UNIVERSITY OF ALBERTA

TEMPORAL LOCUS OF KNOWLEDGE OF RESULTS (KR) AND MOTOR LEARNING: SELF-PACED STUDIES

BY

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance a thesis entitled Temporal Locus of Knowledge of Results (KR) and Motor Learning: Self-Paced Studies submitted by Antonios K. Travlos in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Dedication

To my little Raphael Penalosa Carpio from Colombia.

Abstract

Three experiments, using the self-paced procedure, were conducted to investigate the effects of unconfounded temporal locus of KR in the acquisition of a simple linear positioning task. The purpose of Experiment One was to identify changes in the chronological profile of KR delivery when participants manipulate the time course of the experiment at their own discretion. Experiment Two investigated the effects of KR-withdrawal on both the chronological profile of KR delivery and the performance scores. Experiment Three examined what was learned and transferred regarding the surface and the deep features of the criterion task using a transfer task and a self-paced procedure. It was found that under self-paced procedures both the KR-delay and post-KR interval decreased congruently with performance error scores. Different KR-withdrawal effects were noted in performance scores and KR-time intervals during early and later learning. During practice, participants developed a functional interaction between the surface and the deep features of the criterion task that was transferable to the transfer task. The findings are discussed in terms of the existing learning theories and views about transfer of learning.

Acknowledgement

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Over the years theorists have speculated regarding the processes that underlie human motor learning. In the area of motor skill acquisition, specifically, feedback is considered to be "one of the most important learning processes" (Schmidt, 1991, pp. 228). One form of extrinsic feedback (FB) that has been researched to determine its influence on motor learning is knowledge of results (KR). Although theorists vary according to their definition of KR, it can be broadly defined as terminal and augmented FB regarding the response outcome.

KR has been considered as a critical learning variable and failure to provide KR to the learner may have detrimental effects in motor skill acquisition (Salmoni, Schmidt, & Walter, 1984). Functionally, KR is an important source of information to the learner about performance, that orients error detection and correction, motivates the learner to keep moving toward experimental goals and reinforces correct performance (Magill, 1989).

One of the ways that KR has been varied experimentally is in terms of its temporal locus. Despite the extensive amount of research conducted on the temporal locus of KR, there is still conflicting evidence regarding the effects of various lengths of KR time intervals (See Appendix A for definitions) on motor skill acquisition (Salmoni et. al., 1984; Travlos, 1991; Travlos, Pratt, & Wilberg, 1990).

Theories of Motor Learning

The concept of learning and learning theories have evolved in parallel. Originally psychologists used the term learning to denote any change in human and animal behaviour. Currently, learning is more contemporarily defined in the motor learning literature "as a change in the capability of the individual to perform a skill that must be inferred from a relatively permanent improvement in performance as a result of practice or experience (Magill, 1989, pp. 48).

The earliest theorizing in human motor learning arose from Thorndike's (1927) examination of the role of the Law of Effect in human movement experiments. According to that Law, rewards strengthen the stimulus response connection, while punishment weakens it. Thorndike (1913) verified this law in animal studies, and in his initial human learning studies (Thorndike, 1927) used KR as one form of reward. Based on later human learning studies, Thorndike (1932) suggested that punishment may not weaken the stimulus - response connection, but it may create a different kind of behaviour.

In comparison to Thorndike's behaviourist approach, Adams (1971) developed a cognitive theory called the closed-loop theory of motor learning. The two main constructs of the theory are the perceptual trace and the memory trace. The perceptual trace determines the extent of the movement, compares the movement that is made with the ongoing sensory feedback (muscles, eyes and so on), and adjusts the next response on the basis of KR. The memory trace, an open loop construct in the theory, is used to "select and initiate the response, preceding the use of the perceptual trace" (p. 125).

Two stages of motor learning have been outlined in Adams' closed-loop theory - the verbal-motor stage and the motor stage. The verbal-motor stage is evident early in practice where the learner makes corrections on the basis of KR, and <u>verbally</u> transforms them in order to adjust the next response. When the difference between the perceptual trace and the ongoing FB is repeatedly small and stable then the perceptual trace strengthens and KR is not needed any further. This is the transition from the verbal-motor stage to the motor stage, where the individual can learn without KR. Performance at this level is error free and internally controlled via proprioceptive FB. Learning under these circumstances coexists with the term <u>subjective reinforcement</u> (Adams, 1967, 1971; Adams & Bray, 1970).

The time course of KR delivery has been used as a determinative factor for supporting Adams closed-loop theory. Based on experimental evidence provided by Bilodeau and Bilodeau (1958b), Bilodeau and Ryan, (1960), Lorge and Thorndike (1935), Adams (1971) suggested that the KR-delay "has little or no effect on acquisition" (p.132), and that the strength of the perceptual trace is determined by the interresponse interval. Also, the role of post-KR interval is considered to be important at the verbal-motor stage of motor learning as this interval has to be of sufficient time in order for the individual to process the information delivered by KR (Adams, 1971).

Adams (1971) developed his theory based on simple limb-positioning movements, but felt that it could also account for more complicated movements. This proved not to be the case. His theory was not able to deal with rapid ballistic movements (Schmidt, 1975). Other limitations of the theory are that the system cannot account for novel responses. Further, the theory as proposed, has the potential of exceeding the limited capacity of short-term memory.

In order to overcome the aforementioned limitations, Schmidt (1975) developed a schema theory of discrete motor skill learning. Schmidt's schema theory proposes that "we learn skills by learning rules about the functioning of our bodies, forming relationships between how our muscles are activated, what they actually do, and how those actions feel" (Schmidt, 1988, pp. 488). The concept of a schema is defined as a rule or a set of rules, developed from abstracting the information of past experiences (Schmidt, 1988).

In his theory, a movement is initiated by a generalized motor program. The learner stores the initial conditions (position of the limbs of the body, shape or weight of the object and so on), the response specifications (direction, speed etc), the sensory consequences (sensory FB throughout the movement), and the response outcome (KR). From these sources of information, two forms of schema are generated - the recall schema and the recognition schema.

The recall schema establishes the relationship among the initial conditions, response specifications and the response outcome, while the recognition schema stores the relationship among the initial conditions, the sensory consequences, and the response outcome. The recall schema is responsible for sending the appropriate instructions to the motor program, initiating the movement and determining the desired outcome. The recognition schema is responsible for estimating the correctness of the produced response through proprioception, exteroception and KR (Schmidt, 1975).

Regarding the temporal manipulation of KR and schema theory, Schmidt (1975) suggested that KR-delay appears to influence recognition while leaving recall memory unaffected. Although the theory does not specifically address the role of the post-KR interval or the intertrial interval (ITI), Schmidt (1988) and his colleagues (Salmoni, Schmidt, & Walter, 1984) suggest that the ITI plays a role in motor skill acquisition and that there is an "optimum post-KR" (Salmoni et. al., 1984, p. 361) interval for motor skill acquisition.

KR- Time Intervals and Motor Learning: Functions and Findings

Researchers have focused on three types of KR time intervals, the KR-delay, the post-KR interval, and the ITI. Each is believed to have a different function in motor skill acquisition.

KR-delay. According to Swinnen (1988, 1990), learners use the KR-delay interval to estimate their error. Consequently, the KR-delay interval should be of sufficient duration to allow learners to estimate their performance. When the KR-delay is too short, the learner may not be motivated to continue performing and may have no time for error detection via the movement's response produced feedback (Swinnen, Schmidt, Nicholson

& Shapiro, 1990). During the KR-delay interval the learners seem able to retain certain aspects of information regarding their response until the presentation of KR (Newell, 1981; Salmoni et. al., 1984; Schmidt, 1988; Swinnen, 1990).

At the beginning of the century, psychologists widely accepted the fact that KR-delay had the same effect on performance as did rewards in animal learning; the shorter the KR-delay the better the performance (Tarpy & Sawabini, 1974). Lorge and Thorndike (1935) found, however, that long KR-delays were just as beneficial as short KR-delays. Since then, a number of studies have indicated that KR-delay has no effect on performance (Alexander, 1951; Saltzman, Kanfer, & Greenspoon, 1955; Archer & Nanikas, 1958; Bilodeau & Bilodeau, 1958b; McGuigan, 1959a; Bilodeau & Ryan, 1960; Ryan & Bilodeau, 1962; Becker, Mussina, & Persons, 1963; Schmidt & Shea, 1976; Koch & Dorfman, 1979, ballistic task; Swinnen, 1988; Swinnen et al., 1990). Others have suggested that short KR-delays improved performance in contrast to long KR delays (Greenspoon & Foreman, 1956; McGuigan, Crockett, & Bolton, 1960; Dyal, 1964, 1966; Boulter, 1964; Denny, Allard, Hall, & Rokeach, 1960; Dyal, Wilson, & Berry, 1965; Koch & Dorfman, 1979, linear task; Simmons & Snyder, 1983). A recent quantitative review of the foregoing literature indicates that, across a variety of motor tasks, short KR-delays are superior to long KR-delays in facilitating motor performance (Travlos, Pratt, & Wilberg, 1990).

Most of the foregoing studies used immediate retention to assess learning (McGuigan, 1959a; McGuigan, Crocket & Bolton, 1960; Boulter, 1964; Dyal, Wilson & Berry, 1965; Dyal, 1966; Koch & Dorfman, 1979; Schmidt & Shea, 1976; Marteniuk, 1986). More recently, immediate and delayed transfer designs (Swinnen 1988) and immediate and delayed retention test (Swinnen et. al., 1990) have also been used to assess learning. All of the above studies gave no significant results at the retention phase with the exception of Swinnen et al. (1990). Unlike the bulk of the literature, the Swinnen et al. results suggest that instantaneous KR (210 msec delay) deteriorates learning when it is compared with a 3.2 sec KR-delay at a two day delayed retention test.

Post-KR interval. The second time interval in the KR paradigm, the post-KR interval, directly precedes the production of the next response. The post-KR interval provides an opportunity for the learner to actively process KR in order to plan a strategy of action to produce a subsequent movement more accurately (Adams, 1971; Lee & Magill, 1983, 1987; Salmoni et. al., 1984). If the post-KR interval is not long enough, learners cannot utilize the informational properties of KR in order to produce a plan of action for the next movement. As a result, there is no observable change in performance (Salmoni et. al., 1984; Weinberg, Guy, & Tupper, 1964). Bilodeau & Bilodeau (1958b) were the first to suggest that post-KR interval appears to affect performance and learning in a more important way than KR-delay.

Similar to the KR-delay studies, the post-KR interval studies are in disagreement. Several studies found that the influence of post-KR interval on motor performance was negligible (Magill, 1973, 1977, 1988; Boucher, 1974; Bole, 1976; Simmons & Snyder, 1983; Benedetti & McCullagh, 1987; Lee & Magill, 1987) while others found that longer post-KR intervals (greater than five sec) produced better performance (Weinberg et. al., 1964; Gallagher & Thomas, 1980; Ramella, 1983; Ramella & Wiegand, 1983; Wiegand & Ramella, 1983). A meta-analysis of the aforementioned studies (Travlos, Pratt, & Wilberg, 1990), indicated that longer post-KR intervals (greater than five sec) facilitate motor skill acquisition.

In the post-KR interval literature only three studies tested the effect of post-KR interval on the retention phase in order to identify if learning took place. McGuigan et al. (1960), Lee and Magill (1987) and Magill (1988) revealed no significant effects of post-KR intervals on immediate and delayed (24 hours, Magill, 1988) retention test. The only significant difference, short (5 sec) vs long (20 sec) post-KR intervals was found by Magill (1988) using a transfer test with the 20 sec post-KR interval group performing better.

Intertrial interval (ITI). While KR-delay and post-KR delay have been studied directly, the intertrial interval has been studied indirectly because it is a function of the other two intervals (Schmidt, 1988). Bilodeau and Bilodeau (1958b) believed that the ITI was the most important factor in learning, because with longer ITIs there was generally a decrease in learning. More recently, Salmoni et al. (1984) noted that Bilodeau and Bilodeau's (1958) conclusion was not based on studies with transfer designs. Salmoni et al. (1984) state that with the use of transfer designs "... the conclusions were reversed, with increased intertrial intervals tending to increase - not decrease - learning" (p. 370).

The KR Intervals' Persistent Problems

The findings of the foregoing studies are problematic for two reasons. First, the KR time course has always been controlled by the experimenter and thus, the learner's ability and willingness to receive the information provided by KR was not taken into consideration. If given the opportunity, perhaps the learner might select an entirely different course for KR. The only investigation that employed a self-paced technique did so for the post-KR interval only (Barclay & Newell, 1980). Their study found that early in practice, all groups needed more time to evaluate KR, but as the performance approached the asymptotic level the learners needed less time for processing KR. It seems that after a period of practice the learners do not need all the time set by the experimenter. However, what the chronological profile of KR delivery would be if all of the KR time intervals were controlled by the learner, is not known.

The second problem with the foregoing studies is that two of the KR time intervals are confounded, while the third interval remains constant. For example, by maintaining a constant intertrial interval, the KR-delay and the post-KR interval are automatically confounded. The confounding of KR intervals makes it difficult to determine which interval accounts for the performance changes. Wilberg (1991) suggested that the undifferentiation of the KR-delay and the post-KR interval, and the confounding (among the KR-time intervals) caused by the degrees of freedom problem necessitates a re-examination of the KR-paradigm. Early studies tried unsuccessfully to address the foregoing controversy by utilizing different tasks and experimental designs (McGuigan, 1959b; Bilodeau, 1964; Dyal, 1965). Wilberg further noted that the effects of practice on the <u>total time</u> (interstimulus interval - ISI) needs to be examined.

The following experiments seek to overcome these difficulties by using a self-paced procedure. This procedure gives the learner, unknowingly, the opportunity to manipulate the movement time (MT) of a spatial task, KR-delay, post-KR interval, the ratio (KR-delay/post-KR interval), the ITI and the ISI, in order to optimize performance and learning.

Implementation of the self-paced procedure creates the opportunity for several innovations. First, because the learner will be able to receive, elaborate, and utilize KR at his/her discretion, the lengths of the KR-time intervals across the course of practice can be compared. Second, it will also be possible to examine whether practice on a KR dependent task leads to the development of distinct patterns of KR-time intervals over practice periods. Third, the investigator can address how the relationship among the KR-time intervals is further related to the performance variables. Different patterns of KR-time intervals may have different effects on performance. Fourth, it will be possible to identify whether the subjects use KR and up to what point they need it. Fifth, when the learners are asked to perform another similar task whether they transfer the performance characteristics of the task (surface features), the chronological profile of KR delivery (deep features) (Wilberg, 1991), or both will be revealed (see Appendix A for definitions).

Experiment One

In all of the published KR studies, (except Barclay & Newell, 1980), the time course of KR delivery was always fixed by the experimenter. This procedure generates a confounding between two of the three KR-time intervals. Therefore, any theorizing about the temporal locus of KR and motor skill acquisition should be re-examined.

The purpose of the first experiment was to identify changes in the chronological profile of KR delivery when the participants manipulated the time course of the experiment at their own discretion. The self-paced procedure allowed the investigator to examine the KR-time intervals unconfounded across the course of practice. As the performance improved through practice, the changes in the time intervals surrounding KR delivery were explored. The possible relationships among the chronological profile of KR delivery and the performance scores of the performed task were also examined.

Method

Subjects. Twenty nine volunteer subjects from the University of Alberta participated in the experiment. The age ranged from 18 to 32. All volunteers were required to sign a consent form (Appendix B) before participating in the study. They were informed about the nature of the study and were free to withdraw from involvement without repercussion.

Apparatus and task. The subject's task was to find the length of an 8 inch line by performing a linear tapping task on a Summagraphics Supergrid digitizing tablet using a pen shaped digitizing probe. The digitizing tablet was used as the subjects' panel (512 mm X 512 mm) and was tilted upwards and away from the subjects at a 27 degree angle. The distance between the lower edge of the panel and the floor was 86.5 cm. A shield was placed above the Supergrid at an adequate height so subjects could not observe their movement. A DEC PDP11/10 computer interfacing with the Supergrid allowed for synchronous recording of time in milliseconds and X - Y coordinate pairs (accuracy: .001 inch), whenever the probe touched the digitizing tablet.

The target line had no fixed starting and ending points. The subjects were required to perform the task with their dominant hand. They were not able to watch their movements and the target movement distance was not known to the subjects. The purpose of following this procedure was to minimize the sources of feedback. Knowledge of results was computer calculated as the deviation of subject's response from the target movement distance in millimetres. KR was presented to subjects on a monochrome computer monitor whenever they touched the probe to the tablet's surface following a required movement. The monitor was placed 160 cm above the floor and 80 cm in front and away from the subjects. Movement time, KR-delay, post-KR interval and spatial accuracy data were calculated by a PDP11/10 computer using data gained from the Supergrid digitizing tablet.

Procedure. The subjects held the stylus and attempted to find the target movement distance by tapping the stylus at two consecutive horizontal grid points. A movement trial was initiated by a single tap on the left side of the digitizing tablet, and was terminated by a second tap on the right side. The distance between the two taps represented the performed movement distance, while the time interval between them reflected the movement time. The subjects were told to ask for KR at their own discretion by tapping the stylus on the tablet for a third time. Signed directional KR in millimetres appeared on the computer screen. The time interval between the second tap and the third tap reflected the KR-delay chosen by the subject. KR remained on the screen as long as the subject needed it. When ready, the subjects could start the next trial at their own pace. The time interval between the presentation of the KR and the first tap of the next response represented the post-KR interval.

The subjects were asked to produce the same movement distance for three consecutive days. Once the subject accurately estimated the movement distance, he or she attempted to maintain her/his performance for the remainder of the trials. The subjects performed 52 practice trials on each day. The first trial was omitted from the analysis because it was not a KR trial. The 52nd trial was needed only for calculating the post-KR of the 50th trial (the last trial used in the analysis). To become familiar with the experimental protocol, five practice trials of a different movement distance (4 inch) were given to each subject.

Analysis and design. Eight dependent variables were used in the data analyses. The absolute error (AE) for the spatial deviation of the target movement distance was chosen as the most appropriate error term (Newell, 1976) for overall spatial accuracy. The variable error (VE) for the spatial deviation of the target movement distance was used to examine the consistency of learners' performance across practice trials. Both errors were measured to the nearest (.001) of an inch. (See Appendix C for definitions and calculations of AE and VE.) Movement time, KR-delay, post-KR interval, ITI, ISI and ratio were recorded in order to identify possible changes in their temporal lengths.

A one-way repeated measures ANOVA across blocks of practice (30) was performed for all the dependent variables. Each block was consisted of five trials, and results were taken for the average of five trials (10 blocks per day). All the assumptions associated with the univariate repeated measures ANOVA were tested and the degrees of freedom were adjusted according to the Greenhouse-Geisser method (Geisser & Greenhouse, 1958) when the assumption of sphericity was violated (Stevens, 1986). Tukey's post-hoc analyses were used to locate significant differences among the blocks of practice for all dependent variables. However, simple linear regression analyses were conducted to evaluate the relationship between practice and each dependent variable (Pedhazur, 1982). The alpha (α) level of significance was set at .05 for all ANOVAs, post-hocs and regression analyses. The means and standard deviations for all dependent variables are presented in Appendix D.

Pearson product correlations (r) were computed to determine the relationship among the KR-time intervals and the performance scores (AE, VE). In order to examine if the response pattern underlying the first block of practice was different than the response pattern underlying the other blocks of practice for each dependent variable, interblock correlations were computed.

Results.

Absolute error and variable error. The ANOVAs indicated that there was a significant main effect of blocks of practice for the AE scores ($F(8.7, 244.9) = 5.47$, $p<.001$, *M.S. Error* = 76414.47) and for the VE scores ($F(9.1, 253.6) = 6.35$, $p<.001$, *M.S. Error* = 70444.99). The data for AE and VE are plotted in Figures 1 and 2, respectively.

Post-hoc analysis indicated that the significance of the blocks of practice for the AE was due to the statistical difference of Block 1 with all the other blocks of practice, and Block 11 with Blocks 22, 24, 26, 27, 28, 30. The significance of the blocks of practice for the VE was related to the statistical difference of Block 1 with all the other blocks of practice, Block 2 and Block 11 with Blocks 22 and 28, and Block 3 with Block 28.

Regression analyses revealed that the regressions of the AE and VE scores on the blocks of practice were significantly different than zero ($F(1, 868) = 49.14$, $p<.0001$, *M.S. Residual* = 76414.47 and $F(1, 868) = 63.03$, $p<.0001$, *M.S. Residual* = 87695.26). The intercept and the slope of the regression equation were $a = 657.099$ and $b = -8.354$ for AE scores and $a =$

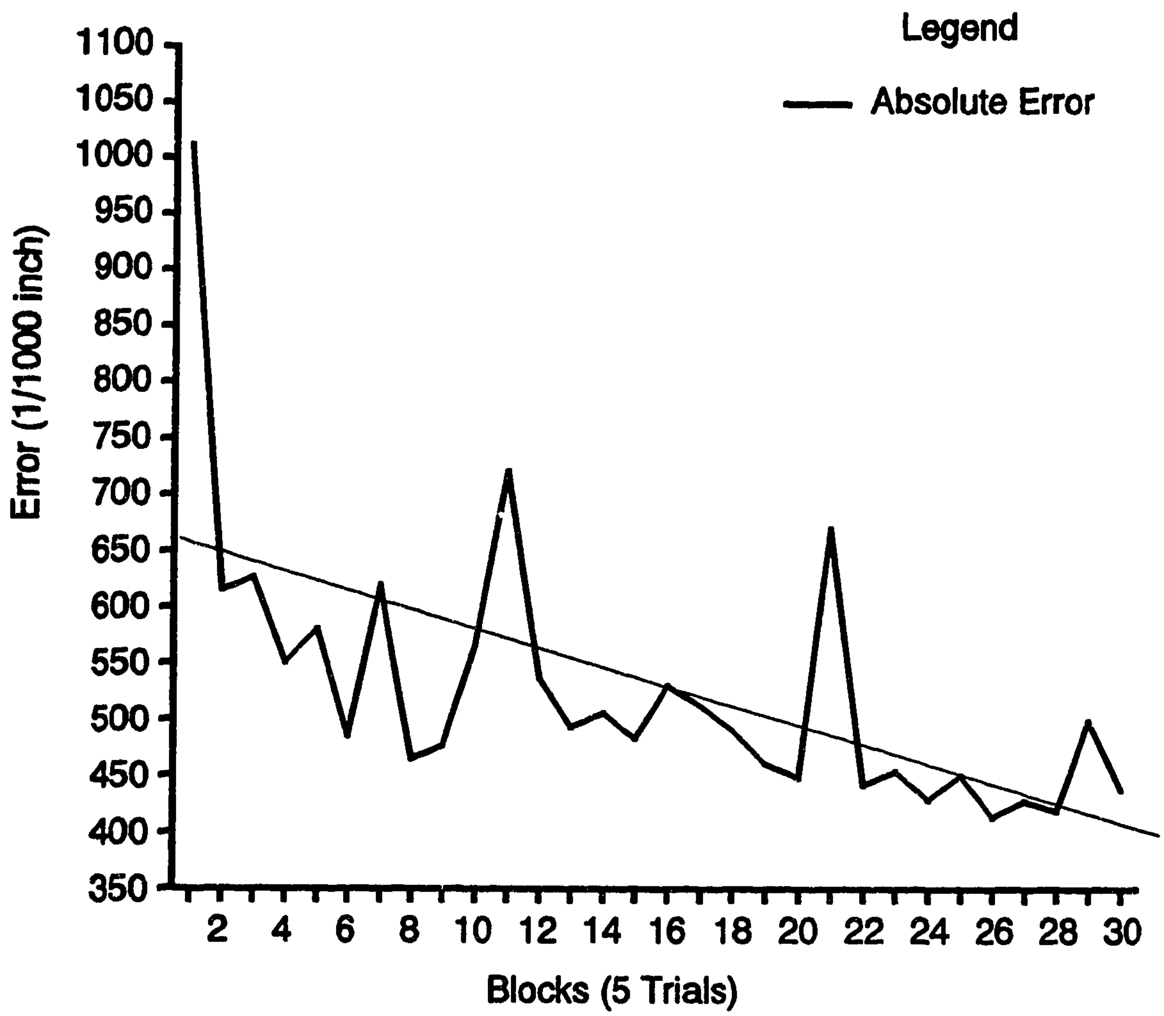

Figure 1. Experiment One - Absolute error scores as a function of practice and regression line.

