for more guidance. As a consequence, a simple test of the guidance hypothesis would be to utilize a very brief acquisition phase. Because KR is important in guiding the learner toward the correct response early in practice, reducing the relative frequency of KR over a short practice period might be detrimental to learning rather than beneficial, as with longer acquisition phases.

The three research paradigms outlined by Schmidt (in press) were each investigated to test the generalizability of the guidance hypothesis to a brief acquisition phase. The first experiment investigated four conditions of relative KR frequency, over a 5-trial acquisition phase. Experiment 2 utilized three summary-KR lengths over a 15-trials acquisition phase. Finally, the trials-delay procedure was employed in Experiment 3. Five KR statements were presented during the acquisition phase with delays of 0, 1, 3, and 5 trials.

EXPERIMENT 1

The recent view regarding relative frequency of KR is that a lower relative frequency results in a higher rate of learning compared to a higher relative frequency (Salmoni et al., 1984; Schmidt, 1988; Sherwood, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). The initial research on relative frequency found that a higher percentage of KR was best. However, those studies failed to employ retention tests (McGuigan, 1959b; Schmidt, in press). Thus, the conclusions of the early investigations were based exclusively on acquisition trials that assess performance effects only, not learning effects.

In the 1960's, investigators began to incorporate retention tests to determine the effect of relative frequency of KR on learning (Black, 1970; Schulz & Runquist, 1960; Taylor & Noble, 1962). The retention tests revealed that the trends indicated during the acquisition phase reversed on retention tests. That is, subjects who experienced a lower relative frequency of KR actually performed better during the retention phase despite their poorer performance on the acquisition trials (Salmoni et al., 1984; Schmidt, 1988; Sherwood, 1988; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989).

To date, most studies have incorporated rather long acquisition phases. It is during such acquisition phases that the guidance effect of KR may actually become detrimental to learning. The guidance hypothesis proposes that the individual develops a reliance on KR when it is presented too often. This dependency on KR interferes with the learning of task-relevant cues, thus, reducing the rate of learning (Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1989; Swinnen et al., 1990). It is likely that such dependency is related to the length of the acquisition phase.

The guidance hypothesis predicts that feedback is most beneficial early in practice, when the learner needs to be guided toward the correct response (Winstein & Schmidt, 1990). Studies employing a faded feedback schedule have supported this prediction (Ho & Shea, 1978; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989). Thus, with a short acquisition phase, which is comparable to the initial trials of lengthier phases, a higher percentage of KR should be best for learning. The present experiment was an attempt to determine if a relatively short acquisition phase, and subsequently a very low amount of KR, would contradict the previously proven benefits of a reduced relative frequency.

Method

Subjects

The subjects were 32 male and 16 female undergraduate students enroled in the School of Physical Education and

Athletics at Lakehead University. Participation in the experiment was voluntary and the task was novel to all participants.

Apparatus

The apparatus consisted of two telegraph keys, mounted on a board 50 centimetres apart. Movement time (MT) was measured using a Hunter Klockcounter millisecond timer (Model 220C). The clock began timing when the left key was released and ended when the right key was depressed. A barrier prevented the subjects from viewing the clock (see Figure 3).

Procedures

Subjects were randomly assigned to one of four relative frequency groups: a) 100% relative frequency (KR on every trial); b) 60% relative frequency (KR on trials 1, 3, and 5); c) 20%-1 relative frequency (KR on the first trial); and d) 20%-5 relative frequency (KR on the last trial) (see Figure 2). Each group performed five acquisition trials. Prior to beginning the experiment proper, the subjects received an instruction sheet that explained the task and that they would periodically receive KR during the experiment.

The task required the subjects to perform a limb movement from the left key to the right key in 500 ms.

Group 1 - 100% relative frequency

```
R-1 ─┬── R-2 ─┬── R-3 ─┬── R-4 ─┬── R-5 ─┐
   KR-1     KR-2     KR-3     KR-4     KR-5
```

Group 2 - 60% relative frequency

```
R-1 ─┬── R-2 ──── R-3 ─┬── R-4 ──── R-5 ─┐
   KR-1              KR-3              KR-5
```

Group 3 - 20% relative frequency

```
R-1 ─┬── R-2 ──── R-3 ──── R-4 ──── R-5
   KR-1
```

Group 4 - 20% relative frequency

```
R-1 ──── R-2 ──── R-3 ──── R-4 ──── R-5 ─┐
                                       KR-5
```

Figure 2. Relative frequency experimental groups.

Subjects also were required to perform two additional tasks (the retention tests), one ten minutes later and the other two days later. Subjects were not told the specific nature of these tests. After reading the instruction sheet, subjects signed a consent form. The experimenter answered any questions that the subject had.

The subjects sat with their sagittal mid-line perpendicular to the mid-line of the apparatus. A black partition, 36 cm high, prevented the subjects from viewing the timer. A review of the task was verbally explained to the subjects. A tape recorder cued the subjects when to start each movement. To begin, subjects heard the command "READY", at which time they used their right hand to depress the left key (the home key). Next, the command "ESTIMATE" cued the subject to move his/her right hand to the right key (the target key). As soon as the subject's hand moved off the home switch the timer began. This was not a reaction time task. Subjects were told that they were free to move off the home key anytime after the cue. The subjects goal was to perform this movement in what they estimated to be 500 "units". After depressing the target switch (thereby stopping the timer), subjects sat with their hand on their lap until they heard the command "READY" again. The subjects were required to perform 5 trials and periodically received KR about their performance.

Figure 3. Experimental apparatus.

In order to give the subjects a general idea of the criterion task, they performed one practice trial prior to beginning the 5 experimental trials. The experimenter verbally gave the commands for the practice trial. An indication of the subject's performance was given according to the following: a) if they were $\pm$100 units off the criterion time, they were told that they were "a little fast" or "a little slow"; b) if they were $\pm$200 units off, they were told that they were "too fast" or "too slow"; c) if they were $\pm$300 units (or more) off, were told they were "much too fast" or "much too slow".