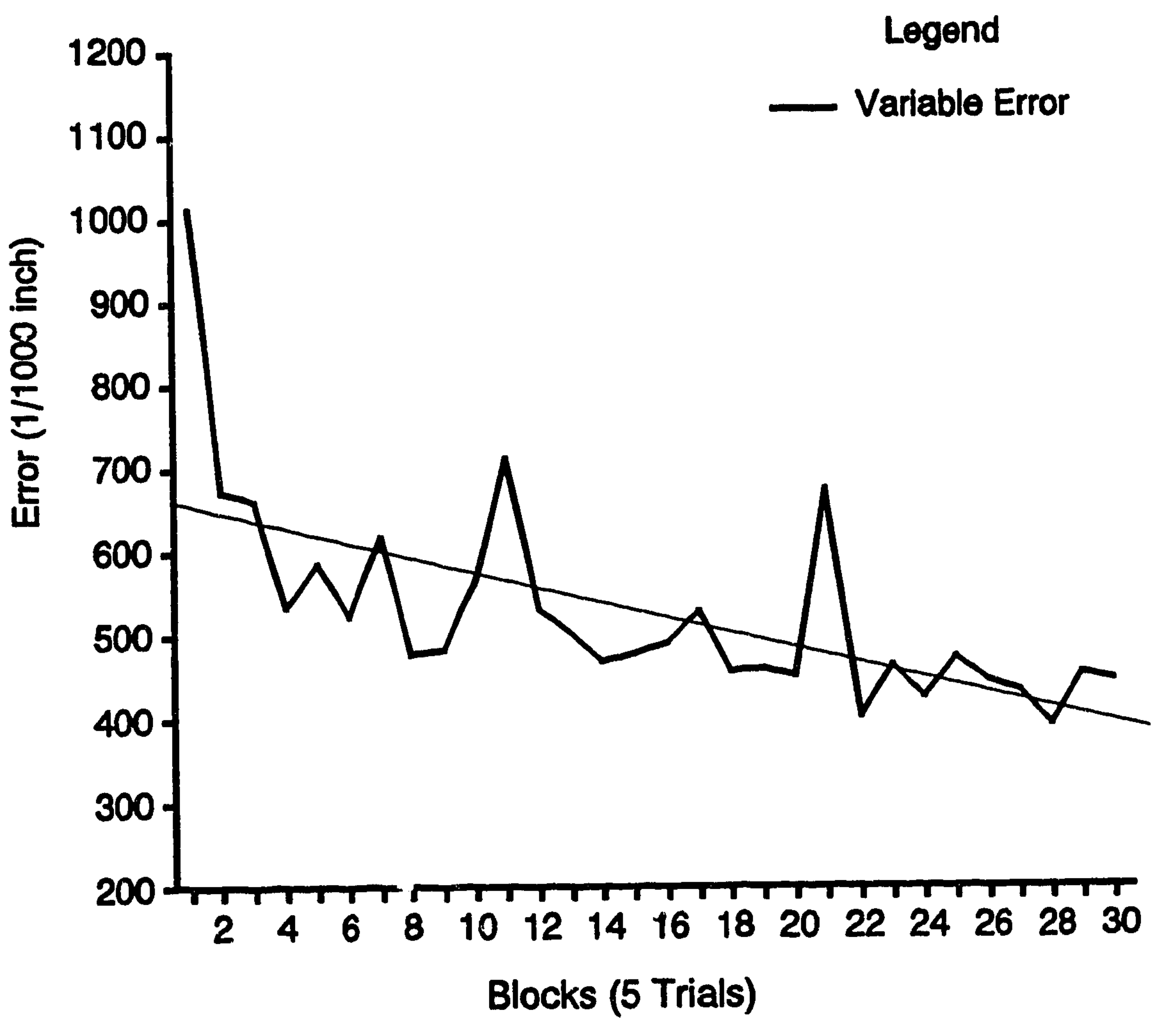

Figure 2. Experiment One - Variable error scores as a function of practice and regression line.

670.419 and b = - 9.2089 for the VE scores, respectively.

Movement time. The ANOVA yielded no significant difference in the MT scores across blocks of practice ($F(29, 812) < 1$, $p = .634$, M.S. Error = 121846.33). The regression analysis indicated the regression of MT scores on practice was not significantly different than zero ($F(1, 868) < 1$, $p > .05$, M.S. Residual = 754585.6). The data for the MTs are plotted in Figure 3.

KR-delay. The ANOVA revealed a significant main effect for the blocks of practice ($F(3.1, 86.6) = 9.72$, $p < .001$, M.S. Error = 20001.69). The data for the KR-delays are plotted in Figure 3. The post-hoc analysis indicated that this significance was due to the statistical difference of: a) Block 1 with all the other blocks, except Block 2. b) Block 2 with Blocks 8, 10, and 12 to 30. c) Blocks 3, 5, and 6 with Blocks 22 to 30. d) Block 4 with Blocks 23, 24, and 26 to 30. e) Block 7 with Block 30. f) Block 11 with Blocks 26 to 30.

The regression analysis revealed that practice significantly affected KR-delays $F(1, 868) = 63.06$, $p < .0001$, M.S. Residual = 71238.61). The intercept and the slope of the regression line were a = 746.29 and b = -8.3, respectively.

Post-KR interval. The ANOVA revealed that there

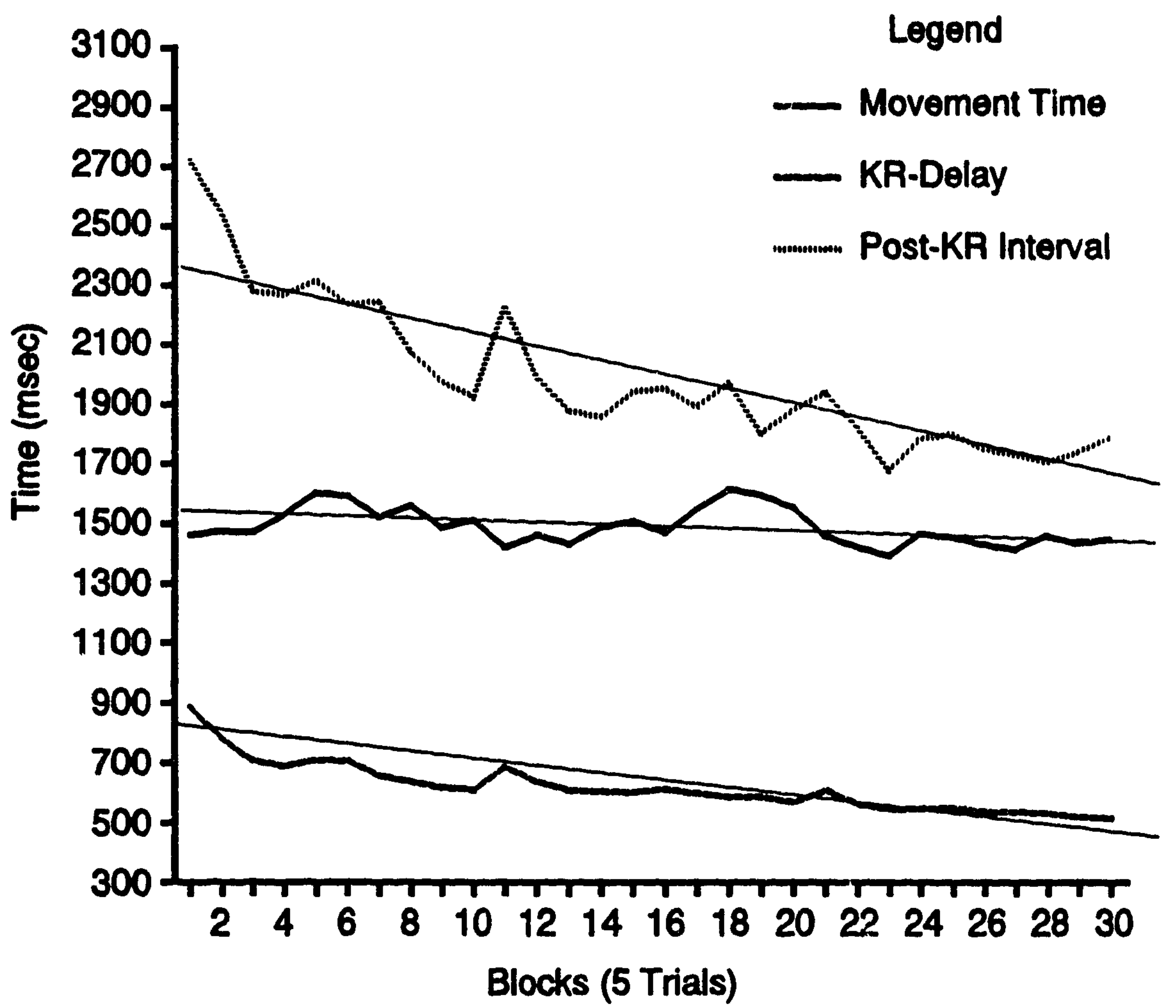

Figure 3. Experiment One - Movement time, KR-delay and post-KR intervals as a function of practice and regression lines.

was a significant main effect of blocks of practice ($F(7, 196.2) = 9.25$, $p < .001$, M.S. Error = 204489.90). The data for the post-KR intervals are plotted in Figure 3. According to the post-hoc analysis the significance arose from the following statistical differences: a) Block 1 with all blocks of practice, except Blocks 2 and 5. b) Block 2 with Blocks 8 to 30. c) Blocks 3 and 4 with Block 19, and Blocks 23 to 30. d) Block 5 with Blocks 14 and 19, and Blocks 22 to 30. e) Block 7 and 11 with Blocks 23, 24, and 27 to 30.

The regression analysis yielded a significant effect of practice on post-KR intervals $F(1, 868) = 76.76$, $p < .0001$, M.S. Residual = 552603.25). The regression line was best fitted with an intercept a = 2387.18 and a slope b = -25.51.

Intertrial interval. The ANOVA yielded a significant main effect for the blocks of practice ($F(6.3, 177.7) = 12.58$, $p < .001$, M.S. Error = 260764.87). The data for the ITIs are plotted in Figure 4. Post-hoc analysis indicated that the significance was due to the following statistical differences: a) Block 1 with all blocks of practice, except Block 2. b) Block 2 with Blocks 8 to 10, and Blocks 12 to 30. c) Block 3 with Blocks 14, 19, 20, and Blocks 22 to 30. d) Block 4 with Blocks 19 and 20, and Blocks 22 to 30. e) Block 5 with Blocks 13, 14, 17, 19 and 20, and Blocks

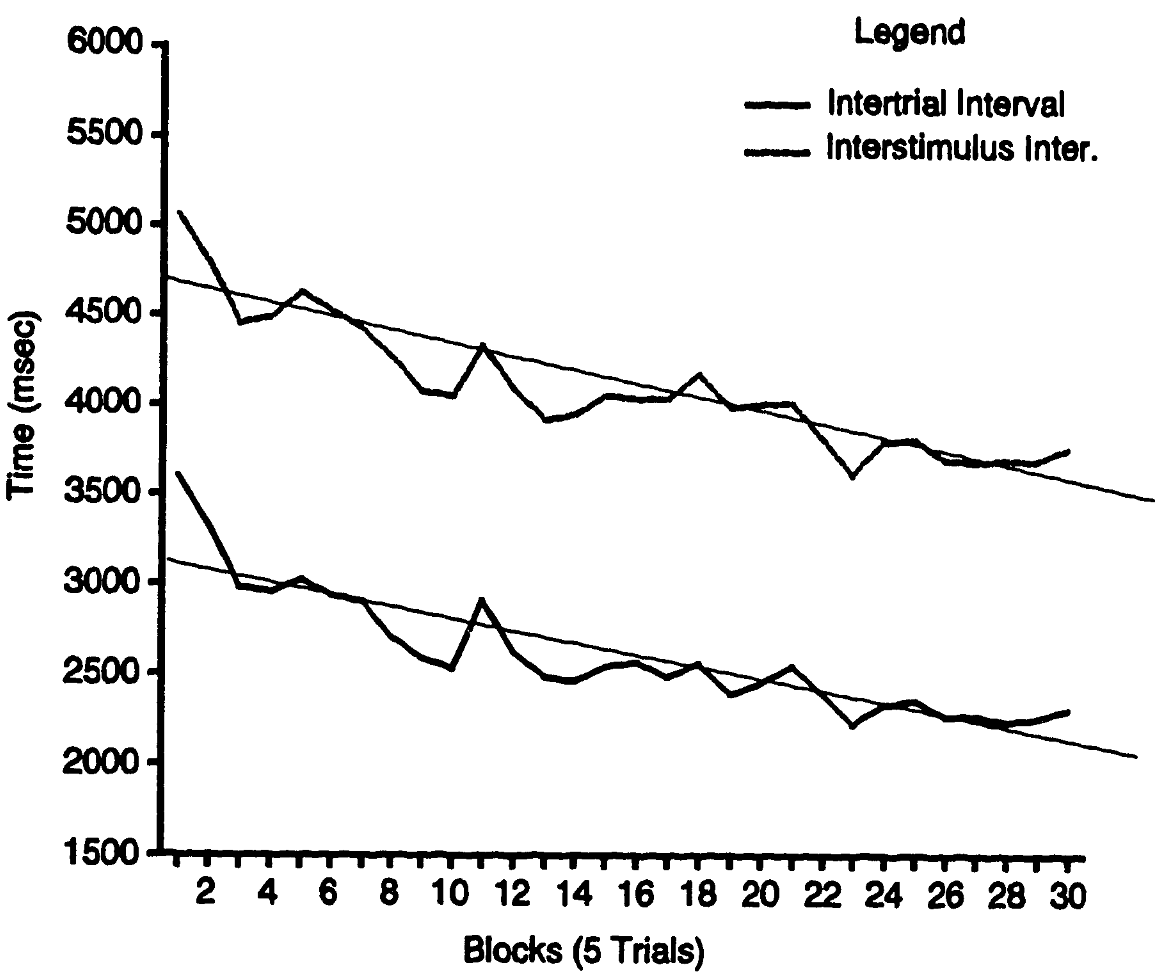

Figure 4. Experimental One - Intertrial interval and interstimulus interval as a function of practice and regression lines.

22 to 30. f) Blocks 6, 7 and 11 with Blocks 19, and 22 to 30.

The regression analysis indicated that the regression of the ITIs on the blocks of practice was significantly different than zero $F(1, 868) = 117.78$, $p < .0001$, M.S. Residual = 635980.82). The intercept and the slope on the regression line were a = 3133.95 and b = -33.9, respectively.

Interstimulus Interval. The ANOVA revealed that there was a significant main effect of blocks of practice ($F(5.1, 143) = 7.00$, $p < .01$, M.S. Error = 529543.56). The data for the ISIs are plotted in Figure 4. According to the post-hoc analysis the significance was due to the following statistical differences: a) Block 1 with Blocks 8 to 30. b) Block 2 with Blocks 13 to 17 and 19 to 30. c) Block 3 and 7 with Blocks 23 and 26 to 29. d) Block 4 with Blocks 23 and 26 to 30. e) Block 5 with Blocks 22 to 30. f) Block 6 with Blocks 23 to 30. g) Block 11 with Block 23.

The regression analysis indicated that practice significantly affected ISIs $F(1, 868) = 39.24$, $p < .0001$, M.S. Residual = 2224168.93). The regression line was best fitted with an intercept a = 4665.88 and a slope b = -36.59.

Ratio (KR-delay/post-KR interval). No significant change occurred in the ratio scores across blocks of practice (F(29, 812) < 1, p =.95, M.S. Error = 99.52). The regression analysis revealed no significant regression of practice on ratios F(1, 868) < 1, p>.05, M.S. Residual = .04798). The ratio between KR-delay and post-KR delay appeared to remain constant across blocks of practice.

Relationship among the performance scores and the temporal locus of KR. Correlations among the AE, VE, MT, KR-delay, post-KR interval, ITI, ISI and ratio revealed that AE and VE scores were correlated with post-KR interval, ITI, and ISI, while MT, KR-delay and ratio were unrelated (Table 1). Movement time was

Table 1

Pearson Correlations for AE, VE, MT, KR-delay, Post-KR Interval, ITI, ISI and Ratio (n=870)

	AE	VE	MT	KRDEL	POSTKR	ITI	ISI	RATIO
AE	--	.85	.12	.14	.27	.29	.23	-.06
VE		--	.15	.12	.31	.32	.26	-.09
MT			--	-.11	.67	.57	.89	-.52
KRDEL				--	.10	.41	.17	.70
POSTKR					--	.94	.91	-.52
ITI						--	.88	-.25
ISI							--	-.43
RATIO								--

moderately correlated with post-KR, ITI and ratio, while the KR-delay and post-KR interval were only slightly correlated.

Correlations between KR-time intervals and AE (Table 2) and VE (Table 3) suggested a subtle pattern regarding the effects of these types of errors on the post-KR interval. The strength of this pattern tended to increase slightly from Day 1 to Day 3.

Interblock correlation analyses for performance scores and KR time intervals indicated that for all KR-time intervals (MT, KR-delay, post-KR interval ITI, ISI and ratio) each block of practice is highly correlated with all the other blocks of practice. As the number of the intervening blocks increased, the correlation between any two blocks decreased, but remained significant ($p < .05$).

Table 2

Pearson Correlations for AE and KR-time Intervals across Blocks of Practice

Day 1		
	MT	10[1] (.34)[2]
	KR-Delay	5 (.34)
	Post-KR	5 (.30), 6 (.34), 7 (.53)
	Ratio	
Day 2		
	MT	11 (.51), 19 (.36)
	KR-Delay	
	Post-KR	11 (.60), 14 (.41), 15 (.39)
	Ratio	11 (-.33)
Day 3		
	MT	
	KR-Delay	30 (.34)
	Post-KR	26 (.35), 27 (.36), 29 (.39), 30 (.48)
	Ratio	

1 = Block of practice

2 = Pearson correlation

Table 3

Pearson Correlations for VE and KR-time Intervals across Blocks of Practice

Day 1		
	MT	
	KR-Delay	
	Post-KR	6[1] (.35)[2], 7 (.47), 10 (.41)
	Ratio	7 (.32), 10 (.35)
Day 2		
	MT	11 (.43), 19 (.42)
	KR-Delay	
	Post-KR	11 (.48), 14 (.34), 15 (.46), 19 (.34)
	Ratio	11 (.36)
Day 3		
	MT	25 (.33)
	KR-Delay	
	Post-KR	24 (.38), 25 (.41), 26 (.42), 27 (.32), 30 (.38)
	Ratio	24 (-.35)

1 = Block of practice

2 = Pearson correlation

Discussion

Unlike previous studies, Experiment One provided the learner with the opportunity to manipulate the time course of the task, and thus allowed for the examination of the relationship among performance (AE and VE) and self-paced KR-time intervals. The results indicate that unlike the previous experiments employing simple tasks, performance continued to improve at a constant rate throughout practice. The results further revealed that the performer did not use feedback related time intervals of equal duration throughout the course of practice in order to maintain performance characteristics. Instead, participants tended to decrease their KR-delay and post-KR intervals as their AE and VE scores decreased. Past experiments with fixed time intervals may have therefore inadvertently provided participants with more time than was necessary, or conversely, they may have provided less time than required.

Irrespective of task performance, analysis of the relationship between the post-KR interval and KR-delay intervals suggests that a complex relationship exists between these intervals. While there is an insignificant correlation between the KR-delay and post-KR intervals, the ratio between the KR-delay and post-KR interval across blocks of practice remains constant. Thus, while the KR-delay and post-KR intervals have separate functions in terms of the task, it appears that learners are more comfortable in receiving and elaborating KR using certain temporal patterns. Similarly, the MT of the task remained constant across blocks of practice regardless of task performance.

The significant changes of ITI and ISI throughout the course of practice are related to the changes that occur in the KR-delay and post-KR interval. Therefore, theories (Bilodeau & Bilodeau, 1958b; Salmoni et. al., 1984) of the facilitative effects of long and short ITIs in motor skill acquisition should account for the concurrent changes that occur in both KR-delay and post-KR interval.

In terms of task performance, small but significant correlations were found between the performance scores and post-KR interval at different points in the course of practice. That is, for certain blocks, with any change in the performance scores there was a corresponding change in the same direction of the post-KR interval. For example, if the AE and VE increased then the post-KR interval increased, if the AE and VE decreased then the post-KR interval decreased. It is unclear why these correlations are only significant for certain blocks of practice. It may be the case that these correlations represent the points that the participants use the information provided by KR. Further investigation is required to uncover the mechanisms responsible for the pattern of these correlations. Such investigation may also reveal the point at which KR is no longer required.