Following the practice trial the experimenter began the experiment proper. The intertrial interval for each trial was 15 seconds. On the trials that required KR, the KR delay was as minimal and consistent as possible. Upon completion of the acquisition trials, subjects left the test room for ten minutes before returning to perform another task. After the time had elapsed, subjects were instructed that they should attempt to perform the same action as they had just done, except that they would not receive any KR. Subjects were reminded that they were trying to achieve the movement in the criterion time of 500 units.

Following the first retention test, subjects were asked to return in two days to perform another task. On this delayed no-KR retention test, subjects were reminded again of the task prior to completing the five trials. At the completion of the testing subjects were debriefed.

Design and Analysis

The performance scores obtained from the acquisition phase and the two retention tests were grouped into three blocks of five trials for the purpose of analyzing the data. The practice trial was not considered. Measures of absolute constant error (ACE) and variable error (VE) were computed for each subject (see Appendix A for a worked example of error measures). These dependent measures were each submitted to a Groups x Blocks analysis of variance with repeated measures on the second factor to determine the performance and learning effects for each group. Follow-up analyses were conducted using the Neuman-Keul's procedure.

Results

Variable Error

Although there was an overall tendency for the 60% group to perform with the most consistency, the groups did not differ significantly, F (3,44) = 1.44, p = .24. The means were 82, 65, 118, and 92 for the 100%, 60%, 20%-1, and 20%-5 relative frequency groups, respectively.

Analysis of the VE scores did reveal a significant block effect, F (2, 88) = 13.48, $p < .00005$. The means (143, 64, and 61) indicate that, overall, the groups became more consistent across the acquisition block and the two retention blocks. A post-hoc comparison indicated that the acquisition phase differed significantly from both the immediate retention test and the delayed retention test in terms of consistency. The two retention tests, however, did not differ significantly from each other.

Finally, the Groups x Blocks interaction was not significant, $\underline{F}$ (6, 88) = 1.14, $\underline{p}$ = .34, although the means indicated a trend towards an effect. The performance of the 60% group on the retention tests was considerably superior to that of the other groups. The mean scores for each group across the three blocks are presented in Table 5.

Table 5

Variable Error Means (in ms)

GROUP	ACQUISITION	IMMEDIATE RET.	DELAYED RET.
100%	116	60	69
60%	111	45	30
20%-1	217	74	63
20%-5	127	77	72

Absolute Constant Error

Analysis of the (ACE) scores did not reveal a significant main effect of group, $\underline{F}$ (3, 44) = 2.50, $\underline{p}$ < .07, however, a trend toward an effect was noticed. As indicated by the means, the groups that were given the greatest frequency of KR were generally more accurate (100% = 100 and

60% = 52 versus 20%-1 = 238 and 20%-5 = 184). Similar to the trends noticed for VE, the 60% group performed the best. However, a main effect of block was not observed for ACE, $\underline{F}$ (2,88) = 1.35, $\underline{p}$ = .27. As well, the Groups x Blocks interaction did not reach statistical significance, $\underline{F}$ (6, 88) = .45, $\underline{p}$ = .86. Refer to Table 6 for a presentation of the cell means for ACE during the acquisition phase and the two retention tests.

Table 6

Absolute Constant Error Means (in ms)

GROUP	ACQUISITION	IMMEDIATE RET.	DELAYED RET.
100%	94	83	122
60%	61	58	37
20%-1	331	171	213
20%-5	262	140	151

Discussion

For both acquisition and retention the results demonstrated a trend whereby the group receiving 60% KR was superior, both in terms of accuracy and consistency. The groups that performed under the lowest relative frequency of KR (20% conditions) generally displayed the greatest amount of error. Thus, the benefits of reducing the relative frequency of KR have limits within the context of brief acquisition phases. For the two 20% conditions it appears that giving only one KR statement during the five acquisition trials was not sufficient to guide an individual toward the correct response.

The trends noticed during the analysis of VE and ACE could be interpreted as providing support for the guidance hypothesis. Relative to 100% KR, presenting a reduced frequency of KR (60%) was beneficial to learning. According to Ho and Shea (1978), performance of a simple task reaches an asymptote after only minimal practice. However, it appears from the results of this experiment that five trials were not enough to allow the trends in the present experiment to attain statistical significance.

According to Winstein and Schmidt (1990), the guidance hypothesis predicts that information regarding error should be most beneficial early in practice as it is needed to guide the person toward the correct response. On the other hand, the guidance hypothesis states that frequent feedback degrades learning because a dependency on KR develops that interferes in the learning of task relevant cues (Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1989; Swinnen et al., 1990). Recently, these ideas have been combined in relative frequency studies employing a "faded" feedback schedule (e.g., Wulf & Schmidt, 1989). In a faded feedback experiment, feedback is provided at a very high percentage in the initial trials and then slowly faded, resulting in a low average relative frequency of KR. Both Wulf and Schmidt (1989) and Winstein and Schmidt (1990) found that faded feedback groups displayed superior learning compared to immediate-KR groups. The faded schedule experiments suggest that both the previous statements are true. Error information is important early in practice but an over-all reduced frequency of feedback is best for learning.

The brief acquisition phase used here can be compared to the initial trials of the longer acquisition periods. During the initial trials of the extended acquisition phases, the faded procedure would recommend 100% KR. Yet, even for the brief acquisition phase tested in this experiment the 60% group tended toward greater learning than 100% KR group. If further studies of this type can use greater subject numbers and obtain statistically significant results it appears that the logic behind the faded feedback procedure may have to be rethought.

EXPERIMENT 2

The investigation into the effects of a reduced amount of KR has led to the summary-KR procedure. This procedure was of interest to the investigation of the guidance hypothesis as it supported the idea that conditions that enhance attention to task relevant cues benefit learning. As early as 1962, Lavery had studied the effect of summary-KR. Lavery's research indicated that this procedure was beneficial to learning despite the detrimental effects shown during the acquisition phase.

Recently, Schmidt and his colleagues (1989) examined the effect of various summary lengths on learning a lever sliding task. They concluded that over a 90-trial acquisition phase the experimental group receiving the longest summary length (15-trial summary) performed the best on the no-KR retention test. Interestingly, that group displayed the <u>greatest</u> error during the acquisition phase.

Recently, the effects of summary-KR have been investigated in our laboratory. Marsh (1990) examined the effects of three summary lengths on learning, during a 15-trial acquisition phase. The summary conditions included a 1-trial summary (immediate KR), a 5-trial summary, and a 15-trial summary. During the acquisition phase the 1-trial summary group displayed the least amount of errors while the 15-trial summary group performed the worst. During the immediate no-KR retention test (10 minutes later), the three groups converged to the same performance level. During the delayed no-KR retention test (2 days later) the 15-trial summary group performed the best despite producing the greatest number of errors during the acquisition phase. This was particularly interesting when one considers that the group received only a single KR statement.

The interesting question that emerged was, whether the critical factor was the length of the summary (e.g., the amount of KR summarized) or simply that a single KR statement was presented. The following experiment attempted to answer this question by varying the amount of KR summarized in a single KR statement.

Method

Subjects

The subjects were 20 male and 16 female first year undergraduate students enroled in the School of Physical Education and Athletics at Lakehead University. Participation in the experiment was voluntary and subjects had not participated in the previous experiment.

Apparatus

The apparatus was the same as in Experiment 1.

Procedures

Subjects were randomly assigned to one of three groups: a) 1-trial summary KR (trial 15); b) 5-trial summary (trials 11-15); and c) 15-trial summary KR (15 trials).

Group 1 - 1- trial summary KR (trial 15)

R-1 ———————————————————— R-15 ┬ KR

Group 2 - 5-trial summary KR (trials 11-15)

R-1 ——————————— R-11 R-12 R-13 R-14 R-15 ┬ KR

Group 3 - 15-trial summary KR (trials 1-15)

R-1-R-2-R-3-R-4-R-5-R-6-R-7-R-8-R-9-R-10-R-11-R-12-R-13-R-14-R-15 KR

Figure 4. Summary-KR experimental groups.

For all groups, KR was presented after the last trial of the acquisition phase. Prior to beginning the experiment, the subjects received an instruction sheet that explained the task and were told that they would periodically receive KR during the experiment.

The task required the subjects to perform the same limb movement described in Experiment 1. The general protocol was similar to Experiment 1 except with respect to the number of trials and the actual group conditions. Subjects received KR about their performance via a summary graph.

The graph recorded the movement time (expressed as units) for certain trials, depending upon which group the subject was in. A line was drawn horizontally to indicate the criterion time (500 units). The words fast and slow were printed beside the y-axis to clearly indicate the time below 500 units and above 500 units, respectively. The x-axis marked the 15 trials. The KR trials were indicated on the graph by a dot placed at the movement time. The dots were subsequently joined by straight lines to indicate the subject's progress. It was the responsibility of each subject to interpret the information contained on the graph.

The intertrial interval for each trial was ten seconds, except for trial 15 which was 15 seconds. The extra five seconds was allotted for the presentation of the graph. The KR delay on the last trial was approximately six seconds. Following the 15 acquisition trials, subjects performed two retention tests (10 minutes later and 2 days later).

Design and Analysis

The performance scores obtained from the acquisition phase and the two retention tests were grouped into five blocks of five trials for the purpose of analyzing the data. Measures of absolute constant error (ACE) and variable error (VE) were computed for each subject. These dependent measures were each submitted to Groups x Blocks analyses of variance with repeated measures on the second factor to determine the performance and learning effects for each group. Acquisition effects were analyzed using the results from the three acquisition blocks (blocks 1, 2, and 3). The last acquisition block (block 3) and the two retention blocks (blocks 4 and 5) were analyzed to determine learning effects. Follow-up analyses were conducted using the Neuman-Keul's procedure.

Results

Variable Error

Acquisition Phase. The acquisition phase showed no significant group effect for VE, F (2, 33) = 2.26, $p < .12$. Further, the main effect of block was not significant, F (2, 66) = 1.67, $p < .19$. Finally, the Groups x Blocks interaction for VE was not significant, F (4, 66) = 2.02, $p < .10$. These findings were somewhat expected, as the groups did not receive any KR until the completion of the acquisition phase. Table 7 presents the means for each group.

Retention Phase. Analysis of the retention phase included the last acquisition block and the two retention tests. Analysis of VE failed to reveal a significant main effect of group, F (2, 33) = .01, $p < .98$, with means of 79, 80, and 82 for the 15-trial summary, 5-trial summary, and 1-trial summary groups, respectively. Similarly, a significant block effect was not found, F (2, 66) = .37, $p < .70$, with means of 87, 77, and 77, respectively. However, there was a significant Groups x Blocks interaction for VE, F (4, 66) = 2.70, $p < .04$. Post-hoc tests revealed that there was a significant difference between the 5-trial summary group and the 1-trial summary group in terms of consistency across the retention phase. The 5-trial summary group displayed means of 113, 63, and 63 on the last acquisition block, the immediate retention test and the delayed retention test respectively. Across the same blocks the 1-trial summary group displayed means of 56, 99, and 91. The post-hoc test failed to reveal a significant difference between the 15-trial summary group and the 5-trial summary group. Significant differences were not found between the 15-trial summary group and the 1-trial summary group (see Table 7).

Table 7

Variable Error Means (in ms)

GROUP	ACQ. 1	ACQ. 2	ACQ. 3	IMM. RET.	DEL.RET.
15-trial	166	87	91	68	78
5-trial	74	76	113	63	63
1-trial	69	52	56	99	91

Absolute Constant Error

Acquisition Phase. The ACE scores for the acquisition phase revealed a main effect for group, F (2, 33) = 3.81, $p < .03$. A post-hoc comparison of the groups revealed that there was a significant performance difference between the 15-trial summary group (M = 320) and the 1-trial summary group (M = 110). However, the 15-trial summary and the 5-trial summary (M = 171) groups did not differ significantly from each other in terms of accuracy; nor did the 5-trial summary and the 1-trial summary differ.