In a theoretical sense, changes in the AE and VE scores and post-KR interval may be related to the distinction between the surface features and the deep features of a task (Wilberg, 1991). While, improvement in the surface features are reflected in the increased accuracy and consistency in performance, it is possible that the chronological profile of KR is directly related to the development of the deep features of a task. If this is the case, examination of the chronological profile of KR delivery and the current performance may lead to more specific insight into the nature of what is learned in a KR dependent task.

In summary, four points should be made. First, under self-paced procedures the performers significantly reduce their performance errors, KR-delay and post-KR interval while leaving the temporal component of the task unaffected. Second, the ratio between the KR-delay and the post-KR interval remains unchanged. Third, any effect on ITI and ISI in motor skill acquisition should be examined in terms of the

KR-delay and post-KR interval. Fourth, the relationship between the performance scores and post-KR interval may indicate the point at which KR is no longer required.

Experiment Two

Adams (1971) and Schmidt (1975) have hypothesized that early in learning, improvements in performance during practice trials are associated with the presence of KR. During this period of time it is thought that the learners develop error detection and correction mechanisms or models of correct performance which are KR dependent. Adams' perceptual trace and Schmidt's recognition schema are dependent on the presence of KR until they develop to the point that performance can be maintained without KR.

Using KR-withdrawal paradigms investigators have verified that KR is important to performance, particularly during the early trials. Bilodeau, Bilodeau, and Schumsky (1959) had participants perform a linear positioning type task while blindfolded and withdrew KR after 0, 2, 6, and 19 acquisition trials. They concluded that learning did not occur in the absence of KR and that performance suffered even after moderate practice. Newell (1974) replicated the foregoing study and found that participants were able to maintain their performance on a rapid linear tapping task when KR was withdrawn at points later in practice, but needed KR early in practice. Similar results have been found by Adams, Goetz, and Marshall (1972), Schmidt and White (1972), and Wallace, DeOreo, and

Roberts (1976).

To date, research has been limited to examining the effects of KR-withdrawal on performance and learning in terms of performance scores such as AE, VE, constant error (CE) and absolute constant error (|CE|). The effects of KR-withdrawal on the chronological profile of KR delivery has never been examined. In Experiment One, the use of a self-paced procedure paradigm revealed that the performers did not need fixed KR-time intervals in order to improve their performance. The performers continued to increase the accuracy and consistency in performance in congruence with the chronological profile of KR delivery. Longer KR-delays and post-KR intervals were required early in practice and shorter ones later in practice. The reason the learner reduced the KR-time intervals with the concurrent improvement in performance is unclear. It may be that the performer is still learning, but the nature of what is learned is not evident.

The purpose of the second experiment was to examine the effects of KR-withdrawal on both the chronological profile of KR delivery and the performance scores. A self-paced procedure was utilized so participants could vary the chronological profile of KR delivery and a blank trial technique was used as a form of KR-withdrawal. Under the blank trial technique, participants remain without knowledge concerning number, order, and position of No-KR trials in the sequence of training. The self-paced procedure was employed in the same manner as in Experiment One. The blank trial technique was used in order to examine how the performance scores and the chronological profile of KR delivery were affected when KR was unexpectedly withdrawn. With the aforementioned techniques it may be possible to identify whether KR is useful and up to what point KR is required.

In the present study, when KR is withdrawn early in practice, performance scores should decline. At the same time, the KR-time intervals may change significantly from those KR time intervals that occur when KR is present. The literature (Adams, Goetz, and Marshall 1972; Newell, 1974; Schmidt and White, 1972; Wallace, DeOreo, and Roberts, 1976) shows that the performer still needs KR at this level of practice and more time will be needed to develop the error detection and correction mechanisms. Consequently, any withdrawal of KR at this stage of learning should have detrimental effects on both the surface and deep features of the task.

The aforementioned changes in performance scores and the KR-time intervals should continue to a point where the withdrawal of KR no longer has any effect on performance scores, KR-time intervals, or both. The development of significant relationships between performance scores and post-KR interval should indicate the point in the course of practice where the participant uses KR. That is, more error requires more processing time while less error requires less processing time. If the participants need KR at these points of practice then the removal of KR may affect performance and KR-time intervals. If KR is not required, performance and KR-time intervals should not be significantly affected.

Method

Subjects. One hundred and twenty volunteer subjects from the University of Alberta participated in the experiment. The age ranged from 18 to 43. In order to examine the effects of KR-withdrawal in performance and chronological profile of KR delivery throughout the course of practice, the subjects were randomly separated into 12 groups. Each group received 10 consecutive blank trials at a different point during practice (Table 4). The subjects were uninformed to the order, number and point at which the blank trials were given. All volunteers were required to sign a consent form (Appendix B) before participating in the study.

Apparatus and task. Same as in Experiment One.

Table 4

Presentation of Blank Trials According to Group and Block of Practice

Blocks of Practice		Groups											
		1	2	3	4	5	6	7	8	9	10	11	12
D	1	X	X	X	X	X	X	X	X	X	X	X	X
a	2	X	X	X	X	X	X	X	X	X	X	X	X
y	3	O	X	X	X	X	X	X	X	X	X	X	X
	4	O	X	X	X	X	X	X	X	X	X	X	X
1	5	X	O	X	X	X	X	X	X	X	X	X	X
	6	X	O	X	X	X	X	X	X	X	X	X	X
	7	X	X	O	X	X	X	X	X	X	X	X	X
	8	X	X	O	X	X	X	X	X	X	X	X	X
	9	X	X	X	O	X	X	X	X	X	X	X	X
	10	X	X	X	O	X	X	X	X	X	X	X	X
D	11	X	X	X	X	X	X	X	X	X	X	X	X
a	12	X	X	X	X	X	X	X	X	X	X	X	X
y	13	X	X	X	X	O	X	X	X	X	X	X	X
	14	X	X	X	X	O	X	X	X	X	X	X	X
2	15	X	X	X	X	X	O	X	X	X	X	X	X
	16	X	X	X	X	X	O	X	X	X	X	X	X
	17	X	X	X	X	X	X	O	X	X	X	X	X
	18	X	X	X	X	X	X	O	X	X	X	X	X
	19	X	X	X	X	X	X	X	O	X	X	X	X
	20	X	X	X	X	X	X	X	O	X	X	X	X
D	21	X	X	X	X	X	X	X	X	X	X	X	X
a	22	X	X	X	X	X	X	X	X	X	X	X	X
y	23	X	X	X	X	X	X	X	X	O	X	X	X
	24	X	X	X	X	X	X	X	X	O	X	X	X
	25	X	X	X	X	X	X	X	X	X	O	X	X
	26	X	X	X	X	X	X	X	X	X	O	X	X
	27	X	X	X	X	X	X	X	X	X	X	O	X
	28	X	X	X	X	X	X	X	X	X	X	O	X
	29	X	X	X	X	X	X	X	X	X	X	X	O
	30	X	X	X	X	X	X	X	X	X	X	X	O

X = KR Trials
O = KR-Withdrawal Trials

Procedure. The same procedure was followed as in Experiment One, with the exception that each group received blank trials on 2 consecutive blocks of practice. This procedure was followed in order to examine the chronological profile of KR when KR was not given. The first 2 blocks of practice for Days 1, 2, and 3 were KR-trials, and were given in order to overcome any warm-up decrement (see page 67 for definition) that may have developed over the rest period. Subjects were instructed to request KR at their own discretion. The dependent variables used in Experiment One were used here also.

Data treatment and analyses. For the analyses only three blocks of practice were used; the block of practice before KR was withdrawn (Block 1) and the two blocks of practice following KR-withdrawal (Blocks 2 and 3). However, all data were plotted by using 4 blocks of practice, 2 before KR was withdrawn and 2 when KR was withdrawn. The means and the standard deviations for all dependent variables are presented in Appendix E.

The experimental design used in Experiment Two was a 12 groups by 3 blocks of practice design with groups as the between subjects factor and blocks of practice as the within subjects factor. Appropriate ANOVAs were conducted for analyzing all the dependent variables.

The assumptions associated with the aforementioned design were tested. Tukey's post hoc analyses were used to examine any significant ($p < .05$) main effect. The interaction between groups and blocks of practice was tested with a priori contrasts (Keppel, 1991). To avoid changes on test size (i.e., Type I error) and power of the F tests associated with repeated measures designs, different error terms were calculated for each contrast (Boik, 1981; Boik & Kirk, 1968; Keppel, 1991).

In the aforementioned design, group differences were not considered as an interpretative factor since only three blocks of practice for each group were used in the analyses. These blocks of practice represented different points in the course of practice and were chosen for testing the effects of KR-withdrawal on performance scores (AE, VE) and the chronological profile of KR delivery. The a priori contrasts (Table 5) were formulated to examine the effects of KR-withdrawal in performance and the chronological profile of KR delivery. The literature (e.g., Bilodeau, Bilodeau, and Schumsky, 1959; Newell, 1974) showed that KR-withdrawal early in practice deteriorates performance. Thus, Contrasts 1, 2, 3, and 4 were formulated to test the effects of KR-withdrawal on AE, VE and KR-time intervals early in practice, when KR was withdrawn for 5 trials. The contrasts 5, 6, 7, and 8 were used to examine the effects of KR-withdrawal early in practice when KR was deprived for 5 additional trials.

Adams et al. (1972), and Newell (1974) suggested that KR-withdrawal later in practice did not affect

Table 5

A Priori Contrasts

1. Block 1 vs Block 2 of Group 1 [B1 vs B2 (G1)]
2. Block 1 vs Block 2 of Group 2 [B1 vs B2 (G2)]
3. Block 1 vs Block 2 of Group 3 [B1 vs B2 (G3)]
4. Block 1 vs Block 2 of Group 4 [B1 vs B2 (G4)]
5. Block 1 vs Block 3 of Group 1 [B1 vs B3 (G1)]
6. Block 1 vs Block 3 of Group 2 [B1 vs B3 (G2)]
7. Block 1 vs Block 3 of Group 3 [B1 vs B3 (G3)]
8. Block 1 vs Block 3 of Group 4 [B1 vs B3 (G3)]
9. Block 1 vs Block 2 of Groups 5 to 12
   [B1 vs B2 (G5-G12)]
10. Block 1 vs Block 3 of Groups 5 to 8
   [B1 vs B3 (G5-G8)]
11. Block 1 vs Block 3 of Groups 9 to 12
   [B1 vs B3 (G9-G12)]

performance significantly. In order to examine the effects of immediate KR-withdrawal (Block 2) on performance and chronological profile of KR-delivery later in practice (Days 2 and 3), Contrast 9 was formulated. However, Contrasts 10 and 11 were chosen to examine the effects of a KR-withdrawal (Block 3) later in practice after 1 and 2 days of practice, respectively.

Pearson product correlations (r) were computed to determine the overall relationship between the KR-time intervals and the AE. Because Experiment One revealed that VE scores follow the same pattern as the AE scores, VE scores were not [illegible]ed in the analysis. In order to estimate the relationship between the KR-time intervals and the AE scores for each block of practice up to the 22nd block of practice, correlational analyses were conducted for groups 9 to 12. These blocks were selected for analyses because they were not affected by the KR-withdrawal trials. Correlational analyses were not performed for blocks 23 to 30 due to the possible influence on the dependent variables of the KR-withdrawal trials. Analysis of each block of practice per group was not conducted because of the small number of subjects per group. The correlational analysis from Experiment One was used for further interpretation regarding the remaining blocks of practice.

Results

Absolute error. The results of the ANOVA of the AE data revealed that there were significant main effects for groups ($F(11, 108) = 4.54$, $p<.0001$, M.S. Error = 609638.02) and blocks of practice ($F(1.5, 167.4) = 27.23$, $p<.0001$, M.S. Error = 179838.86). The a priori contrasts (Table 6) indicated that KR-withdrawal affected performance early in practice (Contrasts 1, 2, 5, 6 and 8) and later in practice (Contrasts 10 and 11). The data for AE are plotted in Figure 5.

Tukey's post hoc analysis of the significant group main effect indicated that Group 1 was significantly different than Groups 4 to 12, and Group 2 was significantly different than Groups 5, 6, 8, 9, 10, 11 and 12. The significant main effect for the blocks of practice was related to the increase of the AE of Block 3 as compared with Blocks 1 and 2. However, Blocks 2 and 3 were not significantly different from each other.

Variable error. The ANOVA for the VE data yielded a significant main effect for groups ($F(11, 108) = 4.36$, $p<.0001$, M.S. Error = 157600.93), while the main effect for the blocks of practice did not achieve statistical significance ($F(1.8, 191.3) = 2.64$, $p>.05$, M.S. Error = 79745.79). The a priori contrasts for the interaction (Table 7) indicated that KR-withdrawal

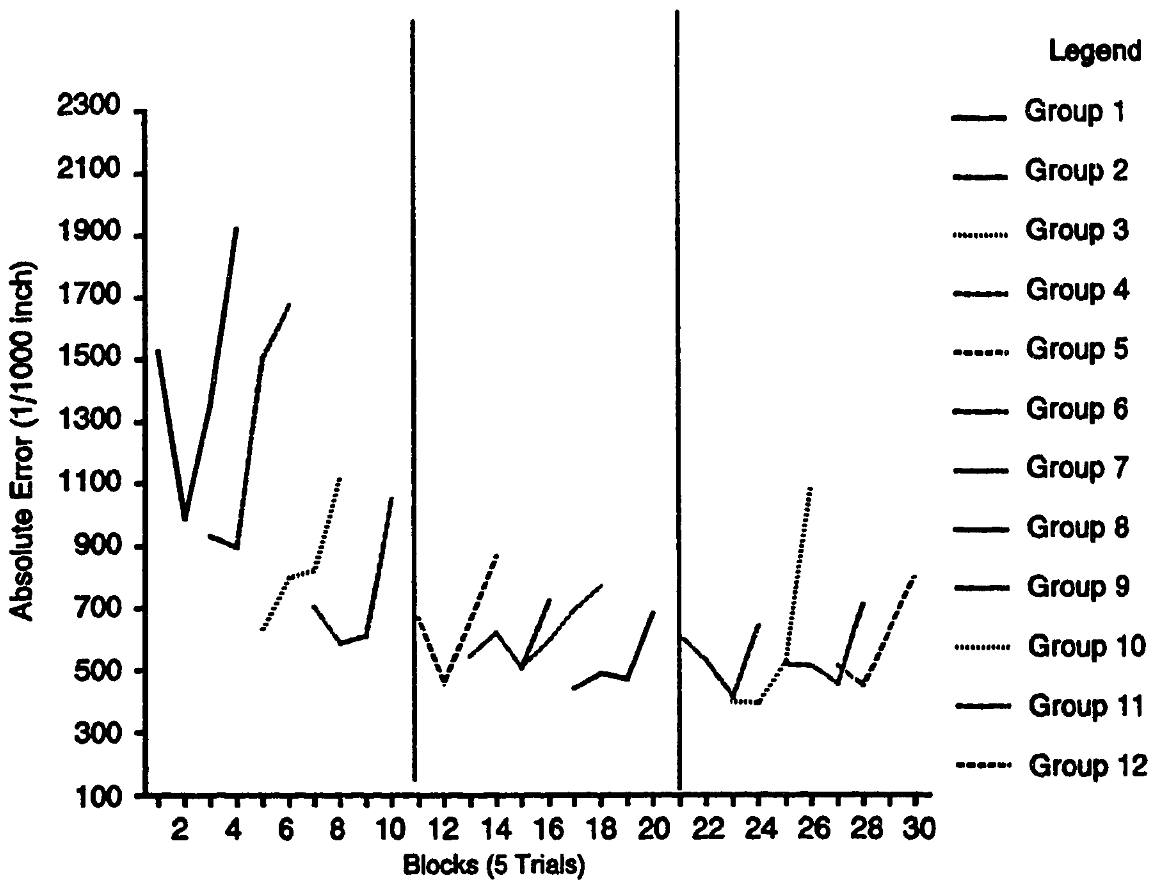

Figure 5. Experiment Two - Absolute error scores as a function of practice and KR-withdrawal.

Table 6

Summary ANOVA for the Absolute Error (AE) Scores (A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	664957.53	1	6.80	<.05
	Error	97776.36	9		
2.	B1 vs B2 (G2)	1841089.1	1	4.48	<.07
	Error	411259.19	9		
3.	B1 vs B2 (G3)	2259.94	1	< 1	N.S.
	Error	72400.41	9		
4.	B1 vs B2 (G4)	2803.72	1	< 1	N.S.
	Error	91886.99	9		
5.	B1 vs B3 (G1)	4342639.2	1	6.64	<.05
	Error	654331.18	9		
6.	B1 vs B3 (G2)	3027811.3	1	3.19	<.11
	Error	949215.23	9		
7.	B1 vs B3 (G3)	507637.5	1	2.54	N.S.
	Error	200152.59	9		
8.	B1 vs B3 (G4)	1064203.8	1	3.82	<.09
	Error	278426.54	9		
9.	B1 vs B2 (G5-G12)	53868.42	1	< 1	N.S.
	Error	67169.44	72		
10.	B1 vs B3 (G5-G8)	944951.08	1	6.87	<.02
	Error	137532.63	36		
11.	B1 vs B3 (G9-G12)	2237019.2	1	15.32	<.0003
	Error	146003.26	36		

Table 7

Summary ANOVA for the Variable Error (VE) Scores A Priori Contrasts

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	10451.21	1	< 1	N.S.
	Error	93334.22	9		
2.	B1 vs B2 (G2)	14221.05	1	< 1	N.S.
	Error	[illegible]	9		
3.	B1 vs B2 (G3)	72196.69	1	2.17	N.S.
	Error	33257.03	9		
4.	B1 vs B2 (G4)	175724.31	1	6.85	<.05
	Error	25654.52	9		
5.	B1 vs B3 (G1)	102701.57	1	< 1	N.S.
	Error	654331.18	9		
6.	B1 vs B3 (G2)	307.86	1	< 1	N.S.
	Error	227122.51	9		
7.	B1 vs B3 (G3)	113634.81	1	1.55	N.S.
	Error	73197.72	9		
8.	B1 vs B3 (G4)	843.2	1	< 1	N.S.
	Error	110096.22	9		
9.	B1 vs B2 (G5-G12)	252785.63	1	5.98	<.05
	Error	42278.13	72		
10.	B1 vs B3 (G5-G8)	307173.97	1	6.92	<.05
	Error	44404.47	36		
11.	B1 vs B3 (G9-G12)	.112	1	< 1	N.S.
	Error	133377.35	36		

produced more consistent performance when KR was not present at the eighth block of practice (Contrast 4). The withdrawal of KR on the second day created less variable performance (Contrasts 9 and 10), while on the third day the participants were more consistent only for the first block of KR-withdrawal (Contrast 10). The data for VE are plotted in Figure 6.

Post hoc analysis (Tukey) of the significant group main effect showed that Group 2 was significantly different than Groups 3 to 12.

Movement time. The ANOVA revealed no significant differences in the MT scores for groups ($F(11, 108) = 1.37$, $p > .05$, M.S. Error = 1974800) and blocks of practice ($F(1.9, 206.2) < 1$, $p > .05$, M.S. Error = 47496.54). The contrasts of the interaction indicated that MT decreased significantly when KR was withdrawn after 40 trials of practice (Contrasts 4). MT also decreased when KR remained absent for 5 additional trials (Contrasts 5 and 8) early in practice (Table 8). The data for MT scores are plotted in Figure 7.

KR-delay. The ANOVA indicated that there were no significant differences among groups ($F(11, 108) = 1.19$, $p > .05$, M.S. Error = 325362.09) and blocks of practice ($F(1.9, 202) = 3.07$, $p > .05$, M.S. Error = 6181.38). The contrasts of the interaction (Table 9) indicated that the withdrawal of KR increased the KR-

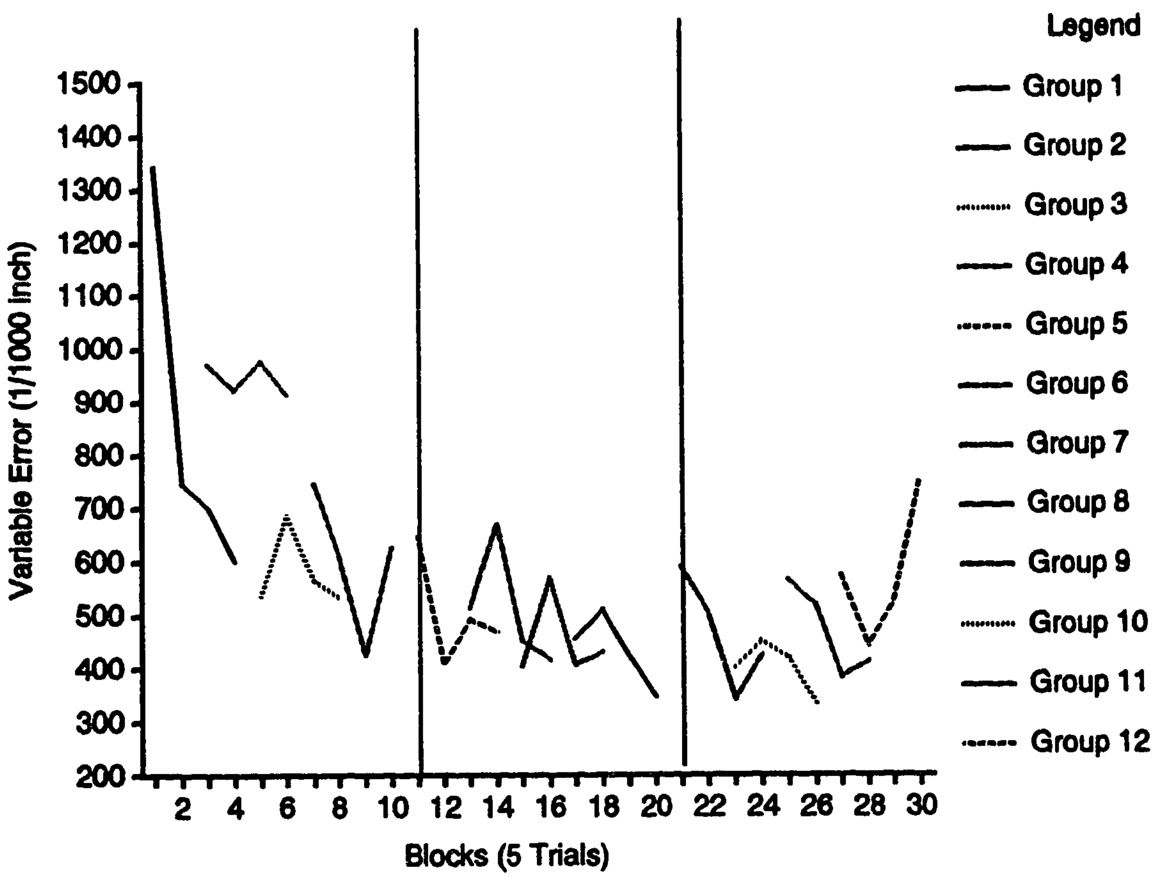

Figure 6. Experiment Two - Variable error scores as a function of practice and KR-withdrawal.