There also was a significant main effect for block, F (2, 66) = 6.80, $p < .002$ for ACE (Ms = 162, 206, and 233 for the 3 blocks respectively). This reflects the fact that in the absence of KR, accuracy deteriorated over the acquisition phase. Post-hoc tests indicated that the first block of acquisition trials differed significantly from both the second and third blocks which were not different from each other.

Finally, the ACE analysis failed to yield a Group x Block interaction for the acquisition phase, F (4, 66) = .67, $p < .62$. Table 8 presents the cell means from the analysis of ACE.

Retention Phase. The ACE analysis for the final acquisition block and two retention tests revealed no significant main effect of group, F (2, 33) = 3.26, $p < .05$.

There was a significant main effect for block, F (2, 66) = 15.46, $p < .00003$. Subjects clearly benefited on the retention tests from have received KR. A post-hoc comparison of the blocks found that the last acquisition block differed significantly from each of the retention tests which were not different from each other. The means were 233, 84, and 118, respectively.

A Groups x Blocks interaction was also observed, F (4, 66) = 2.50, $p < .05$. The interaction reflects the fact that accuracy of the 5-trial summary and accuracy of the 1-trial summary group was maintained across the retention blocks but not maintained for the 15-trial summary group. Furthermore, the post-hoc analysis indicated that the 15-trial summary group differed significantly from the 1-trial summary group across the retention phase.

Table 8

Absolute Constant Error Means (in ms)

GROUP	ACQ. 1	ACQ. 2	ACQ. 3	IMM. RET.	DEL.RET.
15-trial	274	331	356	110	194
5-trial	127	164	222	65	72
1-trial	87	124	119	78	87

Discussion

As was previously mentioned, this experiment was a follow-up to Marsh (1990) in which the length of KR summaries was varied over a brief acquisition phase. Utilizing summaries of 1, 5, and 15 trials over a 15 trial acquisition phase, Marsh (1990) found that the 15-trial summary group demonstrated the same level of performance on the immediate retention test as the other two, shorter summary lengths. Thus, even with brief acquisition phases longer summary lengths did not degrade learning. Marsh's results were particularly interesting when you consider that the 15-trials summary group essentially received only one KR statement.

Given that a single KR statement can be so effective, Experiment 2 was conducted in an attempt to determine if it is the amount of information contained within that single statement that is important. According to the guidance hypothesis it is the frequency of KR presentation that effects learning. However, recall that early in learning the guidance hypothesis would predict that more KR is better (Winstein & Schmidt, 1990). Thus, in studies utilizing a brief acquisition phase, as in Marsh (1990), one would expect that the group who received "more" KR would exhibit a greater learning effect. This, of course, was not the case in the Marsh study. Thus, it may be that the dependency on KR that the guidance hypothesis infers is due to something other than the frequency with which feedback is presented.

From the results of the present experiment, it now appears that the amount of information contained within that statement does influence learning. The 1- and 5-trials summary groups displayed superior performance in terms of accuracy compared to the 15-trial summary group despite receiving information about fewer trials. This finding is similar to Schmidt's finding that the group who received KR more often produced twice as much error as the group who had the longest summary length (1-trial summary vs. 15-trials summary) (Schmidt et al., 1989). Even within one KR statement, a reduced percentage of feedback is beneficial to learning.

The Groups x Blocks interaction indicates that there were significant differences in terms of the amount of information presented during one KR statement. The groups who received a reduced percentage of KR within the one statement maintained their level of accuracy across the retention trials. The 15-trial summary group, on the other hand, was unable to maintain the level of accuracy on the final retention test. Thus, it appears that providing only one KR statement that contains information about a reduced percentage of KR can benefit learning.

EXPERIMENT 3

One of the three research paradigms discussed by Schmidt (in press) involved separating KR from its respective trial by one or more intervening trials. This trials-delay procedure, was discussed as early as 1935 by Lorge and Thorndike. However, using a 1-trial delay, they concluded that the delay resulted in no gain in accuracy for a ball-throwing task (Lorge and Thorndike, 1935). The trials-delay procedure was investigated in greater detail in the late 1950's by Bilodeau (Bilodeau, 1956). In two separate studies, he considered delays of 0, 1, 2, 3, and 5 trials. Bilodeau concluded that there was an inverse relation between length of delay and performance; as the length of trials-delay increased, performance decreased.

Lavery and Suddon (1962) performed two experiments to determine the effect of length of trials-delay on accuracy. The conditions included 0-, 2-, and 5-trials delay. The results indicated that the longest trials-delay condition exhibited the most accuracy during the no-KR retention test. Lavery continued his investigation again in 1964, employing 0-, 1-, and 5-trials delay conditions. Again, the 5-trials delay group displayed the greatest amount of learning as demonstrated by the retention test. The results of Lavery and his colleagues are consistent with those of the previous investigators (e.g., Lorge & Thorndike and Bilodeau &

Bilodeau).

Each of the studies mentioned above have employed relatively lengthy acquisition phases. Bilodeau (1956) employed the least number of trials (17) and provided 16 KR statements. Lavery and Suddon (1962), on the other hand, required subjects to perform 105 acquisition trials for each of three tasks. Thus, the absolute frequency of KR in these studies could have led to the over-reliance on KR, predicted by the guidance hypothesis.

Method

Subjects

The subjects were 41 female and 19 male undergraduate students enroled in either the School of Physical Education and Athletics or the Department of Psychology at Lakehead University. Participation in the experiment was voluntary and subjects had not participated in the previous experiments.

Apparatus

See Experiment 1 for a description of the apparatus.

Procedures

Subjects were randomly assigned to one of four groups: a) 0-trial delay (essentially immediate KR); b) 1-trial delay; c) 3-trials delay; and d) 5-trials-delay. Because each group received 5 KR trials, the total number of acquisition trials for each group was 5, 6, 8, and 10, respectively. Prior to beginning the experiment, the subjects received an instruction sheet that explained the task and were told that they would periodically receive KR during the experiment.