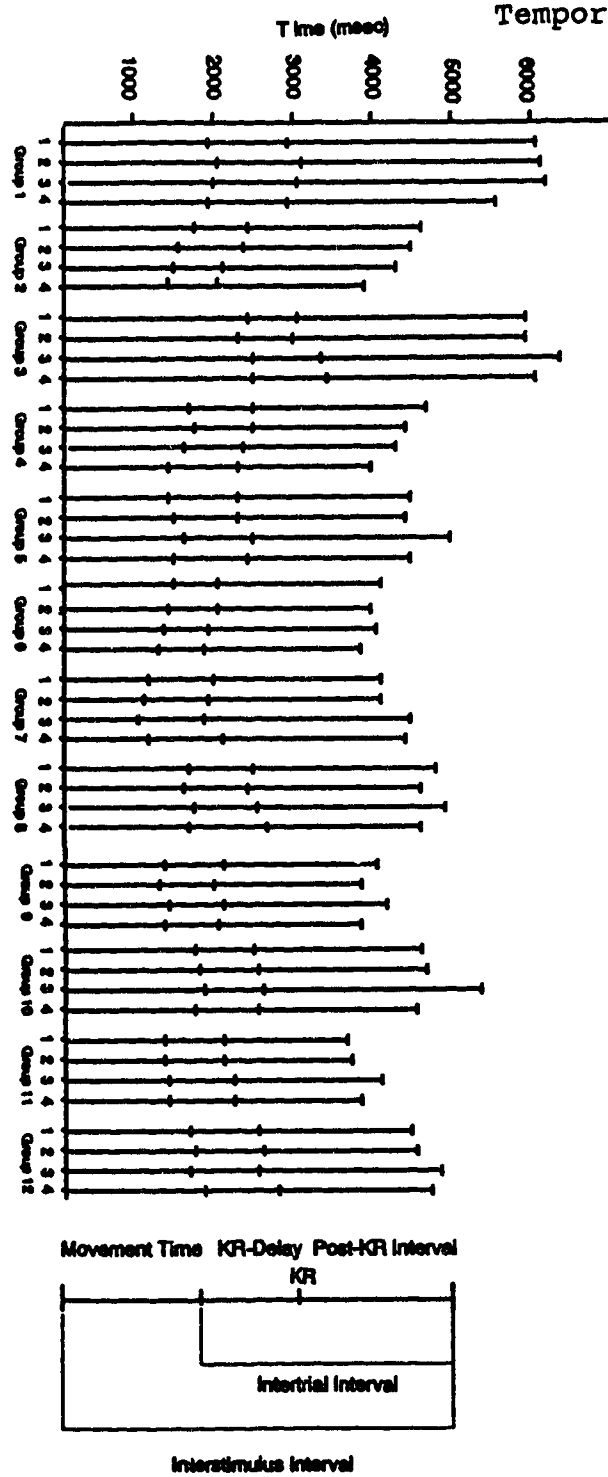

Figure 7. Experiment Two - The chronological profile of KR-delivery as a function of practice and KR withdrawal.

Table 8

Summary ANOVA for the Movement Time (MT) Scores (A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	30842.72	1	< 1	N.S.
	Error	63570.16	9		
2.	B1 vs B2 (G2)	155655.39	1	2.74	N.S.
	Error	56775.15	9		
3.	B1 vs B2 (G3)	184665.21	1	1.38	N.S.
	Error	134083.82	9		
4.	B1 vs B2 (G4)	231598.28	1	5.15	<.05
	Error	44945.76	9		
5.	B1 vs B3 (G1)	274623.13	1	3.78	<.1
	Error	72720.89	9		
6.	B1 vs B3 (G2)	171199.08	1	1.25	N.S.
	Error	136611.96	9		
7.	B1 vs B3 (G3)	128160.13	1	1.39	N.S.
	Error	92413.15	9		
8.	B1 vs B3 (G4)	549925.42	1	4.95	<.05
	Error	110096.22	9		
9.	B1 vs B2 (G5-G12)	43401.81	1	1.81	N.S.
	Error	24024.80	72		
10.	B1 vs B3 (G5-G8)	513.08	1	< 1	N.S.
	Error	23041.52	36		
11.	B1 vs B3 (G9-G12)	49770.27	1	1.06	N.S.
	Error	46911.94	36		

Table 9

Summary ANOVA for KR-delay (A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	2358.8	1	< 1	N.S.
	Error	13152.37	9		
2.	B1 vs B2 (G2)	22311.19	1	1.51	N.S.
	Error	14763.49	9		
3.	B1 vs B2 (G3)	11606.54	1	1.76	N.S.
	Error	6585.44	9		
4.	B1 vs B2 (G4)	758.91	1	< 1	N.S.
	Error	3514.66	9		
5.	B1 vs B3 (G1)	24696.43	1	1.86	N.S.
	Error	13246.51	9		
6.	B1 vs B3 (G2)	4158.73	1	2.60	N.S.
	Error	1600.26	9		
7.	B1 vs B3 (G3)	28773.71	1	< 1	N.S.
	Error	31501.89	9		
8.	B1 vs B3 (G4)	15825.94	1	1.30	N.S.
	Error	12189.11	9		
9.	B1 vs B2 (G5-G12)	29642.55	1	12.72	<.001
	Error	2331.24	72		
10.	B1 vs B3 (G5-G8)	5584.49	1	1.75	N.S.
	Error	3199.47	36		
11.	B1 vs B3 (G9-G12)	49074.26	1	10.29	<.005
	Error	4768.18	36		

delay later in practice when Block 1 was compared with Block 2 (Contrasts 9) and Block 1 with Block 3 (Contrast 11). The KR-delays are plotted in Figure 7.

Post-KR interval. The ANOVA yielded significant main effects for groups ($F(11, 108) = 2.45$, $p<.05$, M.S.Error = 1641400) and blocks of practice ($F(1.9, 209) = 22.91$, $p<.0001$, M.S. Error = 118263.29). The a priori contrasts (Table 10) indicated that the post-KR interval increased significantly when KR was withdrawn later in practice (Contrast 9). Interestingly, the post-KR interval decreased when KR was removed for five additional trials at the end of the first day (Contrast 8). The data for the post-KR intervals are plotted in Figure 7.

Tukey's post hoc analysis showed that the significant main effect for groups was due to the statistical difference of Group 11 with Groups 1 and 3. The blocks of practice were significantly different from each other. The first KR-withdrawal block of practice increased the post-KR interval while the second KR-withdrawal block of practice decreased the post-KR interval when compared with the first block of practice.

Intertrial interval. The ANOVA yielded significant main effects for groups ($F(11, 108) = 2.78$, $p<.05$, M.S. Error = 2228700) and blocks of practice ($F(1.9, 206.7)$

Table 10

Summary ANOVA for the Post-KR Interval (A Priori Contrasts)

Source	MS. Error	df	F	p
1. B1 vs B2 (G1)	79304.28	1	< 1	N.S.
Error	201394.02	9		
2. B1 vs B2 (G2)	14034.42	1	< 1	N.S.
Error	110569.22	9		
3. B1 vs B2 (G3)	9723.77	1	< 1	N.S.
Error	219515.11	9		
4. B1 vs B2 (G4)	45715.94	1	< 1	N.S.
Error	69495.87	9		
5. B1 vs B3 (G1)	788601.05	1	3.11	N.S.
Error	253208.40	9		
6. B1 vs B3 (G2)	322224.52	1	2.70	N.S.
Error	118848.13	9		
7. B1 vs B3 (G3)	152950.14	1	< 1	N.S.
Error	181756.66	9		
8. B1 vs B3 (G4)	830770.20	1	3.99	<.1
Error	208331.85	9		
9. B1 vs B2 (G5-G12)	2363000.00	1	20.76	<.001
Error	113830.60	72		
10. B1 vs B3 (G5-G8)	14596.22	1	< 1	N.S.
Error	70160.28	36		
11. B1 vs B3 (G9-G12)	38272.47	1	< 1	N.S.
Error	134928.45	36		

Table 11

Summary ANOVA for the Intertrial Interval (A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	54309.04	1	< 1	N.S.
	Error	190033.97	9		
2.	B1 vs B2 (G2)	7785.54	1	< 1	N.S.
	Error	146416.69	9		
3.	B1 vs B2 (G3)	58622.59	1	< 1	N.S.
	Error	207204.65	9		
4.	B1 vs B2 (G4)	58255.23	1	< 1	N.S.
	Error	65975.35	9		
5.	B1 vs B3 (G1)	1092400.00	1	4.11	<.1
	Error	265973.83	9		
6.	B1 vs B3 (G2)	475368.50	1	3.34	=.10
	Error	142250.38	9		
7.	B1 vs B3 (G3)	34478.00	1	< 1	N.S.
	Error	297774.57	9		
8.	B1 vs B3 (G4)	617269.11	1	3.60	<.1
	Error	171289.07	9		
9.	B1 vs B2 (G5-G12)	2911200.00	1	22.70	<.001
	Error	128252.39	72		
10.	B1 vs B3 (G5-G8)	38237.15	1	< 1	N.S.
	Error	86681.32	36		
11.	B1 vs B3 (G9-G12)	670.49	1	< 1	N.S.
	Error	150938.15	36		

= 19.99, p<.0001, M.S. Error = 131191.11). The a priori contrasts showed significance in the same direction as the post-KR interval contrasts (Table 11). Early in practice ITIs decreased when KR was removed for 10 trials (Contrasts 5, 6, and 8). However, later in practice under the KR-withdrawal condition ITIs increased when Block 1 was compared with Block 2 (Contrast 9). The data for the ITIs are plotted in Figure 7.

Tukey's post hoc analysis of the groups main effect indicated that Group 1 was different than Group 11, and Group 3 than Groups 8 and 11. The significance of the main effect of blocks of practice was due to the increase of the ITI on the first KR-withdrawal block of practice and the decrease of the ITI on the second KR-withdrawal block of practice. Blocks 1 and 3 were not significantly different from each other.

Interstimulus interval. The ANOVA revealed that there were significant main effects of groups (F(11, 108) = 2.15, p<.05, M.S. Error = 7274000), and blocks of practice (F(1.8, 198.2) = 14.50, p<.001, M.S. Error = 214265.46). The a priori contrasts (Table 12) revealed that the ISI increased significantly when Block 1 was compared with Block 2 later in practice (Contrast 9). When KR was removed for 5 additional trials (Block 3) early in practice, ISIs decreased

Table 12

Summary ANOVA for the Interstimulus Interval (A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	6874.43	1	< 1	N.S.
	Error	227074.20	9		
2.	B1 vs B2 (G2)	233494.99	1	< 1	N.S.
	Error	298923.03	9		
3.	B1 vs B2 (G3)	451379.40	1	< 1	N.S.
	Error	226980.12	9		
4.	B1 vs B2 (G4)	57545.91	1	< 1	N.S.
	Error	135791.58	9		
5.	B1 vs B3 (G1)	2383100.00	1	5.53	<.05
	Error	430556.85	9		
6.	B1 vs B3 (G2)	1217155.22	1	2.58	N.S.
	Error	472201.27	9		
7.	B1 vs B3 (G3)	29690.76	1	< 1	N.S.
	Error	546348.63	9		
8.	B1 vs B3 (G4)	2332400.00	1	6.27	<.05
	Error	372103.38	9		
9.	B1 vs B2 (G5-G12)	3677600.00	1	21.87	<.001
	Error	168147.17	72		
10.	B1 vs B3 (G5-G8)	47609.63	1	< 1	N.S.
	Error	131139.28	36		
11.	B1 vs B3 (G9-G12)	61993.64	1	< 1	N.S.
	Error	248719.34	36		

significantly after practising 10 and 40 KR-trials (Contrasts 5 and 8). The data for the ISIs are plotted in Figure 7.

Tukey's post hoc analysis did not locate any significant differences among the different groups. The significant main effect of blocks of practice was reflected in the significant increase in the ISI for the first KR-withdrawal block of practice and the decrease of the ISI for the second KR-withdrawal block of practice. Blocks 1 and 3 were not significantly different from each other.

Ratio (KR-delay/Post-KR interval). The ANOVA yielded a significant main effect of blocks of practice ($F(1.8, 190.2) = 19.13$, $p<.001$, M.S. Error = 0.0024), while the twelve groups were not significantly different from each other ($F(11, 108) = 1$, $p>.05$, M.S. Error = 0.11). The a priori contrasts (Table 13) revealed a significant decrease in the ratio used when Block 1 was compared to Block 2 later in practice (Contrast 9). The deprivation of KR for 5 additional trials early in practice created an increase in ratio after practising 40 KR-trials that approached statistical significance (Contrast 8). Post hoc analysis for the main effect of blocks of practice revealed that all blocks were significantly different from each other. This significance was achieved by a

Table 13

Summary ANOVA for the Ratio (KR-delay/Post-KR Interval)

(A Priori Contrasts)

	Source	MS. Error	df	F	p
1.	B1 vs B2 (G1)	.003585	1	< 1	N.S.
	Error	.003705	9		
2.	B1 vs B2 (G2)	.000549	1	< 1	N.S.
	Error	.003606	9		
3.	B1 vs B2 (G3)	.000771	1	< 1	N.S.
	Error	.005664	9		
4.	B1 vs B2 (G4)	.001348	1	< 1	N.S.
	Error	.002887	9		
5.	B1 vs B3 (G1)	.000603	1	< 1	N.S.
	Error	.005192	9		
6.	B1 vs B3 (G2)	.009688	1	< 1	N.S.
	Error	.009811	9		
7.	B1 vs B3 (G3)	.001527	1	1.52	N.S.
	Error	.001003	9		
8.	B1 vs B3 (G4)	.03	1	3.72	<.1
	Error	.006897	9		
9.	B1 vs B2 (G5-G12)	.02	1	25.49	<.001
	Error	.000838	72		
10.	B1 vs B3 (G5-G8)	.000505	1	< 1	N.S.
	Error	.001331	36		
11.	B1 vs B3 (9-G12)	.003628	1	< 1	N.S.
	Error	.002777	36		

decrease in the ratio of the first KR-withdrawal block of practice (*M* = .328) when compared with the block of practice when KR was present (*M* = .349) and with the second KR-withdrawal block of practice (*M* = .37).

Correlational analysis. The correlational analysis between the KR-time intervals and AE, after adjusting the data according to each group's mean, indicated that AE is slightly correlated with all KR-time intervals (KR-delay, Post-KR interval, ITI, and ISI), while MT is highly correlated with the post-KR interval (Table 14). It should be noted, that the KR-withdrawal trials were included in this analysis.

The second correlational analysis between AE scores and post-KR intervals up to the 22th block of practice indicated that a relationship developed early in practice and reached its highest value at the eighth block of practice (Table 15). Interestingly, a significant correlation was observed on the first block of practice on the second day.

Table 14

Pearson Correlations for AE, MT, KR-delay, Post-KR Interval, ITI, ISI and Ratio (n=3600)

	AE	MT	KRDEL	POSTKR	ITI	ISI	RATIO
AE	--	.08	.20	.23	.27	.20	.03
MT		--	.12	.72	.67	.90	-.38
KRDEL			--	.21	.50	.35	.69
POSTKR				--	.95	.92	-.45
ITI					--	.93	-.18
ISI						--	-.30
RATIO							--

Table 15

Significant Correlations $p<0.05$ Between AE and Post-KR Interval for the First 22 Blocks of Practice (n=40)

$3^1(.46)^2$	4(.42)	7(.58)	8(.65)	11(.37)

1 = Block of Practice

2 = Pearson Correlation

Discussion

Performance scores. The findings from Experiment Two, regarding performance as measured by AE scores were in agreement with Adams, Goetz, and Marshall (1972), Newell (1974), Schmidt and White (1972), and Wallace, DeOreo, and Roberts (1976). Performance decreased significantly when KR was withdrawn early in practice, but it was not affected when KR was removed after 30 and 40 trials of practice for at least five no-KR trials. The deprivation of KR for five additional trials (Block 3) decreased performance significantly throughout the course of practice except the sixth and eighth block of practice.

Examining the effects of KR-withdrawal later in practice, it was found that the participants retained the same level of performance for the first five no-KR trials. The deprivation of KR for five additional trials created an overall deterioration in performance for Days 2 and 3. However, this finding does not confirm the hypothesis regarding the importance of KR throughout practice because all second blocks of KR-withdrawal (Block 3) for Days 2 and 3 were included in the analysis. The significance achieved was due to the compounding effect of the second KR-withdrawal block of practice. Further analysis of the AE scores for Days 2 and 3 regarding the second KR-withdrawal block of practice indicated that the significant difference was achieved by Group 5 on Day 2, and Groups 10 and 12 on Day 3, respectively.

The analysis of the VE scores indicated that, early in practice, the participants were performing at the same level of consistency even when KR was withdrawn for five or ten acquisition trials. Interestingly, VE scores indicated that later in practice, the participants were less variable in their performance when KR was withdrawn for five trials (Days 2 and 3) and ten trials (Day 2). However, the same trend was noticed early in practice only for the eighth block of practice when KR was withdrawn for five trials. This may be the case because the participants are likely to choose the plan of action for the next response according to their conception of the task and the knowledge gained from the presence of KR.

The chronological profile of KR-delivery. The findings regarding the KR-time intervals from Experiment Two indicated that MT, KR-delay and post-KR interval were affected differently during the early and later stages of practice. It should be noted, however, that the ITI and the ISI are not examined independently since they are derived directly from MT, KR-delay and post-KR interval.

Early in practice when KR was withdrawn for five trials, the participants decreased MT significantly after 40 KR-trials. At the same time, the KR-delay and the post-KR interval remained unchanged. After practising for five additional no-KR trials, participants maintained the same KR-delays as when KR was present, and they decreased MT after 10 and 40 KR-trials and post-KR interval after 40 KR-trials.

These changes in the chronological profile of KR-delivery early in practice indicated that the participants did not develop a strong reference mechanism in order to perform successfully under the KR-withdrawal condition. The inability to access KR and the existence of a weak reference mechanism led participants to decrease MT and post-KR interval.

Later in practice when KR was withdrawn for five trials, MT remained unchanged while KR-delay and post-KR interval increased significantly. The deprivation of KR for five additional trials created a significant increase in KR-delay for Day 3, while post-KR interval and MT remained constant. According to Swinnen (1988, 1990) during the KR-delay the participants use an error detection mechanism for estimating their performance. The increase of KR-delay in the same direction for most of the groups (5, 7, 9, 10, 11, 12) under no-KR conditions may indicate that the participants use the already developed error detection mechanism. It should be noted, however, that an additional analysis of the KR-delays at this stage of learning indicated that the significance achieved was due to the increase in KR-delay for Groups 11 and 12 on Day 3.

Regarding the post-KR interval, the participants at this later stage of learning developed a strong error correction mechanism. The increase in the post-KR interval after five KR-withdrawal trials indicates that the participants need some extra time to formulate the appropriate plan of action for the next response. This plan of action is formed according to the estimation provided to the participant during the KR-delay and the representation of the task already developed. Continued practising without the presence of KR for five additional trials led participants to return to the same post-KR intervals that occurred when KR was present. It should be noted, however, that additional analyses on the post-KR intervals between the last acquisition block (Block 1) and the first KR-withdrawal block of practice (Block 2) revealed that the significance achieved was due to the significant increase of the post-KR interval by Groups 5, 7 and 8 on Day 2, and Groups 11 and 12 on Day 3.

All groups used the same KR-delay with post-KR interval ratio for performing the task, however, when KR was withdrawn there was a decrease in this ratio.

The change in the ratio corresponded more to the significant increase in the post-KR interval than to the KR-delay throughout practice.

Relationship between performance scores and the temporal locus of KR. The results of the overall correlational analyses of the KR-time intervals and the AE scores were similar to the results found in Experiment One. Examination of the correlations up to the 22nd block of practice showed that there was a gradually increasing positive relationship between the post-KR interval and AE scores that reached its highest value at the eighth block of practice. This indicates that during the initial stages of learning, even though performance may approach an asymptote very early for a simple positioning task (first five trials, Experiment One), the participants still need KR. The high correlation between the AE scores and the post-KR intervals at the eighth block of practice may indicate the development of an error correction mechanism. It is possible that at this point of practice, participants can be transferred to a similar task without affecting any of the developed surface and/or deep features of the task.

The reappearance of the positive relationship during the first block of practice on the second day is an indication of the necessity of KR at the beginning of the practice trials. Adams (1952, 1961) suggested that learners have a loss in motor performance when they perform the task after an intervening retention interval. This phenomenon is called warm-up decrement. In order to interpret the warm-up phenomenon, Schmidt (1988) suggested that this decrement "is related to the loss of some temporary internal state(s), or set, that underlies and supports the skill in question" (pp. 509). It can be postulated that at this point the participants recruit and retest the already developed error correction mechanism. The break down of this relationship may indicate that KR is no longer required and that participants have learned the surface and deep features of the task. At this level of proficiency participants can perform errorlessly without the presence of KR.

Experiment Three

According to Schmidt and Young (1987), one way of assessing whether learning has taken place is to transfer participants from a practice task to a similar but different task. Transfer of learning in this instance has been defined by Magill (1989) as "the influence of having previously practiced a skill or skills on the learning of a new skill" (pp. 369).

To date, researchers have not combined transfer of learning paradigms with self-paced procedures in investigations of learning, although such a combination may provide more specific insight into the nature of what is learned. For example, it may be that participants not only learn and transfer knowledge regarding the performance characteristics of a task (the surface features), but they may also learn and transfer knowledge regarding how to adjust and utilize the chronological profile of KR-delivery (the deep features) in order to further elaborate and process the information provided by KR.

The purpose of Experiment Three was to examine what is learned and transferred regarding the surface and deep features of the criterion task using a transfer task and a self-paced procedure. Based on the results of Experiments One and Two, five durations of practice were specifically selected to examine what can be transferred to a new task after these amounts of practice: Block 8 (Day 1), Block 15 (Day 2), Block 20 (Day 2), Block 25 (Day 3), Block 30 (Day 3).

Across these 5 points in practice when KR was present, accuracy (AE), consistency (VE), and the chronological profile of KR-delivery were at the same levels of performance. However, the withdrawal of KR in Experiment Two affected these points in practice differently (Table 16). At Block 8 (Day 1) the KR-time

Table 16

Performance Characteristics of the Selected Points when KR was Withdrawn in Experiment Two

	Group 1	Group 2	Group 3	Group 4	Group 5
AE	same	same	same	increased	increased
VE	same	same	same	increased	increased
MT	same	same	same	same	same
KR-Delay	same	same	same	same	increased
Post-KR	same	same	increased	same	increased

intervals and the performance scores did not change significantly when KR was withdrawn. Moreover, both Experiments One and Two revealed that a high positive relationship developed between the AE error scores and the post-KR interval at this point. At Block 15 (Day 2), again the KR-time intervals and the performance scores did not change significantly when KR was withdrawn, but no significant correlation was present between performance scores and the post-KR interval as previously (Block 11). At Block 20 (Day 2), KR withdrawal did not lead to changes in the performance scores, MT and KR-delay, however, the post-KR interval increased significantly. KR-withdrawal at Block 25 (Day 3) did not significantly affect any of the KR-time intervals but performance scores changed significantly. Notably, Experiment One revealed that at this point a positive relationship reappeared between the post-KR interval and the performance scores. At Block 30 (Day 3), the performance scores and all of the KR-time intervals except the MT changed significantly and the relationship between the post-KR interval and the performance scores continued to be significant. Exploration of what task features are transferred to a new task after these 5 points in practice may clarify what is learned during the criterion task.

Method

Subjects. Fifty volunteer subjects from the University of Alberta participated in the experiment and were randomly assigned into 5 groups. The age ranged from 20 to 45. All volunteers were required to sign a consent form (Appendix B) before participating in the study.

Apparatus, task and transfer task. The same apparatus and criterion task (8 inch line) were used as in Experiments One and Two. The transfer task (task B) was defined as a 10 inch line that the subjects had to find by performing a linear tapping task from right to left. Therefore, the transfer task was different than the criterion task in 2 dimensions, the distance and the direction.

Procedure. The same procedure developed for Experiment One was followed in the third experiment. Again the subjects were instructed to request KR at their own discretion. However, the groups were transferred to task B after practising 40, 75, 100, 125, and 150 KR-trials on the criterion task. Following the completion of the assigned acquisition trials the subjects were given a 2 minute rest. During this time interval it was explained to them that next they would perform the transfer task which was different than the criterion in length and direction. Each transferred group perform 5 KR-trials following the same procedures as in Experiments One and Two. The dependent variables used in Experiments One and Two were used here also.

Data treatment and analysis. Two blocks of practice were used for the analyses; the last block of criterion task practice (Block 1) and the block of the transfer trials (Block 2). The data were plotted using 5 blocks of practice. These were the first and the last two blocks of practice on the criterion task and the block of practice on the transfer task. The means and the standard deviations are presented in Appendix F.

The experimental design used in Experiment Three was a 5 X 2 (groups X blocks of practice) design with repeated measures on the last factor. Appropriate ANOVAS were conducted to analyze all dependent variables. In order to examine the effects from terminal acquisition of the criterion task (Block 1) on the initial phase of transfer (Block 2), a priori contrasts were conducted for each group separately for all dependent variables. The assumptions made and tested in Experiment Two were used here as well.

Results

Absolute error and variable error. The results of the ANOVA revealed significant main effects for groups ($F(4, 45) = 2.96$, $p < .05$, *M.S. Error* = 106599.56), ($F(4, 45) = 3.36$, $p < .05$, *M.S. Error* = 166611.13) and blocks of practice (_F_(1, 45) = 24.72, _p_<.001, _M.S. Error_ = 108962.86), (_F_(1, 45) = 27.85, _p_<.001, _M.S. Error_ = 127885.27) for AE and VE scores, respectively. The data for the AE and VE scores are plotted in Figures 8 and 9, respectively. The a priori contrasts (Tables 17, 18) indicated that for Groups 1, 3 and 5, performance as measured by AE and VE scores, declined at the transfer phase when compared with the terminal acquisition block of practice. Groups 2 and 4 performed the transfer task at the same level of accuracy as the criterion task. However, Group 4 did not achieve the same level of consistency on the transfer task as they did on the criterion (_p_<.10).

Movement time. The ANOVA yielded no significant differences for the groups (_F_(4, 45) < 1, _p_>.05, _M.S. Error_ = 935332.82), the blocks of practice (_F_(1, 45) < 1, _p_>.05, _M.S. Error_ = 77069.75), and the a priori contrasts (Table 19). The data for the MT scores are plotted in Figure 10.

KR-delay. The ANOVA revealed significant main effects for groups (_F_(4, 45) = 4.67, _p_<.05, _M.S. Error_ = 152503.84) and blocks of practice (_F_(1, 45) = 4.41, _p_<.05, _M.S. Error_ = 63721.97). The data for the KR-delays are plotted in Figure 11. The analyses of the a priori contrasts (Table 20) indicated that the participants for Group 1, 2, and 4 maintained the same

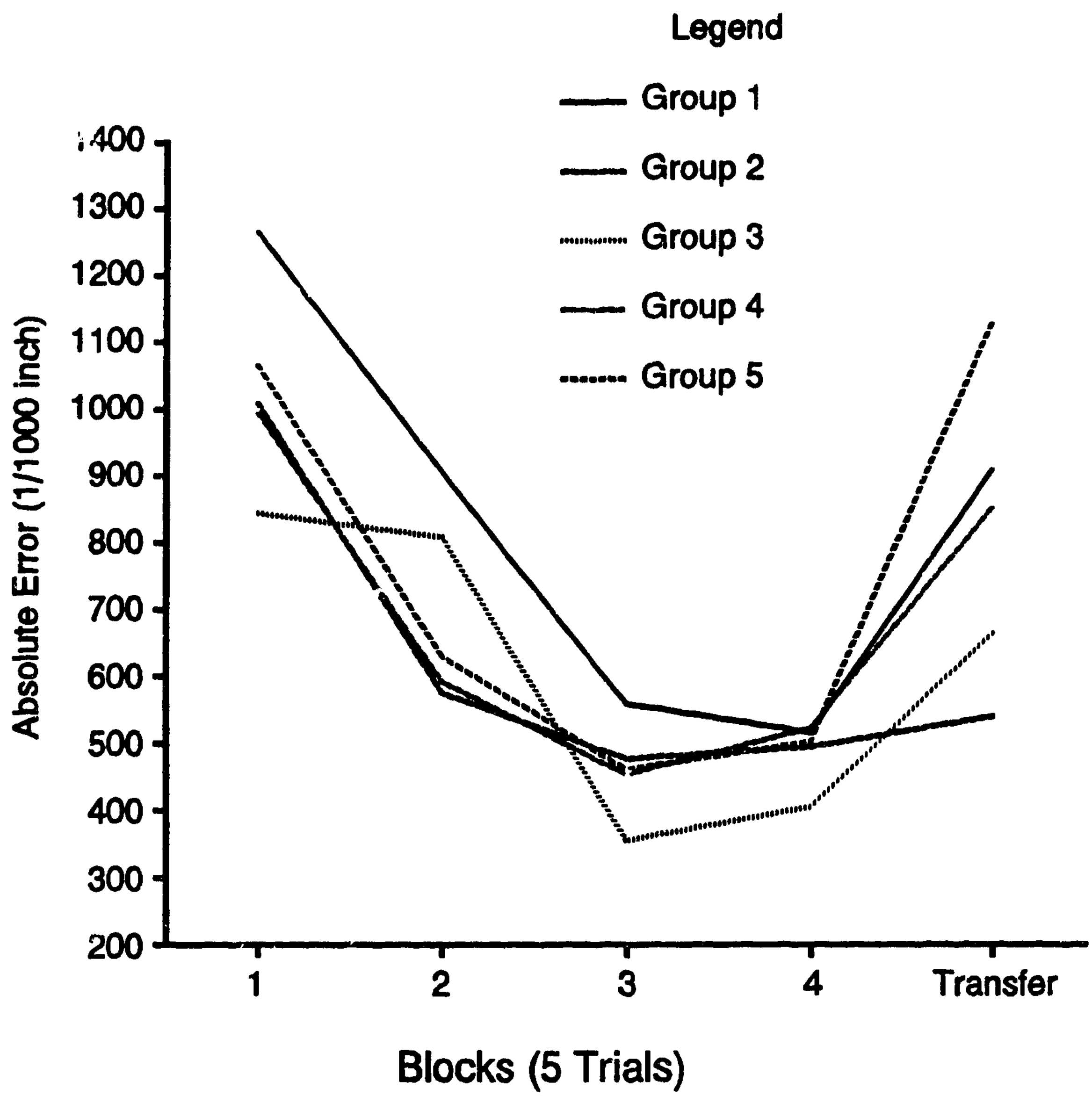

Figure 8. Experiment Three - Absolute error scores as a function of practice and transfer.

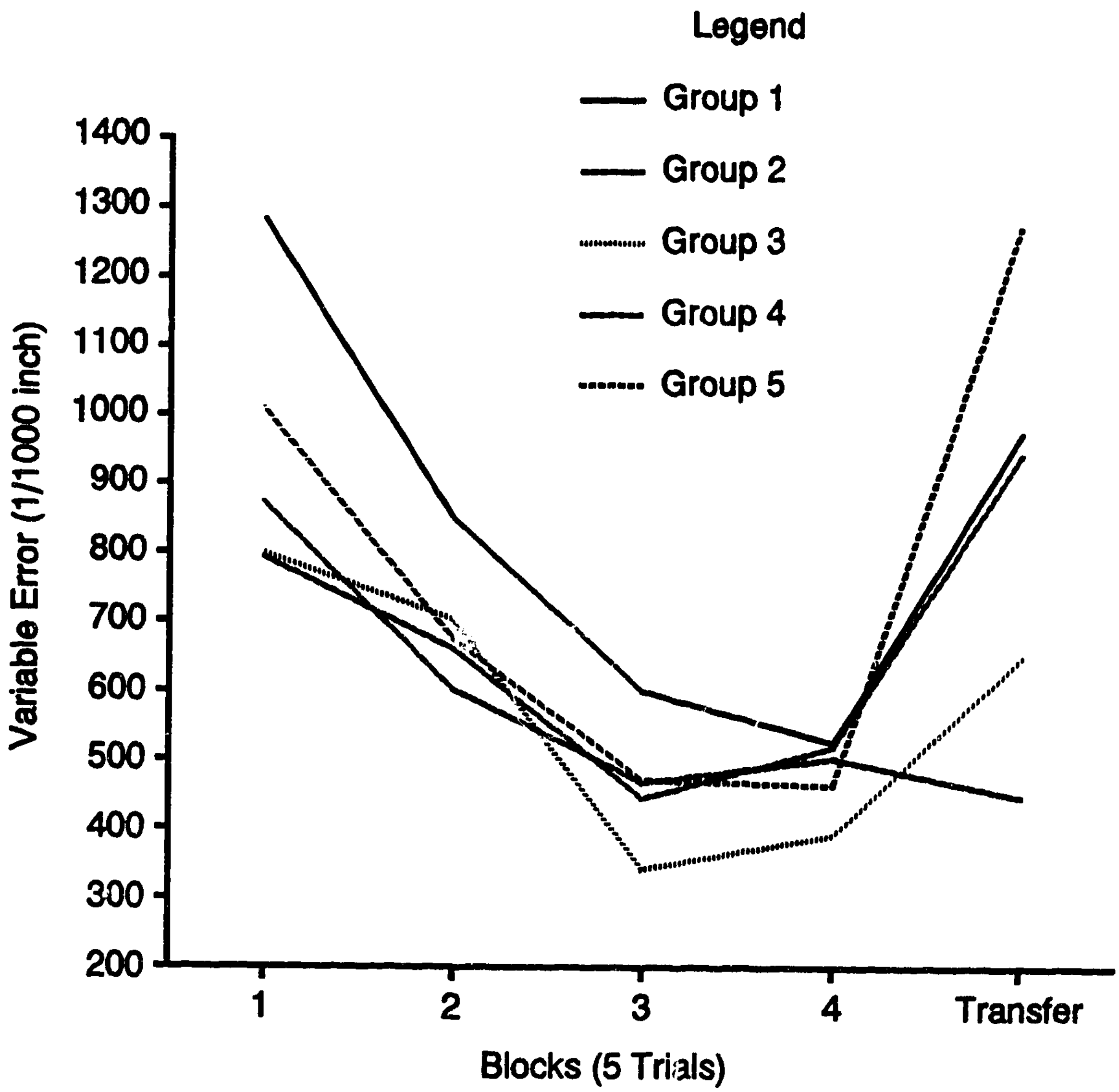

Figure 9. Experiment Three - Variable error scores as a function of practice and transfer.

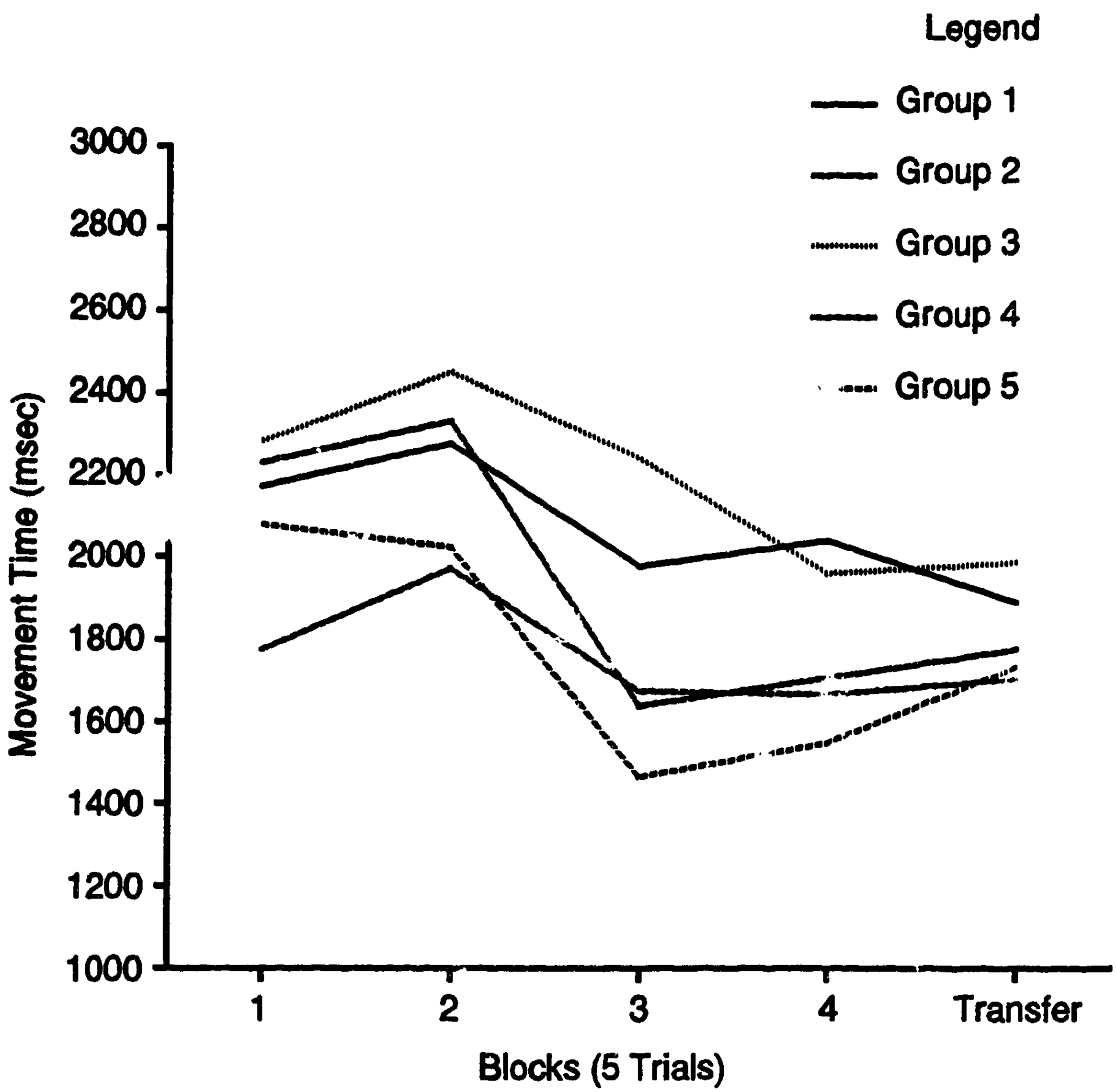

Figure 10. Experiment Three - Movement time scores as a function of practice and transfer.

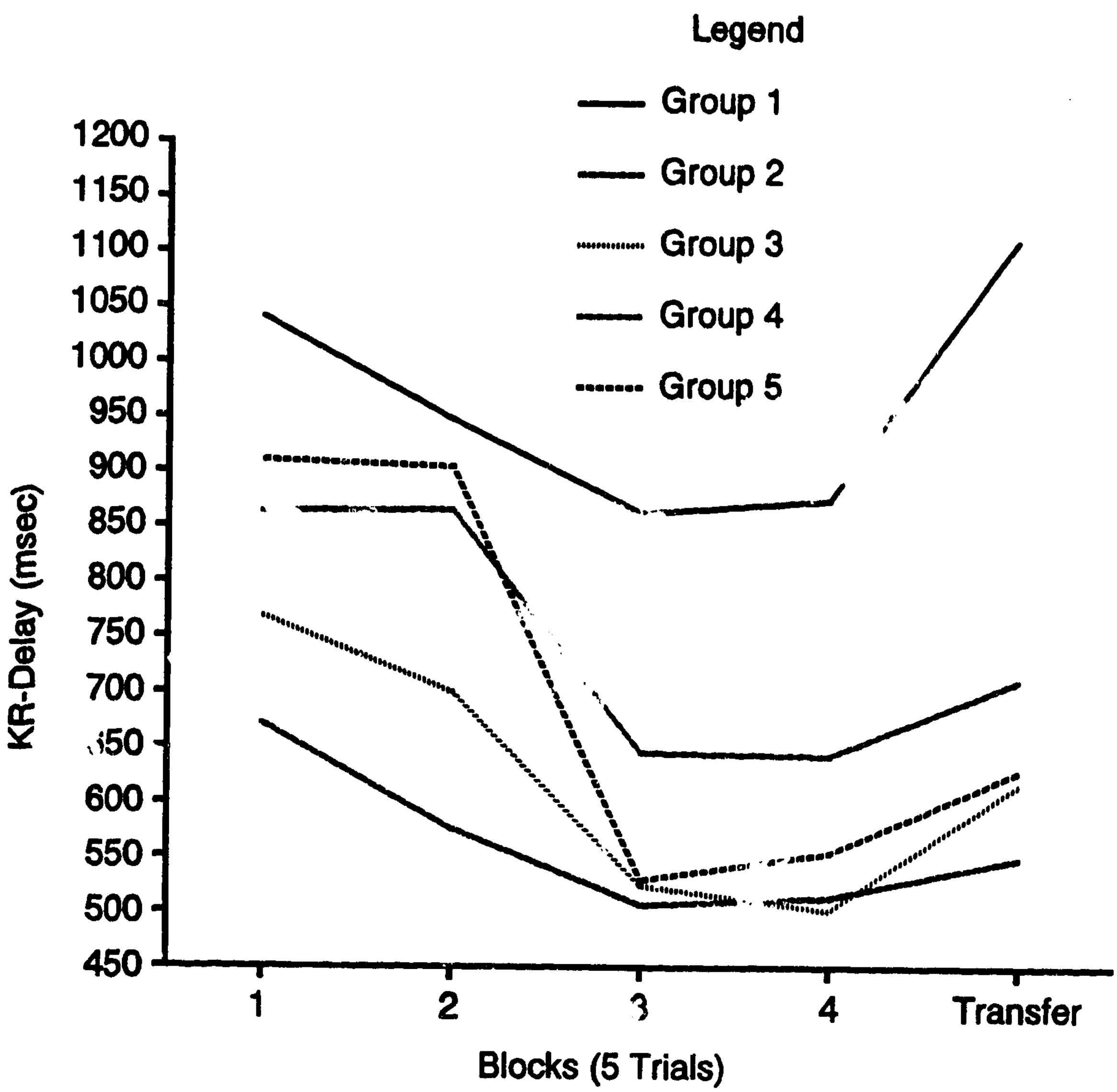

Figure 11. Experiment Three - KR-delay as a function of practice and transfer.

Table 17

Summary ANOVA for Absolute Error (AE) Scores

Source	M.S.	df	F	p
Groups	315450.23	4	2.96	<.05
Error	106599.56	45		
Blocks	2693700.00	1	24.72	<.001
Error	108962.86	45		
Contrasts				
B1 vs B2 for Group 1	763076.20	1	11.77	<.01
Error	64804.22	9		
B1 vs B2 for Group 2	9383.12	1	< 1	N.S.
Error	33405.58	9		
B1 vs B2 for Group 3	331479.79	1	5.38	<.05
Error	61597.22	9		
B1 vs B2 for Group 4	536805.32	1	3.00	<.12
Error	178701.66	9		
B1 vs B2 for Group 5	1935200.00	1	9.38	<.02
Error	206304.22	9		

Table 18

Summary ANOVA for Variable Error (VE) Scores

Source	M.S.	df	F	p
Groups	549789.51	4	3.36	<.05
Error	166611.13	45		
Blocks	3561300.00	1	27.85	<.001
Error	127885.27	45		
Contrasts				
B1 vs B2 for Group 1	1008400.00	1	6.71	<.05
Error	150238.08	9		
B1 vs B2 for Group 2	14681.08	1	< 1	N.S.
Error	58035.61	9		
B1 vs B2 for Group 3	332799.40	1	7.09	<.05
Error	46934.53	9		
B1 vs B2 for Group 4	904986.37	1	4.93	<.1
Error	183495.65	9		
B1 vs B2 for Group 5	3270700.00	1	16.29	<.005
Error	200722.47	9		

Table 19

Summary ANOVA for Movement Time (MT)

Source	M.S.	df	F	p
Groups	492820.71	4	< 1	N.S.
Error	935332.82	45		
Blocks	27629.09	1	< 1	N.S.
Error	77069.55	45		
Contrasts				
B1 vs B2 for Group 1	113763.48	1	1.06	N.S.
Error	107734.39	9		
B1 vs B2 for Group 2	23943.20	1	< 1	N.S.
Error	95314.35	9		
B1 vs B2 for Group 3	3251.24	1	< 1	N.S.
Error	62580.14	9		
B1 vs B2 for Group 4	7542.71	1	< 1	N.S.
Error	59575.03	9		
B1 vs B2 for Group 5	168397.94	1	2.80	N.S.
Error	60143.84	9		

Table 20

Summary ANOVA for KR-delay

Source	M.S.	df	F	p
Groups	712273.24	4	4.67	<.005
Error	152503.84	45		
Blocks	280794.01	1	4.41	<.05
Error	63721.97	45		
Contrasts				
B1 vs B2 for Group 1	280371.32	1	< 1	N.S.
Error	282664.78	9		
B1 vs B2 for Group 2	6209.28	1	< 1	N.S.
Error	9347.20	9		
B1 vs B2 for Group 3	65436.83	1	4.52	<.1
Error	14474.66	9		
B1 vs B2 for Group 4	23392.80	1	3.3	N.S.
Error	7079.83	9		
B1 vs B2 for Group 5	28170.04	1	5.59	<.05
Error	5043.41	9		

KR-delays on the transfer task as on the criterion task, except Group 5 who increased KR-delay on the transfer task significantly and Group 3 who achieved borderline significance ($p < .10$).