The task was the same limb movement described in the previous experiments and the same general protocol was followed. The exceptions of course, were the number of trials given, and the amount and scheduling of KR presented to the subject.

The intertrial interval for each trial was 15 seconds. During the trials, in which KR was not presented, subjects sat quietly until they heard the command "READY" again.

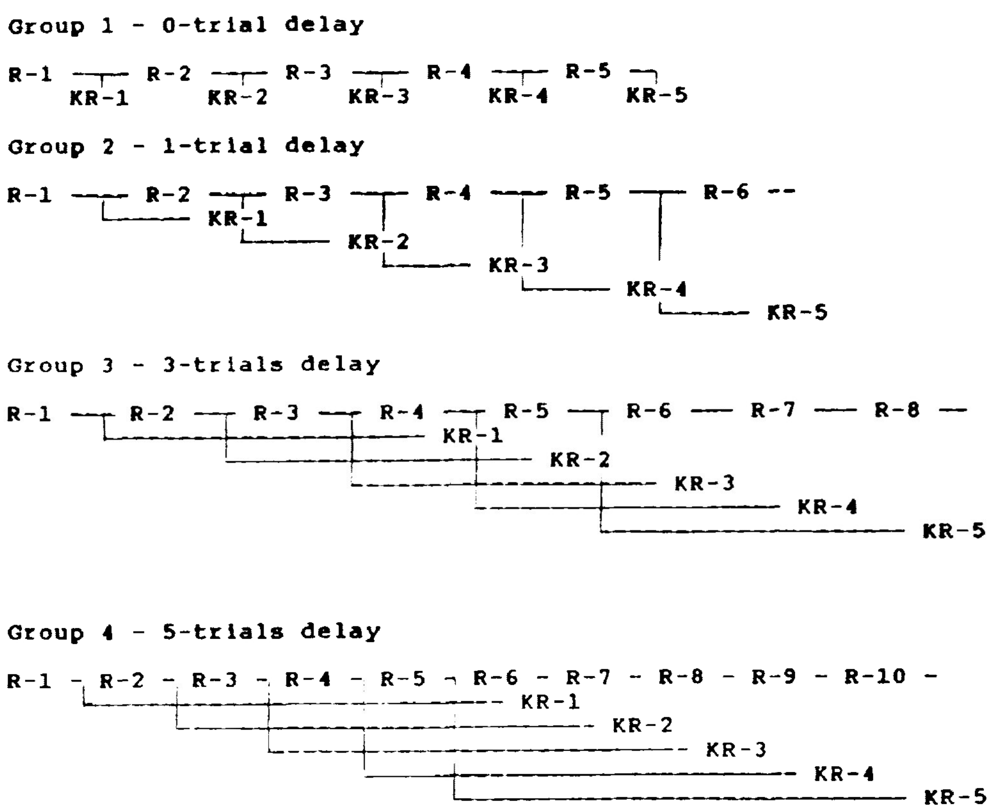

Figure 5. Trials-delay experimental groups.

Design and Analysis

For the purpose of analyzing the data only the KR trials (e.g., the trials which were followed by KR) were considered. The performance scores obtained from the acquisition phase and the two retention tests were grouped into three blocks of five trials. Measures of ACE and VE were computed for each subject. A Groups x Blocks analysis of variance with repeated measures on the second factor was performed to determine the performance and learning effects for each group. The Neuman-Keul's procedure was performed to determine post-hoc differences.

Results

Variable Error

Analysis of VE did not reveal a group effect, $F\ (3, 56) = 1.25$, $p < .3$. The means for the 0-trial delay, 1-trial delay, 3-trials delay, and 5-trials delay groups were 91, 77, 98, and 75, respectively. However, a substantial block effect was found, $F\ (2, 112) = 18.62$, $p < .001$. The means for the three blocks of trials indicated that there was a large improvement in response consistency between the acquisition trials (126) and the immediate retention test (61). The increased consistency was maintained on the delayed retention test (69). A post-hoc comparison of the blocks revealed that the first block (acquisition trials) differed significantly from both the second block (immediate retention test) and the third block (delayed retention test) which were not different from each other. Finally, a Groups x Blocks interaction was not evident, F (6, 112) = .60, p = .74. However, the trend in the data suggests that the 5-trials delay condition was most beneficial for retention performance. Refer to Table 9 for a presentation of the cell means.

Table 9

Variable Error Means (in ms)

GROUP	ACQUISITION	IMMEDIATE RET.	DELAYED RET.
0-trial	134	64	74
1-trial	100	61	71
3-trial	152	60	81
5-trial	118	57	49

Absolute Constant Error

In terms of accuracy (ACE), there was no significant group effect found, F (3, 56) = 1.76, $p < .16$. As well, the main effect for block was not significant, F (2, 112) = .86, $p < .43$. Finally, the Groups x Blocks interaction was not significant, F (6, 112) = .20, $p < .98$. However, the trend was for accuracy on the retention tests to benefit most from a 0-trial delay acquisition phase (see Table 10).

Table 10

Absolute Constant Error Means (in ms)

GROUP	ACQUISITION	IMMEDIATE RET.	DELAYED RET.
0-trial	78	74	98
1-trial	66	78	116
3-trial	160	163	195
5-trial	123	107	112

Discussion

Despite the considerable difference in experimental conditions, the analysis of VE and ACE revealed no significant group effects. This finding is surprising in light of the previous experiments performed by Bilodeau (1956), Lavery and Suddon (1962), and Lavery (1964). However, Bilodeau (1956) noted that it took at least six or seven KR statements before a stabilization in the response pattern was noted.

All groups showed significant improvement in response consistency (VE) between acquisition and the immediate retention test. Although this consistency generally remained over the delayed retention test, the 5-trials delay group showed a nonsignificant trend towards further improvement. Lavery and Suddon (1962) argued that the difference in retention between delay conditions can not be accounted for by the difference in the number of training trials given to each group. Therefore, it can be concluded that the trend toward continued increase in consistency for the 5-trials delay group in the present study can not be accounted for by the extra acquisition trials that this group received. Rather, the benefit is most likely attributable to the trials-delay condition.