Post-KR interval. The ANOVA of the post-KR interval data revealed a significant main effect for blocks of practice ($F(1, 45) = 26.05$, $p < .001$, M.S. Error = 267491.17) while the main effect for groups did not reach statistical significance ($F(4, 45) < 1$, $p > .05$, M.S. Error = 656081.41). The data for the post-KR intervals are plotted in Figure 12. The a priori contrasts indicated that the post-KR interval increased on the transfer task for Groups 3, 4, and 5 while Groups 1 and 2 maintained the same post-KR interval on the transfer task as on the criterion task (Table 21).

Intertrial interval. The ANOVA yielded significant main effects for groups ($F(4, 45) = 2.81$, $p < .05$, M.S. Error = 817172.98) and blocks of practice ($F(1, 45) = 30.18$, $p < .001$, M.S. Error = 332919.65). The data for the ITIs are plotted in Figure 13. The a priori contrasts of the interaction indicated that the intertrial interval increased significantly on the transfer task for Groups 3, 4, and 5. The increase of the ITIs on Group 1 achieved borderline significance ($p < .1$), while on Group 2 the participants utilized the same ITIs for performing the transfer and the criterion

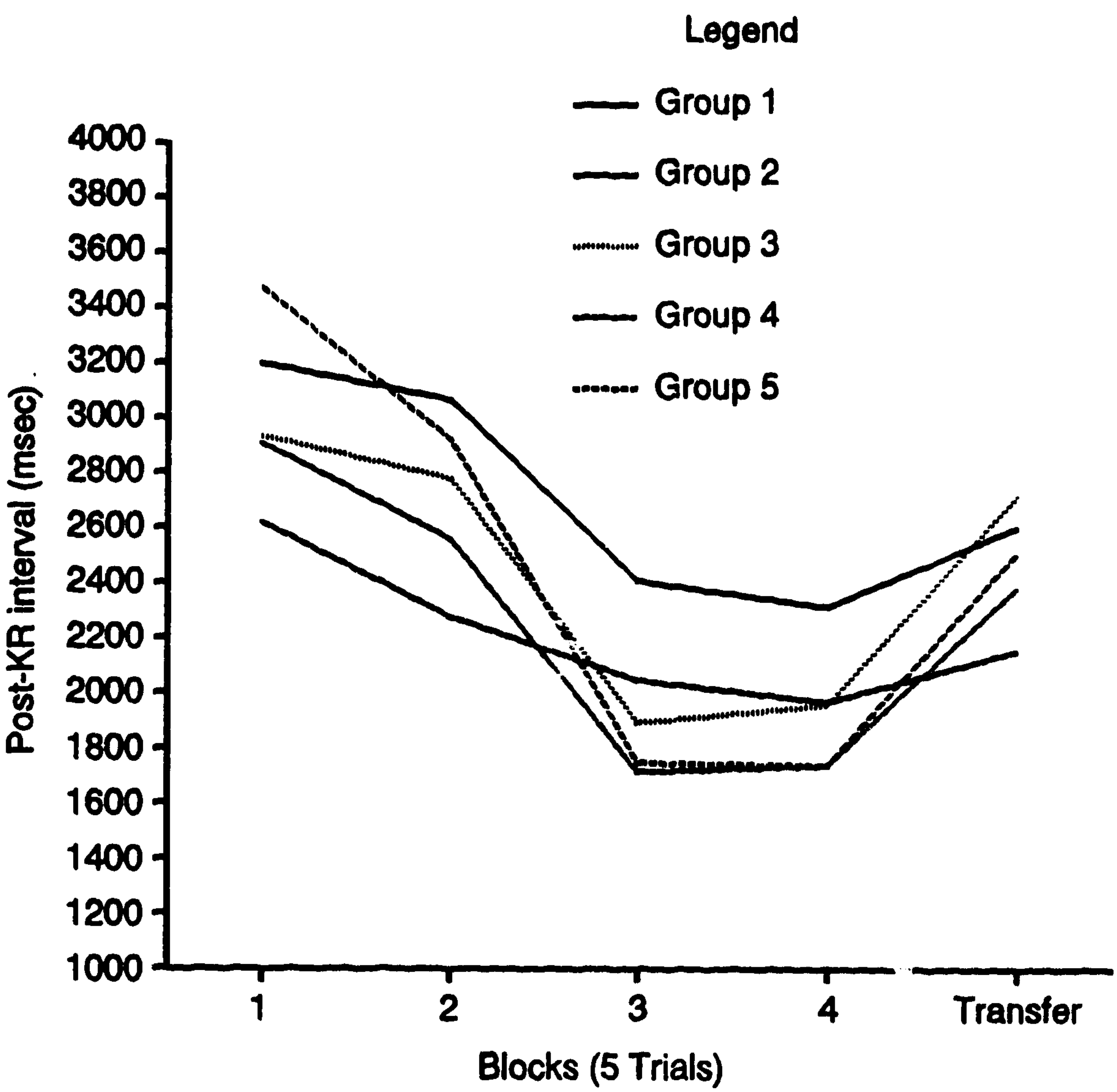

Figure 12. Experiment Three - Post-KR interval as a function of practice and transfer.

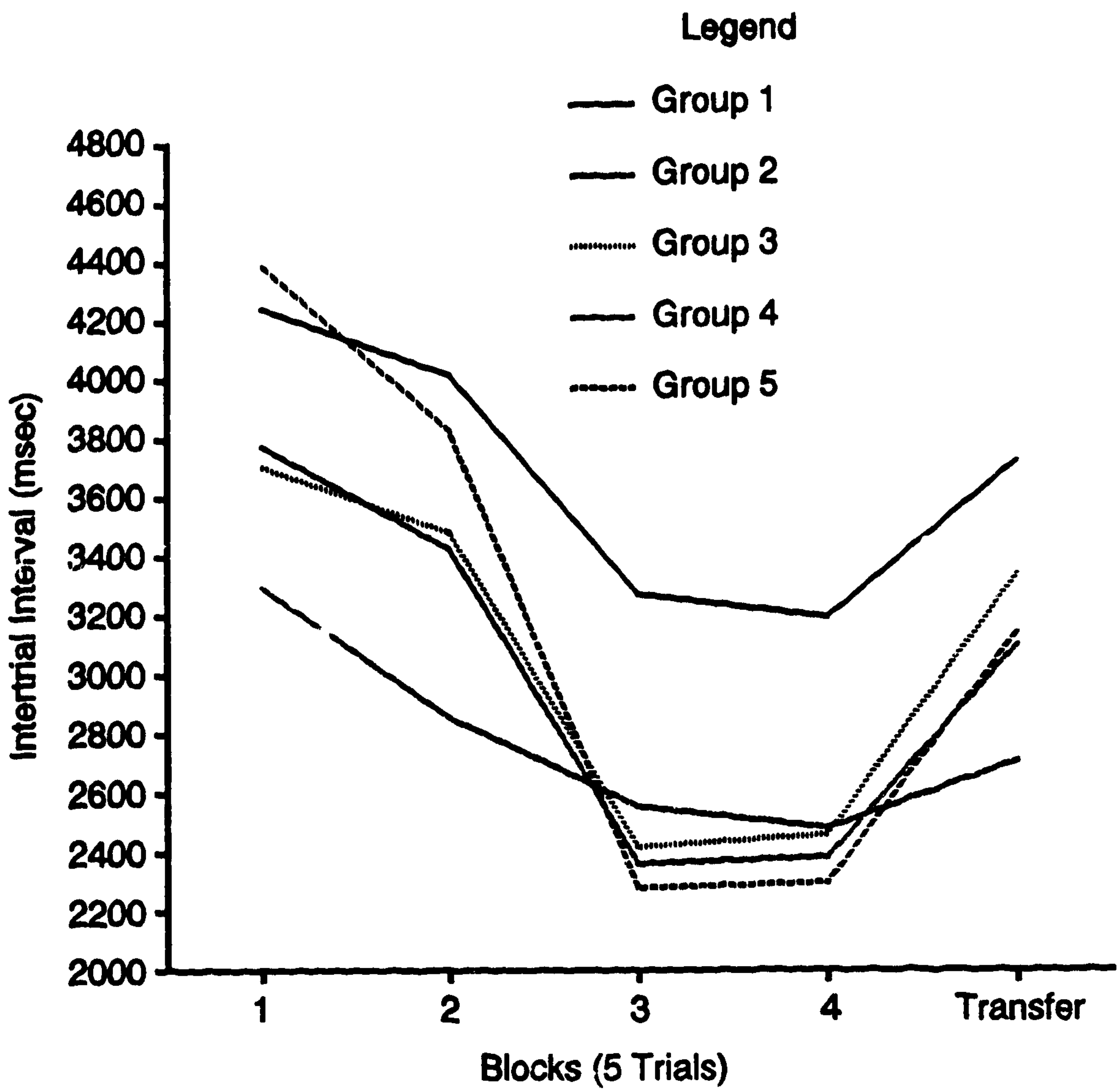

Figure 13. Experiment Three -Intertrial interval as a function of practice and transfer.

Table 21

Summary ANOVA for Post-KR Interval

Source	M.S.	df	F	p
Groups	648873.06	4	< 1	N.S.
Error	656081.41	45		
Blocks	6968000.00	1	26.05	<.001
Error	267491.17	45		
Contrasts				
B1 vs B2 for Group 1	416853.91	1	1.94	N.S.
Error	215370.62	9		
B1 vs B2 for Group 2	172348.15	1	1.94	N.S.
Error	88639.04	9		
B1 vs B2 for Group 3	2875000.00	1	6.43	<.05
Error	447142.12	9		
B1 vs B2 for Group 4	2057000.00	1	5.45	<.05
Error	377450.35	9		
B1 vs B2 for Group 5	2930500.00	1	14.03	<.005
Error	208847.75	9		

tasks (Table 22).

Interstimulus interval. The ANOVA revealed significant main effects for blocks of practice ($F(1, 45) = 21.27$, $p<.001$, M.S. Error = 519055.71) and an insignificant main effect for groups ($F(4, 45) = 1.59$, $p>.05$, M.S. Error = 2894700.00). The data for the ISIs are plotted in Figure 14. The a priori contrasts (Table 23) showed that Group 5 performed the transfer task with significantly longer ISIs and Groups 3 and 4 with intervals who approached statistical significance ($p<.06$). However, the ISIs on the transfer task for Groups 1 and 2 remained the same as on the criterion task.

Ratio (KR-delay/Post-KR interval). The ANOVA of the ratios between KR-delay and post-KR intervals revealed no significant main effects for groups ($F(4, 45) = 1.94$, $p>.05$, M.S. Error = .005), blocks of practice ($F(1, 45) < 1$, $p>.05$, M.S. Error = .009687). The a priori contrasts (Table 24) indicated that all groups used the same ratio between KR-delay and post-KR interval for the criterion and transfer tasks, except Group 5 who the increase of the ratio on the transfer task approached statistical significance ($p<.10$).

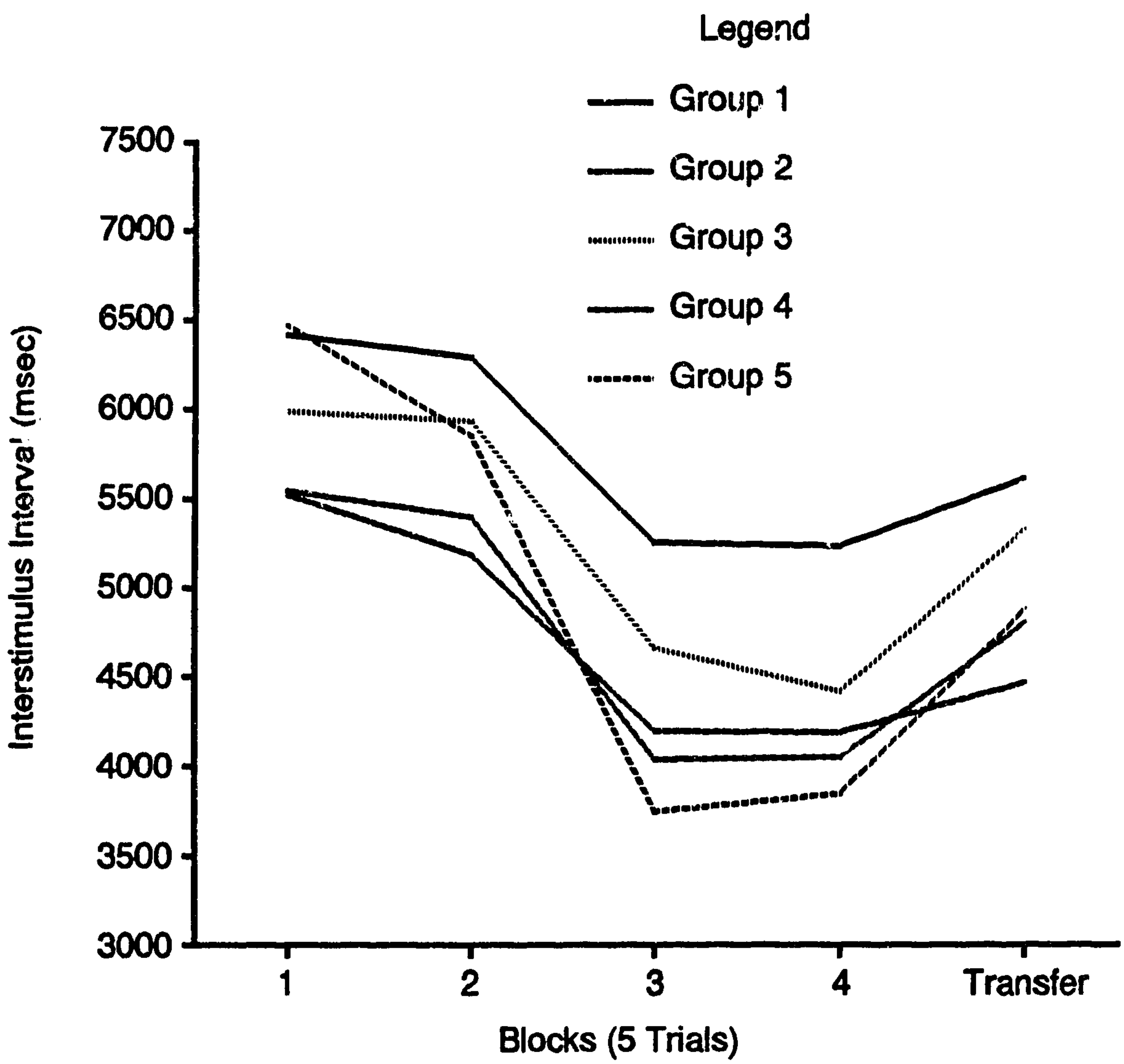

Figure 14. Experiment Three -Interstimulus interval as a function of practice and transfer.

Table 22

Summary ANOVA for Intertrial Interval (ITI)

Source	M.S.	df	F	p
Groups	2292800.00	4	2.81	<.05
Error	817172.98	45		
Blocks	10046000.00	1	30.18	<.001
Error	332919.65	45		
Contrasts				
B1 vs B2 for Group 1	1380900.00	1	3.97	<.1
Error	348043.75	9		
B1 vs B2 for Group 2	243984.16	1	1.94	N.S.
Error	125556.91	9		
B1 vs B2 for Group 3	3808000.00	1	7.21	<.05
Error	528388.89	9		
B1 vs B2 for Group 4	2519200.00	1	5.91	<.05
Error	425998.09	9		
B1 vs B2 for Group 5	3533300.00	1	14.93	<.005
Error	236609.26	9		

Table 23

Summary ANOVA for Interstimulus Interval (ISI)

Source	M.S.	df	F	p
Groups	4366300.00	4	1.51	N.S.
Error	2894700.00	45		
Blocks	11041000.00	1	21.27	<.001
Error	519055.71	45		
Contrasts				
B1 vs B2 for Group 1	702002.28	1	1.33	N.S.
Error	528818.75	9		
B1 vs B2 for Group 2	384198.52	1	1.08	N.S.
Error	355626.25	9		
B1 vs B2 for Group 3	4033800.00	1	5.03	<.06
Error	802718.11	9		
B1 vs B2 for Group 4	2802400.00	1	4.94	<.06
Error	566856.37	9		
B1 vs B2 for Group 5	5244500.00	1	15.37	<.005
Error	341258.74	9		

Table 24

Summary ANOVA for Ratio of KR-Delay with Post-KR Interval

Source	M.S.	df	F	p
Groups	.009	4	1.94	N.S.
Error	.005	45		
Blocks	.007818	1	< 1	N.S.
Error	.009687	45		
Contrasts				
B1 vs B2 for Group 1	.006351	1	< 1	N.S.
Error	.05	9		
B1 vs B2 for Group 2	.001185	1	< 1	N.S.
Error	.001674	9		
B1 vs B2 for Group 3	.0003767	1	< 1	N.S.
Error	.008059	9		
B1 vs B2 for Group 4	.004398	1	2.58	N.S.
Error	.001707	9		
B1 vs B2 for Group 5	.04	1	4.47	$< .1$
Error	.007923	9		

Discussion. When transferring participants to a new task, after practising the criterion task for 40, 75, 100, 125, and 150 KR-trials, it becomes apparent that the performance characteristics and the chronological profile of KR-delivery are affected differently (Table 25). The findings from Experiment Three indicate that when the participants are transferred to a new task after 40 KR-trials on the

Table 25

Performance Characteristics Between the Last Acquisition Block of Practice and the Transfer Block of Practice

	Group 1	Group 2	Group 3	Group 4	Group 5
AE	increased	same	increased	same[1]	increased
VE	increased	same	same	same[2]	increased
MT	same	same	same	same	same
KR-Delay	same	same	same[2]	same	increased
Post-KR	same	same	increased	increased	increased

1 = $p < .12$

2 = $p < .10$

criterion task, they maintained the same chronological profile of KR-delivery, while performance as measured by the AE and VE scores declined significantly. Perhaps, there was insufficient time for the development of the error detection and correction mechanisms which would enhance accuracy and consistency in performance. More practice time on the criterion task appears to be required in order for a correct model of performance to be developed and transferred to the new task.

The results from Group 2 (Block 15) seem to support this notion since a chronological profile of KR-delivery was developed that could functionally interact with the demands of the task. At this point both the performance characteristics and the chronological profile of KR-delivery were transferred to the new task. Participants seem to have learned and transferred both the surface and the deep features of the task.

Practicing on the criterion task beyond this point revealed several shortcomings. When transferred to the new task after 100 KR-trials accuracy and consistency decreased significantly and the post-KR interval and the ITI increased significantly. At 125 KR-trials, both accuracy and consistency tended to decrease while the post-KR interval and the ITI increased significantly.

After 150 KR-trials on the criterion task accuracy and consistency decreased significantly, while the KR-delay, post-KR interval, ITI and ISI increased significantly. Interestingly, the performance characteristics of the transfer task were the same as the performance characteristics observed during the first block of practice on the criterion task.

The above pattern of results suggests that practice beyond a certain point is detrimental to the ability to transfer what is learned. It appears that there is a gradual breakdown of the functional interaction between the surface and the deep features of the task. While performance accuracy and consistency deteriorates the post-KR interval and KR-delay tend to increase indicating that more processing time is required with increased practice. The results do not support the notion that more practice on the criterion task enhances transfer of learning to the new task (Sage, 1984).

General Discussion

The existing motor learning literature has been unable to successfully address the confounding of KR-time intervals in motor skill acquisition. The experimental confounding has always existed and as Salmoni et al. (1984) noted "there are almost no data capable of informing about the effects of the durations of these intervals unconfounded by some other interval" (p. 365). However, the series of experiments presented above demonstrate that the self-paced procedure can allow investigators a view of the KR-time intervals unconfounded by experimenter imposed limitations. Examination of the KR-intervals independently, combined with the use of a KR-withdrawal paradigm, a transfer task, and a self-paced procedure can add new information about the nature of what is learned.

Past investigations in which confounding of the KR-time intervals occurred suggest that KR-delay is not a crucial interval in skill acquisition (Adams, 1971; Bilodeau and Bilodeau, 1958b; Bilodeau and Ryan, 1960), and that the post-KR interval is the time period that affects learning (Bilodeau and Bilodeau, 1958b; Burne and Bunderson, 1963; Burne, Guy, Dodd, & Justesen, 1965; Weinberg et. al., 1964). What emerges from the findings in Experiment One however, is that under self-paced procedures participants improve their performance throughout the course of practice. That is, both the KR-delay and post-KR intervals decrease in parallel with performance error scores. The suggestion is that participants use the error detection and correction mechanisms more efficiently when practicing under the presence of KR. In light of the present results, the assumptions of the traditional KR paradigm regarding the contribution of the KR-delay and post-KR intervals in motor learning, are now open to question.

In a KR-dependent task participants receive, elaborate, and process information provided by KR in order to develop efficient error detection and correction mechanisms. Research employing the KR-withdrawal paradigm indicates that the more KR-trials that precede KR-withdrawal, the better the maintenance of performance (Adams, 1971; Adams, Goetz, & Marshall, 1972; Bilodeau and Bilodeau, 1958a; Bilodeau et. al., 1959; Newell, 1974). Theories of motor learning based on these findings propose that under the presence of KR the perceptual trace (Adams, 1971), or the recognition schema (Schmidt, 1975) becomes stronger and performance can be maintained at the same level of accuracy and consistency when KR is withdrawn. The findings from Experiment Two are in agreement with the foregoing studies regarding the importance of KR at the early stages of practice. However, the results reveal that participants need KR early in learning in order to develop a functional interaction between the surface and the deep features that underlie the task. At this time, withdrawal of KR does not significantly affect performance accuracy and consistency and leaves the chronological profile of KR-delivery unaffected. Beyond this level of proficiency, however, any withdrawal of KR tends to negatively affect the surface and the deep features of the task.