General Discussion

Schmidt (in press) outlined three research paradigms - relative frequency, summary-KR, and trials-delay, that yield data that could be interpreted as support for the guidance hypothesis. According to the guidance hypothesis, when KR is presented too often, the individual develops a feedback dependency that interferes in the learning of task relevant cues (Salmoni et al., 1984; Schmidt, in press; Schmidt et al., 1989; Swinnen et al., 1990).

As a consequence each of the research paradigms manipulates KR in a manner that would decrease the likelihood of such a dependency developing, thereby facilitating conditions that would foster long-term retention. However, previous experiments employing these three techniques have tended to use lengthy acquisition phases. As the number of practice trials is increased so does the amount of KR presented. As a consequence, it is likely that more guidance results.

The guidance hypothesis also predicts that early in practice a high frequency of KR is necessary to drive the individual toward the correct response (Winstein & Schmidt, 1990). Relative frequency studies using a faded feedback schedule have been interpreted as evidence that more KR is needed initially. However, as is also predicted from the guidance hypothesis, an overall reduced percentage of feedback is best for learning. The three experiments presented in this study were used to test the generalizability of the guidance hypothesis to a very brief acquisition phase.

With simple tasks, such as the one employed here, performance during acquisition reaches an asymptote with minimal trials (Ho & Shea, 1978). Each of the three procedures investigated here indicated that an asymptote was not reached even when 15 acquisition trials were presented. This is evident by the highly inflated error terms that were revealed in the analysis of the data for each experiment. It appears that more practice is needed to allow for a stabilization of the response pattern. Thus, during this time it is unlikely that a dependency on KR would develop. Yet, the results still appear to favour the reduced KR-frequency conditions.

Faded Feedback

The faded feedback procedure was designed on two premises: 1) more KR is needed early in practice; and 2) too much KR degrades learning as a dependency develops. Furthermore, Winstein and Schmidt (1990) argue that the spaced-practice view proposed by Landauer and Bjork (1978) for verbal learning provides support for a faded procedure. According to this view, gradually expanding the interval between tests (no-KR trials) optimizes retention performance. Early in practice, short intervals provide for successful execution of the task, while longer periods later in practice, strengthen retrieval skills. Thus, a schedule for the presentation of KR was designed to optimize both effects; more KR early in practice, less KR later (i.e., the faded feedback schedule).

The three research paradigms investigated here have shown that the benefits of a reduced frequency of KR may be more complex than accounted for by the guidance hypothesis. First, each experiment employed a very brief acquisition phase, comparable to conditions early in practice. A close look at the data for each experiment indicated that although the brief acquisition phase did not permit the subjects to build a consistent response pattern, their level of accuracy did increase in each condition. This is especially true for conditions in which a) KR was presented less frequently (i.e., 60% vs. 100%); and b) the KR statement contained less information (i.e., 5-trial summary vs. 15-trial summary). Thus, early in practice, as throughout all of practice, frequent feedback tends to degrade learning.

Secondly, the guidance hypothesis infers that a dependency on KR develops which results in the interference of task-relevant cues. Again, the results of these three experiments indicate that this is not the case - dependency is not the answer. It is impossible for an over-reliance on KR to have developed during any one of these experiments when one considers the minimal amount of KR that was actually given, even under conditions which provided 100% feedback.

The present experiments demonstrate that a reduced frequency of KR is beneficial early in practice, which is counter to the notion behind the faded procedure. However, it does not mean that the faded procedure is wrong. Winstein and Schmidt (1990) discuss some explanations for the success of the faded procedure which were "borrowed" from verbal learning research. These theories may shed light on the present findings. First, presenting KR according to an intermittent schedule allows the learner to develop response accuracy and consistency, both of which are important components of skill learning. More specifically, providing a reduced frequency of KR allows the subject to develop a stable response pattern which, in turn, enhances the use of KR for the development of response accuracy later in practice (Winstein & Schmidt, 1990). Secondly, evidence obtained from the verbal learning domain supports spaced-practice intervals as they strengthen the retrieval skills that are essential for retention (Winstein & Schmidt, 1990).

The present results indicate that there is a need to reconsider the guidance hypothesis. Perhaps the failure of the hypothesis to distinguish between experiments with lengthy and brief acquisition phases lies in its failure to specify a mechanism to account for KR dependency. Thus, while the guidance hypothesis may not be fundamentally incorrect, the theoretical explanations for the detrimental effects due to frequent KR appear too simplistic.

References

Adams, J.A. (1971). A closed-loop theory of motor learning. Journal of Motor Behavior, 3, 111-149.

Adams, J.A. (1987). Historical review and appraisal of research on the learning, retention, and transfer of human motor skill. Psychological Bulletin, 101, 41-74.

Adams, J.A., & Reynolds, B. (1954). Effect of shift in distribution of practice conditions following interpolated rest. Journal of Experimental Psychology, 47, 32-36.

Annett, J. (1959). Learning a pressure under conditions of immediate and delayed knowledge of results. Quarterly Journal of Experimental Psychology, 11, 3-15.

Bilodeau, I. McD. (1956). Accuracy of a simple positioning response in the number of trials by which knowledge of results is delayed. American Journal of Psychology, 69, 434-437.

Bilodeau, I. McD. (1966). Information feedback. In E.A. Bilodeau (Ed.), Acquisition of skill (pp. 255-296). New York: Academic Press.

Bilodeau, I. McD. (1969). Information feedback. In E.A. Bilodeau (Ed.), Principles of skill acquisition (pp. 255-285). New York: Academic Press.

Bilodeau, E.A., & Bilodeau, I. McD. (1958). Variable frequency of knowledge of results and the learning of a simple skill. Journal of Experimental Psychology, 55, 379-382.

Bilodeau, E.A., & Bilodeau, I. McD. (1961). Motor-skills learning. Annual Review of Psychology, 12, 243-280.

Bilodeau, E.A., Bilodeau, I.McD, & Schumsky, D.A. (1959). Some effects of introducing and withdrawing knowledge of results early and late in practice. Journal of Experimental Psychology, 58, 142-145.

Black, P.E. (1970). A "partial reinforcement-extinction effect" in a perceptual-motor task. Psychonomic Science, 18, 125-127.

Bourne, L. E., & Bunderson, C.V. (1963). Effects of delay of informative feedback and length of postfeedback interval on concept identification. Journal of Experimental Psychology, 65, 1-5.

Dees, V., & Grindley, G.C. (1951). The effect of knowledge of results on learning and performance: IV. The direction of the error in very simple skills. Quarterly Journal of Experimental Psychology, 3, 36-42.

Dunham, P. (1971). Communications: Learning and performance. The Research Quarterly, 42, 334-337.

Goldstein, M., & Rittenhouse, C.H. (1954). Knowledge of results in the acquisition and transfer of a gunnery skill. Journal of Experimental Psychology, 48, 187-196.

Ho, L., & Shea, J.B. (1978). Effects of relative frequency of knowledge of results on retention of a motor skill.

Perceptual and Motor Skills, 46, 859-866.

Koch, C.G., & Dorfman, P.W. (1979). Recall and recognition processes in motor memory: Effects of feedback and knowledge of results delay. Journal of Motor Behavior, 11, 23-34.

Lavery, J.J. (1962). Retention of simple motor skills as a function of type of knowledge of results. Canadian Journal of Psychology, 16, 300-311.

Lavery, J.J. (1964). The effects of one-trial delay in knowledge of results on the acquisition and retention of a tossing skill. American Journal of Psychology, 77, 437-443.

Lavery, J.J., & Suddon, F.H. (1962). Retention of simple motor skills as a function of the number of trials by which KR is delayed. Perceptual Motor Skills, 15, 231-237.

Lee, T.D., & Magill, R.A. (1983). Activity during the post-KR interval: Effects upon performance or learning? Research Quarterly For Exercise and Sport, 54, 340-345.

Lorge, I., & Thorndike, E.L. (1935). The influence of delay in the after-effect of a connection. Journal of Experimental Psychology, 18, 186-194.

Marsh, A.J. (1990). Summary knowledge of results for skill acquisition. Unpublished undergraduate thesis, Motor Behaviour Laboratory, Lakehead University, Thunder Bay, Ontario.

McGuigan, F.J. (1959a). Delay of knowledge of results: A problem in design. Psychological Reports, 5, 241-243.

McGuigan, F.J. (1959b). The effect of precision, delay, and schedule of knowledge of results on performance. Journal of Experimental Psychology, 58, 79-84.

McGuigan, F.J., Crockett, F., & Bolton, C. (1960). The effect of knowledge of results before and after a response. The Journal of General Psychology, 63, 51-55.

Newell, K.M., & Walter, C.B. (1981). Kinematic and kinetic parameters as information feedback in motor skill acquisition. Journal of Human Movement Studies, 7, 235-254.

Reeve, T.G., Dornier, L.A., & Weeks, D.J. (1990). Precision of knowledge of results: Consideration of the accuracy requirements imposed by the task. Research Quarterly For Exercise and Sport, 61, 284-290.

Rogers, C.A. (1974). Feedback precision and postfeedback interval duration. Journal of Experimental Psychology, 102, 604-608.

Rubin, W.M. (1978). Application of signal detection theory to error detection in ballistic motor skills. Journal of Experimental Psychology: Human Perception and Performance, 4, 311-320.

Salmoni, A.W., Schmidt, R.A., & Walter, C.B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. Psychological Bulletin, 95, 355-386.

Schmidt, R.A. (1975a). Motor skills. New York: Harper & Row.

Schmidt, R.A. (1975b). A schema theory of discrete motor skill learning. Psychological Review, 82, 225-260.

Schmidt, R.A. (1988). Motor control and learning: A behavioral emphasis. Champaign, Illinois: Human Kinetics Publishers.

Schmidt, R.A. (in press). Frequent augmented feedback can degrade learning: Evidence and interpretations. In G.E. Stelmach & J. Requin (Eds.), Tutorials in motor neuroscience. Dirdrecgt: Kluwer.

Schmidt, R.A., Christenson, R., & Rogers, P.F. (1975). Some evidence for the independence of recall and recognition in motor behavior. In D.M. Landers, D.V. Harris, & R.W. Christina (Eds.), Psychology of motor behavior and sport II (pp. 510-521). State College, PA: Penn State HPER Series.

Schmidt, R.A., Young, D.E., Swinnen, S., & Shapiro, D.C. (1989). Summary knowledge of results for skill acquisition: Support for the guidance hypothesis. Journal of Experimental Psychology, 15, 352-359.

Schulz, R.W., & Runquist, W.N. (1960). Learning and retention of paired adjectives as a function of percentage occurrence of response members. Journal of Experimental Psychology, 59, 409-413.

Sherwood, D.E. (1988). Effect of bandwidth knowledge of results on movement consistency. Perceptual and Motor Skills, 66, 535-542.

Shea, J.B., & Upton, G. (1976). The effects on skill acquisition of an interpolated motor short-term memory task during the KR-delay interval. Journal of Motor Behavior, 8, 277-281.

Skinner, B.F. (1938). The behavior of organisms. New York: Appleton-Century-Crofts.

Swinnen, S.P., Schmidt, R.A., Nicholson, D.E., & Shapiro, D.C. (1990). Information feedback for skill acquisition: Instantaneous knowledge of results degrades learning. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 706-716.

Taylor, A., & Noble, C.E. (1962). Acquisition and extinction phenomena in human trial-and-error learning under different schedules of reinforcing feedback. Perceptual and Motor Skill, 15, 31-44.

Thomas, J.R., Mitchell, B., & Solmon, M.A. (1979). Precision knowledge of results and motor performance: Relationship to age. Research Quarterly, 50, 687-698.

Tolman, E.C. (1932). Purposive Behavior in animals and men. New York: Appleton-Century-Crofts.