It appears that later in learning participants develop a dependency on KR which gradually deteriorates participants' ability to perform at the same level in the absence of KR. Moreover, the already developed functional interaction between the surface and the deep features tends to weaken and can be applied successfully only when KR is present. An interpretation regarding this finding is provided by the guidance hypothesis (Salmoni et. al., 1984), which suggests that when KR is present on every trial it functions to guide and force the participants into a reliance upon KR. Under these circumstances, the reliance on KR has an immediate effect on performance that may be detrimental to the learning sequence (Schmidt, Young, Swinnen, & Shapiro, 1989; Schmidt, Shapiro, Winstein, Young, & Swinnen, 1987; Swinnen et. al., 1990). However, it should be noted that the guidance hypothesis was formulated based on findings related to the surface features of the task. It may be the case that the guidance phenomenon is not only related to the availability of KR but also to the overall processes that underlie the chronological profile of KR delivery and the performance characteristics of the task. Further research is needed to support this speculation.

The results obtained in Experiment Three indicate that participants first learn the deep features of the task and transfer them to the new task. In schema theory terms, it can be postulated that at this point in the course of practice, the recall schema is not fully developed and participants are unable to set the appropriate movement parameters via the generalized motor program. The results can be errorful performance on the transfer task. Additional practice leads to the development of a functional interaction between the surface and the deep features that underlie the task. At this point participants have learned both the surface and the deep features of the criterion task and are able to formulate the appropriate action plan by transferring what is learned on the criterion to the new task. Practice beyond this point, however, weakens transferability to a new task. Thus, statements like "the transfer effect increases with increasing practice on the original task" (Sage, 1984, pp. 341) seem to require qualification. It appears that participants create specific error detection and correction capabilities that can be implemented on the criterion task only under the presence of KR.

Other possible explanations for the transfer of learning found in Experiment Three would focus on the similarities between stimuli and responses (Osgood, 1949; Thorndike, 1914), the encoding of practice and transfer context (Tulving and Thomson, 1973) and the cognitive processes of the criterion and transfer tasks (Morris, Bransford, & Franks, 1977; Bransford, Franks, Morris, & Stein, 1979). These traditional views of transfer can explain the findings of Experiment Three up to the point that an optimal transfer occurred. They cannot, however, account for why transfer deteriorates, what happens in the already developed encoding context between the practice and the transfer task, or the similarity of the cognitive processes between the two tasks.

It should be noted that the optimal point for transfer selected in Experiment Three is not the only point in the course of practice that participants can successfully transfer what is learned. The same learning profile is observed for Blocks 3 and 4 on Day 3. It may be the case that after a retention interval, participants practice on the criterion task in order to retest the existing functional interaction between the surface and the deep features of the task. Perhaps, participants are able to transfer what is learned on the criterion to a new task at more points in the course of practice. However, further research is required to support this supposition.

The series of experiments presented further reveal that under self-paced procedure, participants maintain a constant ratio between KR-delay and post-KR interval constant. This ratio is not seriously affected by KR-withdrawal or transfer to a new task. It is unclear what function is served by maintaining this constant ratio, and further research needs to be conducted on this concept.

In terms of the significant positive correlations between the AE scores and the post-KR intervals at different points in the course of practice (Experiments One and Two), one can speculate that such findings provide additional information about the functional properties of KR in motor skill acquisition. It may be the case that early in practice (Experiments One and Two, Blocks 1 to 8), the participants use KR in order to develop a strong reference mechanism to optimize performance. When this mechanism is developed and the participants are required to perform the task after a rest period (i.e., 24 hours), they use KR to overcome the warm-up decrement that may develop during the rest period (Experiments One & Two, Block 11). It seems that the participants recruit the mechanism developed previously and after a few additional KR-trials, are able to perform the task at the same level of accuracy and consistency without KR. At this time participants can fully transfer the surface and the deep features of the task to a similar task. The reappearance of this positive relationship later in practice (Experiment One, Blocks 26, 27, 29, 30) may indicate the points in the course of practice where the participants become dependent on KR and use it to improve their performance on the practice task. Under these circumstances, the participants cannot perform accurately in the absence of KR and they are unable to transfer the surface and/or the deep features of the task. However, further research is required to justify the possible contribution of the correlational analyses in studying self-paced motor learning.

While the results of the present experiments indicate that both KR-delay and post-KR interval contribute to learning they do not challenge past theorizing regarding the function of the KR-delay and the post-KR intervals in motor skill acquisition. Similar to the related literature the present results suggest that KR-delay and post-KR intervals should be of sufficient duration to allow the development of the error detection and correction capabilities in motor skill learning. During the KR-delay the participants are thought to be engaged in information processing activities to enhance the error detection capabilities via the movement's response produced FB (Schmidt, 1988; Swinnen et. al., 1990). The post-KR interval allows the participants to receive, elaborate and process the information provided by KR in order to formulate an appropriate action plan for the next response (Magill, 1988; Newell, 1977; Salmoni et. al., 1984; Schmidt, 1988). However, the results obtained in Experiments One, Two and Three demonstrate that participants do not need fixed KR-intervals to develop the appropriate processing mechanisms that underlie motor learning.

A noteworthy feature of the present experiments is that investigators in the motor learning area should take into consideration the <u>total time</u> when making predictions about the effects of the temporal locus of KR in motor skill acquisition. Each time interval plays a unique role in the learning sequence and should be examined in context. Travlos (1991, 1992) and Wilberg (1991), suggested that the KR-paradigm should be re-examined. The present investigation, following the self-paced procedure, confirms the speculations outlined by Wilberg (1991) who proposes that all KR-time intervals should be examined concurrently in the learning sequence. Moreover, the following assumptions are fundamental to evaluating the self-paced KR-paradigm (Wilberg, 1991). First, the skill to be acquired is feedback dependent. Second, an inter-stimulus interval exists and the performer has the ability to access the response related feedback within this time interval. Third, the response related feedback exists, is understandable and fully available.

The findings obtained in Experiments One, Two and Three are limited to simple positioning tasks which only have a single degree of freedom controlled (movement distance). Learning tasks where the movement time is controlled require further investigation in order to examine the changes in the chronological profile of KR-delivery and the performance characteristics that underlie the task. It should be noted, however, that the results from Experiments One and Two indicated that under self-paced procedures a high positive correlation exists between MTs and post-KR intervals (r = .67 and r = .72, respectively). How this relationship influences learning when the temporal component of the task is controlled remains unknown. Consequently, learning tasks with more than one degree of freedom require further investigation in order to clarify the learning profile that underlies the surface and the deep features of these tasks.

References

Adams, J. A. (1952). Warm-up decrement in performance no the pursuit rotor. American Journal of Psychology, 65, 404-415.

Adams, J. A. (1961). The second facet of forgetting: A review of warm-up decrement. Psychological Bulletin, 58, 257-273.

Adams, J. A. (1967). Human memory. New York: McGraw-Hill.

Adams, J. A. (1971). A closed-loop theory of motor learning. Journal of Motor Behavior, 3, 111-150.

Adams, J. A., & Bray, N. W. (1970). A closed-loop theory of paired-associate verbal learning. Psychological Review, 77, 385-405.

Adams, J., Goetz, E. T., & Marshall, P. H. (1972). Response feedback and motor learning. Journal of Experimental Psychology, 92, 391-397.

Alexander, L. T. (1951). Knowledge of results and the temporal gradient of reinforcement. American Psychologist, 6, 292-293.

Archer,, E. J., & Namikas, G. A. (1958). Pursuit rotor performance as a function of delay of information feedback. Journal of Experimental Psychology, 56, 325-327.

Barclay, C. R., & Newell, K. M. (1980). Children's processing of information in motor skill acquisition. _Journal of Experimental Child Psychology, 30_, 98-108.

Becker, P. W., Mussina, C. M., & Persons, R. W. (1963). Intertrial interval, delay of knowledge of results, and motor performance. _Perceptual and Motor Skills, 17_, 559-563.

Benedetti, C., & McCullagh, P. (1987). Post-knowledge of results delay: Effects of interpolated activity on learning and performance. _Research Quarterly for Exercise and Sport, 58_, 375-381.

Bilodeau, E. A. (1964). Inadequate resources, experimental design, and review of the informative feedback literature. _Perceptual and Motor Skills, 19_, 121-122.

Bilodeau, E. A., & Bilodeau, I. M. (1958a). Variable frequency of knowledge of results and the learning of a simple skill. _Journal of Experimental Psychology, 55_, 379-383.

Bilodeau, E. A., & Bilodeau, I. M. (1958b). Variation fo temporal intervals among critical events in five studies of knowledge of results. _Journal of Experimental Psychology, 55_, 603-612.

Bilodeau, E. A., Bilodeau, I. M., & Schumsky, D. A. (1959). Some effects of introducing and withdrawing knowledge of results early and late in practice. Journal of Experimental Psychology, 58, 142-144.

Bilodeau, E. A. & Ryan, F. J. (1960). A test of interaction of delay of knowledge of results and two types of interpolated activity. Journal of Experimental Psychology, 59, 414-419.

Boik, R. J. (1981). A priori tests in repeated measures designs: Effects of nonsphericity. Psychometrica, 46, 241-255.

Boik, R. J., & Kirk, R. E. (1977). A general method for partitioning sums of squares of treatments and interactions in the analysis of variance. Educational and Psychological Measurement, 37, 1- 9.

Bole, R. (1976). Post-KR delay intervals and mental practice: A test of Adams' closed-loop theory. Research Quarterly, 47, 316-319.

Boucher, J. S. (1974). Higher processes in motor learning. Journal of Motor Behavior, 6, 131-137.

Boulter, L. R. (1964). Evaluation of mechanisms in delay of knowledge of results. Canadian Journal of Psychology, 18, 281-291.

Bourne, L. E., & Bunderson, C. V. (1963). Effects of delay of information feedback and length of postfeedback interval on concept identification.

Journal of Experimental Psychology, 65, 1-5.

Bourne, L. E., Guy, D. E., Dodd, D. H., & Justesen, D. R. (1965). Concept intensification: The effects of varying length and informational components of the intertrial interval. Journal of Experimental Psychology, 69, 624-629.

Bransford, J.D., Franks, J. J., Morris, C. D., & Stein, B. S. (1979). Some general constraints on learning and memory research. In L. S. Cermak and F. I. M. Craik (Eds.), Levels of processing in Human memory (pp. 331-354), Hillsdale, NJ: Erlbaum.

Denny, M. R., Allard, M., Hall, E., & Rokeach, M. (1960). Supplementary report: Delay of knowledge of results, knowledge of task, and the intertrial interval. Journal of Experimental Psychology, 60, 327.

Dyal, J. A. (1964). Effects of delay of knowledge of results in a line-drawing task. Perceptual and Motor Skills, 19, 433-434.

Dyal, J. A. (1965). Confounded delay-of KR design revisited: Reply to Bilodeau. Perceptual and Motor Skills, 20, 173-174.

Dyal, J. A. (1966). Effects of delay of knowledge of results and subject response bias on extinction of a simple motor skill. Journal of Experimental

Psychology, 71, 559-563.

Dyal, J. A., Wilson, W. J., & Berry, K. K. (1965). Acquisition and extinction of a simple motor skill as a function of knowledge of results. Quarterly Journal of Experimental Psychology, 17, 158-162.

Franks, I. M., & Wilberg, R. B. (1984). Consistent reproduction of movement sequences during acquisition of a pursuit tracking task. Perceptual and Motor Skills, 58, 669-709.

Gallagher, J. D., & Thomas, J. R. (1980). Effects of varying post-KR intervals upon children's motor performance. Journal of Motor Behavior, 12, 41-46.

Geisser, S., & Greenhouse, S. W. (1958). An extension of Box's results on the use of the F distribution in multivariate analysis. Annals of Mathematical Statistics, 29, 885-891.

Greenspoon, J., & Foreman, S. (1956). Effects of delay of knowledge of results on learning a motor task. Journal of Experimental Psychology, 51, 226-228.

Kantowitz, B. H. (1974). Double stimulation. In B. H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. NJ: Lawrence Erlbaum Associates, Publishers. pp. 83-131.

Keppel, G. (1991). Design and Analysis: A researcher's handbook (3rd Ed.). NY: Prentice-Hall Inc.

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

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

Lee, T. D., & Magill, R. A. (1987). Effects of duration and activity during the post-KR interval on motor learning. Psychological Research, 49, 237-242.

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

Magill, R. A. (1973). The post KR interval: Time and activity effects and the relation of motor short-term memory theory. Journal of Motor Behavior, 5, 49-56.

Magill, R. A. (1977). The processing of knowledge of results information for a serial-motor task. Journal of Motor Behavior, 9, 113-118.

Magill, R. A. (1988). Activity during the post-knowledge of results interval can benefit motor skill learning. In O. G. Meijer & K. Roth (Eds.), Complex movement behaviour: The motor-action controversy , (pp. 231-245), Amsterdam: Elsevier Science Publishers.

Magill, R. A. (1989). Motor learning: Concepts and applications (3rd ed.). Dubuque: Wm. C. Brown Publishers.

Marteniuk, R. G. (1986). Information processes in movement learning: Capacity and structural interference effects. Journal of Motor Behavior, 18, 55-75.

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

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

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

Morris, C. D., Bransford, J. D., & Franks, J. J.(1977). Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519-533.

Newell, K. M. (1974). Knowledge of results and motor learning. Journal of Motor Behavior, 6, 235-244.

Newell, K. M. (1976). More on absolute error, etc. Journal of Motor Behavior, 8, 139-142.

Newell, K. M. (1977). Knowledge of results and motor learning. Exercise and Sport Sciences Reviews, 4, 195-228.

Newell, K. M. (1981) Skill learning. In D. H. Holding (Ed.), Human skills, New York: Wiley.

Osgood, C. E. (1949). The similarity paradox in human learning: A resolution. Psychological Review, 56, 132-143.

Pedhazur, E. J. (1982). Multiple regression in behavioral research. Explanation and prediction (2nd Ed.). NY: CBS publishing.

Ramella, R. J. (1983). Processing, knowledge of results, and a multi-dimensional task. Perceptual and Motor Skills, 57, 43-48.

Ramella, R. J., & Wiegand, R. L. (1983). Importance of the post-knowledge delay interval on transit reaction. Perceptual and Motor Skills, 56, 407-412.

Ryan, F. J., & Bilodeau, E. A. (1962). Counter-training of a simple skill with immediate and one-week delays of information feedback. Journal of

Experimental Psychology, 63, 19-22.

Sage, G. H. (1984). Motor learning and control: A neuropsychological approach. Dubuque: Wm. C. Brown Publishers.

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.

Saltzman, I. J., Kanfer, F. H., & Greenspoon, J. (1955). Delay of reward and human motor learning. Psychological Reports, 1, 139-142.

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

Schmidt, R. A. (1988). Motor control and learning: A behavioral emphasis (2nd ed.). Champaign, IL: Human Kinetics Publishers.

Schmidt, R. A. (1991). Motor learning and performance: From principles to practice. Champaign, IL: Human Kinetics Publishers.

Schmidt, R. A., Shapiro, D. C., Winstein, C. J., Young, D. E., & Swinnen, S. (1987). Feedback and motor skill training: Relative frequency of KR and summary KR. Contract No MDA903-85-K-0225, Washington, DC: U.S. Army research Institute.

Schmidt, R. A., & Shea, J. L. (1976). A note on delay of Knowledge of results in positioning responses. Journal of Motor Behavior, 8, 129-131.

Schmidt, R. A., & White, J. L. (1972). Evidence for error detection mechanism in motor skills: A test of Adams' closed-loop theory. Journal of Motor Behavior, 4, 143-154.

Schmidt, R. A., & Young, D. E. (1987). Transfer of movement control in motor skill learning. In S. M. Cormier and J. D. Hagman (Ed.), Transfer of learning: Contemporary research and applications. pp. 48-79.

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: Learning, Memory, & Cognition, 15, 352-359.

Simmons, R. W., & Snyder, R. J. (1983). Variation of temporal locus of knowledge of results on motor performance of a simple task. Perceptual and Motor Skills, 56, 399-404.

Stevens, J. (1986). Applied multivariate statistics for the social sciences. NJ: Lawrence Erlbaum Associates, Publishers.

Swinnen, S. P. (1988). Post-performance activities and skill learning. In O. G. Meijer & K. Roth (Eds.), Complex movement behaviour: The motor-action controversy , (pp. 315-338), Amsterdam: Elsevier Science Publishers.

Swinnen, S. P. (1990). interpolated activities during the knowledge-of-results delay and post-knowledge-of-results interval: Effects on performance and learning. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 692-705.

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.

Tarpy, R. M., & Sawabini, F. L. (1974). Reinforcement delay: A selective review of the last decade. Psychological Bulletin, 81, 984-997.

Thorndike, E. L. (1913). Educational psychology: The psychology of learning (Vol. 2). New York: Teachers College Press.

Thorndike, E. L. (1914). Educational psychology: Briefer course. NY: Columbia University Press.

Thorndike, E. L. (1927). The law of effect. American Journal of Psychology, 39, 212-222.

Thorndike, E. L. (1932). The fundamentals of learning. New York: Teachers College Press.

Travlos, A. K. (1991). Temporal locus of knowledge of results (KR) and motor skill acquisition. Paper presented at the Canadian Society for Psychomotor learning and Sport Psychology. p. 81.

Travlos, A. K. (1992). Chronological profile of knowledge of results (KR) delivery: A self-paced study. Paper presented at the Canadian Society for Psychomotor learning and Sport Psychology. p. 111.

Travlos, A. K., Pratt, J., & Wilberg, R. B. (1990). The temporal locus of knowledge of results: A meta-analytic review. Paper presented at the Canadian Society for Psychomotor learning and Sport Psychology. p. 127.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. Psychological Review, 80, 352-373.

Wallace, S. A., DeOreo, K. L., & Roberts, G. C. (1976). Memory and perceptual trace development in ballistic timing. Journal of Motor Behavior, 8, 133-137.

Wiegand, R. L., & Ramella, R. (1983). The effects of practice and temporal location of knowledge of results on the motor performance of older adults. Journal of Gerontology, 38, 701-706.

Wilberg, R. B. (1991). Learning about learning: A study of the surface and deep features that develop during the learning of a motor skill. Paper presented at the Canadian Society for Psychomotor learning and Sport Psychology. 81.

Weinberg, D. R., Guy, D., & Tupper, R. W. (1964). Variations of postfeedback interval in simple motor learning. Journal of Experimental Psychology, 67, 98-99.

Appendix A

Definitions for KR time intervals

KR-delay is the time interval from the end of a movement to the presentation of KR (Schmidt, 1988).

Post-KR interval is the time interval from the presentation of KR to the production of the next response (Schmidt, 1988).

Intertrial Interval (ITI) is the sum of KR-delay and Post-KR interval (Schmidt, 1988).

Interstimulus Interval (ISI) is the time intervening between two stimuli - see Figure 7- (Kantowitz, 1974).

Ratio is an index that is derived by the division of the KR-delay with the Post-KR interval.

Surface features are associated with any sensory information concerning the performance characteristics of the skill such as KR, knowledge of performance, proprioception, e.t.c.

Deep features are associated with the development of distinct functional patterns in human performance such as the chronological profile of KR-delivery

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Appendix B

Consent Form for Human Research in the Human Motor Performance laboratory

Project Title: Temporal Locus of Knowledge of Results (KR) and Motor Skill Acquisition: Self-Paced Studies.

Principal Investigator: Antonios K. Travlos 431-0633, 492-1039

Experimental Rationale: The proposed experiment is designed to investigate the chronological profile of KR delivery in motor skill acquisition under self-paced procedures. The performer's task is to find the length of a line by performing a linear tapping task on a Summographics Supergrid digitizing tablet. The performer can ask for signed directional KR at his or her own discretion. The performer is given the same task for three consecutive days. Each day of practice consists of 52 trials. To become familiarized with the experimental protocol, five practice trials of a different movement distance are given to the subject. There are not any known side effects related to this type of experimental procedure.

The performers are required to volunteer approximately 10 to 15 minutes per day. They will be assigned with a personal number that will be kept confidential and known only to the performer and the experimenter. The data of the study will be used by the investigator while maintaining the anonymity and confidentiality of all performers. The performer can withdraw from the study at any time without consequences.

Performer's Signature for Consent ______________________

Witness ______________________________

Date _________________

Performer's Initials for receiving copy of consent form _______

Investigator's Signature _________________________

Appendix C

Definitions and Calculations for Absolute Error (AE) and Variable Error (VE)

Absolute Error (AE) is defined "as the average absolute deviation of a set of scores from a target value; a measure of overall error" (Schmidt, 1988; pp. 72). For calaculation see Schmidt (1988) pp. 72.

Variable Error (VE) is a measure of subjects consistancy throughout the course of practice and it is calculated by the following equation.

$$VE_{jk} = \sqrt{\frac{\sum_{i} (X_{kij} - \bar{X}_{k \cdot j})^2}{n_j}}$$

k = subject's ID

i = trial number

j = block number

X = trial score

$\bar{X}$ = the mean of every Block of Practice

n = the number of trials per Block.