Trowbridge, M.H., & Cason, H. (1932). An experimental study of Thorndike's theory of learning. Journal of General Psychology, 7, 245-258.

Winstein, C.J., & Schmidt, R.A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. Journal of Experimental Psychology, 16, 677-691.

Wulf, G., & Schmidt, R.A. (1989). The learning of generalized motor programs: Reducing the relative frequency of knowledge of results enhances memory. Journal of Experimental Psychology, 15, 748-757.

APPENDICES

APPENDIX A

INSTRUCTION SHEETS/CONSENT FORM

Dear Subject:

The experiment that you are about to take part in requires you to perform a simple movement task. The task requires that you move your right hand from one telegraph key to another telegraph key located approximately 50 cm apart. The object of the task is to make the movement in a specific amount of time. You will perform a number of trials, each time trying to come as close to the target time as possible. Periodically, you will be shown exactly how far away you were from the target time.

When the learning trials are completed, you will leave the room for ten (10) minutes. After this ten minutes has elapsed, you will be recalled into the laboratory to perform some additional trials. After these trials are completed, you will be asked to return in two (2) days for another short session.

Thank-you for your co-operation
and participation

Kim Williams

INFORMED CONSENT
FOR
Information Processing Research
Lakehead University
Department of Physical Education

You are invited to participate in a study of human information processing which is being conducted by Dr. Dan Weeks. We hope to increase our knowledge about basic perceptual, cognitive, and motor skills. Specifically, we are interested in how people make rapid judgments and decisions about what to do in reaction to events around them. This information will help us to understand just what it means to be "skilled" at various tasks.

If you decide to participate, each experimental session should last less than an hour. There are no known expected discomforts or risks involved in your participation. This judgment is based on a large body of experience with similar experimental tasks. Hopefully, the results of this experiment will aid us in understanding the nature of human cognition.

Any information obtained in connection with this study that can be identified with you will remain confidential. In any publication or results, information will remain anonymous. If you give us permission by signing this document, we plan to publish the results in an appropriate psychological journal.

Your decision whether or not to participate will not prejudice your future relations with Lakehead University or the Physical Education Department. If you decide to participate, you are free to withdraw your consent and to discontinue participation at any time without penalty. If you decide later to withdraw from the study, you may also withdraw any information which has been collected about you.

If you have any questions, we expect you to ask us. If you have additional questions later, Dr. Dan Weeks may be reached at 343-8189 or at the Motor Behavior Lab in the Fieldhouse. He will be happy to answer any questions that you have.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

______________________________ ______________________________

Date Time Subject's signature

______________________________ ______________________________

Witness Investigator's signature

APPENDIX B

MEASURES OF ERROR

MEASURES OF ERROR

Two common dependent measures have been frequently utilized in motor behavior research to determine the effects of the independent variable - absolute constant error (ACE) and variable error (VE). A manual illustration of these calculations has been presented below, utilizing the data from a single block of five trials in which the criterion goal (T) was 500 ms.

TRIAL	SCORE (X)	x - T	x - CE	$(x - CE)^2$
1	241	-259	-227.4	51710.76
2	201	+299	+330.6	109296.36
3	183	-317	-285.4	81453.16
4	475	- 25	+ 6.6	43.56
5	644	+144	+175.6	30835.36
SUM	1744	-158		273339.20
MEAN	348.8	- 31.6		54667.84
SQ.ROOT				233.81

$$\text{Absolute Constant Error} = \left| \frac{(x - T)}{n} \right|$$

$$= \left| \frac{(-259) + \ldots (+144)}{5} \right|$$

$$= 31.6$$

$$\text{Variable Error} = \sqrt{\frac{(x - CE)^2}{n}}$$

$$= \sqrt{\frac{51710.76 + \ldots\ 30835.36}{5}}$$

$$= 233.81$$

APPENDIX C

ANOVA TABLES

Table 11

VE ANOVA For Experiment 1

SOURCE	SS	df	F
Group	53080.197	3	1.440
Error	542304.152	44	
Block	206263.499	2	13.478*
Group x Block	52485.434	6	1.143
Error	673385.803	88	

Table 12

ACE ANOVA For Experiment 1

SOURCE	SS	df	F
Group	754650.597	3	0.071
Error	4434341.160	44	
Block	144074.431	2	1.346
Group x Block	144418.469	6	0.450
Error	4710384.970	88	

Table 13

VE (Blocks 123) ANOVA For Experiment 2

SOURCE	SS	df	F
Group	55191.680	2	2.260
Error	403774.862	33	
Block	17794.613	2	1.670
Group x Block	43164.508	4	2.020
Error	351958.033	66	

Table 14

VE (Blocks 345) ANOVA For Experiment 2

SOURCE	SS	df	F
Group	175.504	2	0.010
Error	298268.102	33	
Block	2295.152	2	0.370
Group x Block	33170.862	4	2.700*
Error	202854.069	66	

Table 15

<u>ACE (Blocks 123) ANOVA For Experiment 2</u>

SOURCE	SS	df	F
Group	841259.631	2	3.810*
Error	3643819.130	33	
Block	90550.614	2	6.800*
Group x Block	17926.326	4	0.670
Error	439284.740	66	

Table 16

<u>ACE (Blocks 345) ANOVA For Experiment 2</u>

SOURCE	SS	df	F
Group	316040.782	2	3.260
Error	1601268.190	33	
Block	435413.153	2	15.460*
Group x Block	140555.436	4	2.500*
Error	929510.793	66	

Table 17

VE ANOVA For Experiment 3

SOURCE	SS	df	F
Group	16027.537	3	1.251
Error	239197.543	56	
Block	152311.259	2	18.622*
Group x Block	14636.083	6	0.587
Error	458022.646	112	

Table 18

ACE ANOVA For Experiment 3

SOURCE	SS	df	F
Group	232003.112	3	1.764
Error	2455586.900	56	
Block	22757.024	2	0.859
Group x Block	15564.805	6	0.196
Error	1483874.980	112	