Appendix D

Means and Standard Deviations for all Dependent Variables - Experiment One

Table 1

Means and Standard Deviations of the Absolute Error (AE) Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	1011.77	626.03	720.03	543.64	669.23	302.58
2	615.81	377.24	537.34	209.69	442.43	280.22
3	627.20	217.40	493.26	197.87	454.56	175.04
4	550.73	317.74	505.90	331.04	429.31	203.89
5	580.15	345.17	482.99	185.52	450.57	151.67
6	485.35	212.13	530.66	249.86	414.35	131.87
7	619.92	542.27	512.55	221.18	428.78	193.22
8	465.23	214.63	491.01	167.25	419.19	303.08
9	476.67	179.83	460.47	176.88	498.93	311.62
10	566.37	268.07	448.42	218.48	439.05	241.16

Table 2

Means and Standard Deviations of the Variable Error (VE) Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	1012.20	541.93	711.94	481.38	674.38	236.67
2	672.06	455.65	531.76	213.84	403.59	200.01
3	661.20	236.89	502.55	226.81	463.68	188.24
4	534.70	335.24	469.95	325.95	426.58	190.05
5	586.19	420.46	478.96	191.33	473.39	194.66
6	523.08	245.33	490.95	224.50	445.95	170.45
7	618.06	426.81	528.04	234.94	433.67	201.56
8	478.18	222.65	457.49	144.24	392.78	200.11
9	484.06	234.87	460.07	192.62	453.99	250.42
10	562.73	254.99	452.03	195.96	446.26	278.96

Table 3

Means and Standard Deviations of the Movement Time across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	1461.80	984.53	1420.94	891.73	1461.22	866.6[illegible]
2	1473.99	1073.04	1462.66	945.17	1424.53	783.16
3	1470.81	978.59	1431.17	812.83	1391.80	744.03
4	1531.08	1020.37	1487.34	856.61	1466.89	784.03
5	1602.74	1061.63	1510.78	886.06	1455.99	730.43
6	1591.09	1047.52	1470.68	814.95	1430.[illegible]	708.27
7	1522.66	901.78	1549.61	859.43	1415.39	675.78
8	1559.83	978.09	1615.72	956.79	1460.73	693.84
9	1485.17	921.98	1596.80	942.72	1433.61	714.56
10	1512.84	893.88	1555.82	933.89	1450.40	755.03

Table 4

Means and Standard Deviations of the KR-delay Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	884.31	336.87	682.80	269.75	508.03	260.50
2	777.96	297.49	634.90	270.66	564.01	244.80
3	703.81	286.61	607.03	266.47	545.72	266.31
4	688.52	306.09	603.76	261.63	548.54	265.36
5	707.64	311.02	601.72	274.65	549.81	256.25
6	705.12	357.54	613.59	273.40	537.28	244.21
7	657.34	273.94	596.94	250.48	535.81	246.26
8	635.18	267.53	586.57	250.28	532.86	236.67
9	616.03	248.06	586.41	242.79	518.68	218.79
10	610.17	258.76	570.54	241.37	517.03	229.69

Table 5

Means and Standard Deviations of the Post-KR interval Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	2716.26	885.68	2229.68	1005.84	1941.79	578.03
2	2540.69	1001.96	1992.90	622.64	1826.57	618.40
3	2280.63	875.95	1881.20	552.59	1678.32	487.20
4	2269.62	862.20	1858.03	626.49	1785.68	633.84
5	2314.44	1121.63	1942.37	813.82	1802.71	609.02
6	2238.14	1027.16	1954.97	723.83	1750.61	619.25
7	2246.32	964.62	1892.78	720.84	1733.81	590.73
8	2075.22	738.91	1974.46	755.79	1705.73	497.32
9	1976.05	770.86	1804.21	576.71	1740.15	579.81
10	1925.94	687.74	1882.74	655.78	1791.05	592.16

Table 6

Means and Standard Deviations of the Intertrial Interval Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	3600.57	961.64	2912.48	1038.70	2549.83	575.32
2	3318.65	1081.49	2627.79	591.54	2390.58	645.13
3	2984.44	940.03	2488.23	531.21	2224.04	508.73
4	2958.14	977.62	2461.79	599.89	2334.22	667.56
5	3022.08	1270.52	2544.08	790.58	2352.52	605.49
6	2939.82	1273.34	2568.56	763.14	2267.20	625.00
7	2903.66	1024.91	2488.34	719.08	2269.62	591.19
8	2710.40	832.25	2561.03	776.78	2238.59	531.61
9	2592.07	828.39	2390.63	575.52	2258.07	620.77
10	2536.11	769.48	2453.24	635.43	2308.09	665.68

Table 7

Means and Standard Deviations of the Interstimulus Interval Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	5062.37	1697.82	4333.41	1757.58	4011.05	1286.80
2	4792.64	1971.88	4090.45	1367.04	3815.11	1338.32
3	4455.26	1772.20	3919.40	1203.08	3615.84	1118.18
4	4489.23	1725.20	3949.13	1287.85	3801.11	1290.10
5	4624.83	2018.81	4054.86	1580.80	3808.50	1205.57
6	4530.91	2103.59	4039.24	1451.05	3698.12	1206.87
7	4426.32	1807.57	4037.95	1457.88	3685.01	1145.09
8	4270.23	1591.37	4176.75	1636.20	3699.32	1056.86
9	4077.25	1568.24	3987.43	1417.14	3691.68	1213.07
10	4048.95	1494.46	4009.06	1442.21	3758.49	1271.83

Table 8

Means and Standard Deviations of the Ratio Across Blocks of Practice for Day 1, 2, 3 (n=29).

	Day 1		Day 2		Day 3	
Blocks	M	SD	M	SD	M	SD
1	.3692	.1822	.3779	.1976	.3531	.2035
2	.3612	.1655	.3905	.2780	.3516	.2072
3	.3615	.1842	.3765	.2478	.3779	.2422
4	.3547	.1846	.3929	.2669	.3630	.2522
5	.3562	.1801	.3828	.2611	.3655	.2528
6	.3559	.1696	.3796	.2574	.3504	.2173
7	.3564	.2086	.3778	.2550	.3552	.2268
8	.3593	.2119	.3642	.2545	.3547	.2092
9	.3547	.1805	.3798	.2657	.3366	.1913
10	.3574	.1791	.3636	.2578	.3288	.1972

Appendix E

Means and Standard Deviations for all Dependent Variables - Experiment Two

Table 1

Means and Standard Deviations of the Absolute Error Scores for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	1523.86	989.20	1353.88	1921.14
SD	851.76	925.31	982.86	1366.28
Group 2				
M	932.72	896.58	1503.38	1674.76
SD	479.74	408.70	1094.30	1478.67
Group 3				
M	631.48	800.50	821.76	1119.14
SD	347.90	351.26	471.06	473.24
Group 4				
M	702.34	587.86	611.54	1049.20
SD	309.11	294.17	445.95	745.70
Group 5				
M	665.74	460.76	659.96	866.28
SD	304.26	187.86	525.98	571.36
Group 6				
M	548.46	622.64	509.62	722.98
SD	151.93	315.73	264.10	360.51
Group 7				
M	510.80	595.78	690.86	769.90
SD	238.09	304.01	482.62	483.55
Group 8				
M	442.18	491.68	471.94	681.16
SD	208.24	163.02	213.97	391.64
Group 9				
M	608.68	532.74	415.58	641.98
SD	322.40	167.10	132.69	399.90
Group 10				
M	396.46	394.28	527.44	1084.02
SD	160.49	124.42	156.33	684.84
Group 11				
M	519.36	513.24	455.80	708.48
SD	199.45	282.19	187.29	354.50
Group 12				
M	513.84	451.96	625.44	795.50
SD	210.64	157.03	197.34	489.97

Table 2

Means and Standard Deviations of the Variable Error Scores for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	1342.20	745.62	699.90	602.30
SD	768.35	370.71	434.79	241.99
Group 2				
M	970.68	922.95	976.29	915.11
SD	555.64	452.16	598.85	680.79
Group 3				
M	539.25	685.16	564.99	534.41
SD	249.30	302.55	129.62	151.16
Group 4				
M	744.35	611.65	424.18	624.64
SD	316.23	315.21	162.40	484.86
Group 5				
M	645.68	408.64	491.99	468.88
SD	299.13	149.50	421.74	319.16
Group 6				
M	514.65	671.20	451.49	417.60
SD	151.19	383.46	122.99	164.97
Group 7				
M	405.39	570.07	407.46	430.68
SD	251.64	258.41	196.01	140.66
Group 8				
M	456.66	510.13	424.12	347.16
SD	207.63	163.17	129.06	238.29
Group 9				
M	588.08	504.86	341.87	423.94
SD	322.32	125.17	146.69	251.75
Group 10				
M	401.36	450.72	418.52	333.12
SD	207.49	137.31	197.91	141.12
Group 11				
M	564.25	518.81	383.53	411.99
SD	223.30	259.42	118.23	86.95
Group 12				
M	573.97	443.01	522.50	748.04
SD	253.06	178.83	148.63	929.31

Table 3

Means and Standard Deviations of the Movement Time Scores for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	1975.74	2217.12	2138.58	1982.76
SD	853.85	1103.77	1206.61	906.62
Group 2				
M	1740.76	1592.52	1416.08	1407.48
SD	1180.43	744.76	828.97	918.19
Group 3				
M	2294.38	2205.36	2397.54	2365.46
SD	910.28	874.71	1101.99	956.78
Group 4				
M	1713.02	1822.86	1607.64	1491.22
SD	689.27	909.90	739.62	614.72
Group 5				
M	1547.94	1684.52	1771.00	1686.66
SD	790.04	862.72	961.42	880.28
Group 6				
M	1519.86	1490.22	1415.14	1409.16
SD	778.85	716.79	716.55	665.67
Group 7				
M	1378.34	1339.78	1317.44	1447.56
SD	811.61	721.43	703.50	864.05
Group 8				
M	1825.08	1764.52	1885.36	1755.92
SD	723.63	721.62	710.19	647.95
Group 9				
M	1411.96	1382.16	1453.26	1409.84
SD	635.56	695.63	748.04	734.20
Group 10				
M	1806.16	1852.24	1933.78	1821.54
SD	918.11	969.67	800.62	589.88
Group 11				
M	1443.74	1439.88	1484.28	1474.76
SD	490.91	455.16	540.37	502.78
Group 12				
M	1772.42	1823.04	1779.62	1990.72
SD	978.43	1017.76	926.01	1152.32

Table 4

Means and Standard Deviations of the KR-delay Scores for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	1007.40	937.16	915.44	866.88
SD	451.79	532.35	514.11	440.22
Group 2				
M	653.94	751.20	684.40	722.36
SD	367.33	462.25	335.70	436.18
Group 3				
M	746.10	795.76	843.94	871.62
SD	351.94	452.34	464.58	640.81
Group 4				
M	692.06	679.82	692.14	736.08
SD	196.19	201.54	222.38	267.46
Group 5				
M	723.82	674.22	695.90	724.16
SD	189.04	245.36	285.72	324.91
Group 6				
M	531.60	528.78	522.00	513.44
SD	130.33	121.03	128.54	144.01
Group 7				
M	626.00	622.96	666.68	649.60
SD	267.13	256.04	302.09	278.50
Group 8				
M	539.52	528.20	528.92	533.74
SD	255.62	261.58	260.71	266.50
Group 9				
M	613.90	565.86	582.20	572.62
SD	244.36	229.80	241.79	249.42
Group 10				
M	636.40	623.98	675.84	674.48
SD	259.88	280.44	369.38	385.59
Group 11				
M	614.86	620.66	675.34	680.82
SD	314.46	306.13	350.32	325.50
Group 12				
M	724.00	698.32	733.82	779.04
SD	292.26	278.95	258.71	237.48

Table 5

Means and Standard Deviations of the Post-KR Intervals for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	3123.52	2951.00	3076.94	2553.86
SD	736.73	893.72	1039.36	893.70
Group 2				
M	2202.32	2101.80	2154.78	1847.94
SD	613.82	515.53	663.94	614.45
Group 3				
M	2906.26	2988.98	3033.08	2814.08
SD	1043.31	761.63	675.72	558.52
Group 4				
M	2414.22	2187.08	2282.70	1779.46
SD	962.53	804.71	741.89	488.84
Group 5				
M	2283.62	2123.54	2579.22	2262.80
SD	856.30	591.76	1003.27	849.56
Group 6				
M	2144.42	2053.18	2151.50	2013.76
SD	905.47	856.66	883.90	893.00
Group 7				
M	2055.90	2074.60	2258.48	2072.88
SD	832.30	864.69	957.98	970.75
Group 8				
M	1944.46	1899.68	2064.04	1909.62
SD	445.41	518.72	485.26	464.93
Group 9				
M	2027.22	1921.58	2094.86	1893.50
SD	748.53	808.25	832.44	696.79
Group 10				
M	2333.22	2389.32	2618.40	2228.38
SD	991.53	1310.20	1164.90	735.54
Group 11				
M	1632.54	1659.94	1916.02	1678.08
SD	356.00	377.31	456.78	394.90
Group 12				
M	1862.74	1850.90	2234.68	1846.80
SD	842.54	736.38	1172.62	631.40

Table 6

Means and Standard Deviations of the Intertrial Interval for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	4130.92	3888.16	3992.38	3420.74
SD	952.55	1042.54	1216.50	1024.80
Group 2				
M	2856.26	2878.64	2839.18	2570.30
SD	767.83	881.78	837.30	918.17
Group 3				
M	3652.36	3768.74	3877.02	3685.70
SD	1004.20	811.56	1028.00	986.88
Group 4				
M	3106.28	2866.90	2975.84	2515.54
SD	957.86	785.10	767.82	631.72
Group 5				
M	3007.44	2797.76	3275.12	2986.96
SD	949.50	665.30	1120.18	1063.78
Group 6				
M	2676.02	2581.90	2673.50	2527.20
SD	960.06	914.97	935.80	958.16
Group 7				
M	2681.90	2697.56	2921.16	2722.48
SD	983.15	1041.65	1193.43	1134.32
Group 8				
M	2483.98	2427.88	2592.96	2443.36
SD	624.98	685.05	640.07	667.02
Group 9				
M	2641.12	2487.44	2677.06	2466.12
SD	662.40	682.08	694.02	568.76
Group 10				
M	2969.62	3013.30	3294.24	2902.86
SD	1188.37	1421.23	1456.25	1067.94
Group 11				
M	2247.40	2280.60	2591.36	2358.90
SD	237.35	203.88	303.81	300.86
Group 12				
M	2586.74	2549.22	2968.50	2625.84
SD	818.46	707.29	1180.32	641.03

Table 7

<u>Means and Standard Deviations of the Interstimulus Interval for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).</u>

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	6106.66	6093.88	6130.96	5403.50
SD	1583.19	2010.45	2280.11	1867.91
Group 2				
M	4597.02	4471.16	4255.06	3977.78
SD	1670.20	1373.71	1283.13	1444.23
Group 3				
M	5946.74	5974.10	6274.56	6051.16
SD	1829.51	1491.56	1796.94	1779.61
Group 4				
M	4819.30	4689.76	4582.48	4006.76
SD	1459.38	1599.53	1345.92	1192.15
Group 5				
M	4555.38	4482.28	5046.12	4673.62
SD	1639.55	1465.62	2016.32	1811.54
Group 6				
M	4195.88	4072.12	4088.64	3936.36
SD	1693.67	1585.64	1596.35	1573.15
Group 7				
M	4060.24	4037.34	4242.60	4170.04
SD	1607.30	1582.72	1767.59	1820.52
Group 8				
M	4309.06	4192.40	4478.32	4199.28
SD	1321.16	1357.47	1278.58	1233.71
Group 9				
M	40[illegible]3.08	3869.60	4130.32	3875.96
SD	1217.18	1318.40	1312.62	1193.12
Group 10				
M	4775.78	4865.54	5228.02	4724.40
SD	2020.65	2312.28	2184.61	1591.24
Group 11				
M	3691.14	3720.48	4075.64	3833.66
SD	639.20	542.85	773.14	718.99
Group 12				
M	4359.16	4372.26	4748.12	4616.56
SD	1676.86	1696.07	2052.87	1630.11

Table 8

Means and Standard Deviations of the Ratios for Blocks of Practice Before KR-withdrawal (Blocks 1 and 2) and Following KR-withdrawal (Blocks 3 and 4) (n=10).

	Block 1	Block 2	Block 3	Block 4
Group 1				
M	.3476	.3628	.3360	.3737
SD	.1795	.2308	.1869	.1952
Group 2				
M	.3125	.3597	.3492	.4037
SD	.1922	.2078	.1710	.2248
Group 3				
M	.3024	.2929	.2805	.3104
SD	.2007	.1868	.1199	.1874
Group 4				
M	.3384	.3601	.3437	.4317
SD	.1708	.1876	.1374	.1645
Group 5				
M	.3425	.3464	.3041	.3398
SD	.1708	.1443	.1387	.1406
Group 6				
M	.2825	.2904	.2791	.2976
SD	.0980	.0902	.1006	.1172
Group 7				
M	.3280	.3188	.3130	.3432
SD	.1423	.1294	.1207	.1521
Group 8				
M	.2763	.2811	.2608	.2762
SD	.1046	.1256	.1239	.1092
Group 9				
M	.3617	.3737	.3491	.3675
SD	.2394	.2698	.2373	.2563
Group 10				
M	.2845	.2916	.2715	.2963
SD	.0713	.0916	.0901	.1014
Group 11				
M	.4313	.4377	.4233	.4720
SD	.3208	.3415	.3327	.3602
Group 12				
M	.4919	.4757	.4296	.4966
SD	.3404	.3213	.2780	.2668

Appendix F

Means and Standard Deviations for all Dependent Variables - Experiment Three

Table 1

Means and Standard Deviations of the Absolute Error Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	4	5
Group 1					
M	1263.98	905.46	557.70	515.22	905.88
SD	463.67	737.19	274.61	344.71	226.51
Group 2					
M	1007.70	573.74	477.38	494.28	537.60
SD	460.62	339.26	161.64	146.33	220.32
Group 3					
M	844.1	808.38	355.28	404.48	661.96
SD	470.32	699.21	114.88	231.15	223.93
Group 4					
M	994.14	591.60	453.52	522.26	849.92
SD	570.16	207.34	233.64	247.80	457.27
Group 5					
M	1064.90	628.52	461.14	501.80	1123.94
SD	360.41	346.77	205.27	215.91	645.77

Table 2

Means and Standard Deviations of the Variable Error Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3		5
Group 1					
M	1282.64	850.09	599.34	525.06	974.17
SD	724.16	606.07	299.62	386.67	425.93
Group 2					
M	871.42	601.87	467.95	502.43	448.24
SD	399.07	369.83	161.04	195.58	289.11
Group 3					
M	798.36	702.90	341.84	391.13	649.12
SD	403.45	470.36	82.48	170.28	225.37
Group 4					
M	792.82	659.89	444.58	518.49	943.93
SD	387.62	271.86	189.83	210.95	496.75
Group 5					
M	1007.91	674.56	471.18	464.40	1273.19
SD	289.96	424.76	145.33	270.58	758.59

Table 3

Means and Standard Deviations of the Movement Time Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	4	5
Group 1					
M	2172.12	2274.54	1975.70	2037.46	1886.62
SD	707.61	662.18	693.77	842.69	715.55
Group 2					
M	2228.40	2329.36	1637.48	1704.58	1773.78
SD	746.76	633.83	438.00	460.26	694.50
Group 3					
M	2281.54	2449.52	2238.26	1957.70	1983.20
SD	876.69	923.01	1324.94	894.40	1017.78
Group 4					
M	1776.72	1971.14	1673.02	1663.48	1702.32
SD	594.79	699.33	523.35	576.23	647.88
Group 5					
M	2080.22	2021.80	1464.46	1547.46	1730.98
SD	701.15	687.06	396.08	497.41	557.38

Table 4

Means and Standard Deviations of the KR-delay Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	4	5
Group 1					
M	1040.88	947.78	862.74	874.96	1111.76
SD	128.46	111.06	250.52	312.04	588.82
Group 2					
M	671.58	576.04	506.68	513.48	548.72
SD	285.80	269.96	301.42	336.50	271.53
Group 3					
M	768.58	700.50	523.98	501.62	616.02
SD	191.21	160.46	144.57	164.51	194.07
Group 4					
M	863.86	865.12	645.36	642.66	711.06
SD	293.91	299.51	366.91	385.88	442.55
Group 5					
M	910.78	904.38	529.44	553.78	628.84
SD	87.28	274.53	103.84	119.4	162.32

Table 5

Means and Standard Deviations of the Post-KR Interval Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice 1	2	3	4	5
Group 1					
M	3201.08	3067.04	2407.92	2315.30	2604.04
SD	848.70	976.43	638.15	799.50	619.72
Group 2					
M	2620.20	2277.42	2047.88	1967.90	2153.56
SD	760.77	570.41	558.53	564.02	438.75
Group 3					
M	2935.48	2780.14	1895.10	1956.64	2714.94
SD	925.81	863.50	644.79	642.03	1051.98
Group 4					
M	2907.90	2559.50	1716.02	1740.70	2382.12
SD	879.00	759.59	293.66	295.92	913.79
Group 5					
M	3475.16	2923.60	17[illegible]0.28	1741.96	2507.46
SD	1029.30	857.32	438.64	502.28	624.70

Table 6

Means and Standard Deviations of the Intertrial Interval Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	[illegible]	5
Group 1					
M	4241.80	4014.82	3270.66	3190.26	3715.80
SD	879.43	986.26	763.25	878.06	866.72
Group 2					
M	[illegible]1.78	2853.46	2554.56	2481.38	2702.28
SD	341.99	613.08	687.59	706.51	458.44
Group 3					
M	3704.06	3480.64	2419.08	2458.26	3330.96
SD	1009.63	903.64	696.55	695.47	1141.97
Group 4					
M	3771.76	3424.62	2361.38	2383.36	3093.18
SD	998.12	941.44	504.26	506.84	945.35
Group 5					
M	4385.94	3826.38	2279.72	2295.74	3136.38
SD	975.35	863.60	421.11	452.09	613.37

Table 7

Means and Standard Deviations of the Interstimulus Interval Scores for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	4	5
Group 1					
M	6414.08	6289.38	5246.36	5227.72	5602.42
SD	1505.54	1507.91	1279.56	1609.57	1421.57
Group 2					
M	5520.18	5182.82	4192.04	4185.96	4463.16
SD	1538.89	1172.22	1067.23	1104.22	1050.12
Group 3					
M	5985.60	5930.16	4657.34	4415.96	5314.16
SD	1726.64	1718.58	1763.41	1415.03	1808.23
Group 4					
M	5544.48	5395.76	4034.40	4046.84	4795.50
SD	1487.47	1516.66	906.95	1000.54	1428.39
Group 5					
M	6466.16	5849.78	3744.18	3843.20	4867.36
SD	1455.65	1411.94	702.50	872.05	1030.36

Table 8

Means and Standard Deviations of the Ratios for the First and the Last Two Blocks of Practice on the Criterion Task (Blocks 1, 2, 3, and 4) and the Transfer Block of Practice (Blocks) (n=10).

	Blocks of Practice				
	1	2	3	4	5
Group 1					
M	.3484	.3435	.3837	.4155	.4512
SD	.09	.10	.12	.17	.24
Group 2					
M	.2786	.2736	.2611	.2765	.2750
SD	.11	.14	.15	.18	.16
Group 3					
M	.2815	.2778	.2992	.2753	.2666
SD	.09	.09	.10	.10	.12
Group 4					
M	.3227	.3544	.3827	.3749	.3453
SD	.12	.12	.21	.21	.23
Group 5					
M	.2866	.3375	.3272	.3559	.2717
SD	.09	.15	.10	.16	.10