ZHANGYUN CHEN
High Contextual Interference and Reduced Frequency of Knowledge of Results (KR): Effects of Fading and Evenly Distributed KR on Retention and Transfer
(Under the Direction of PATRICIA DEL REY)

The effects on retention and transfer of a fading KR schedule and an evenly distributed KR schedule in a high contextual interference practice order were investigated. Our assumption in administering reduced KR is that there is an optimal relative KR frequency and schedule to maximize the effects of reduced frequency of KR in retention and transfer tests. Thus, 0%, 30% and 70% KR frequencies were tested to determine if there is an optimal range of reduced KR for random practice (RA) participants in practicing timing tasks. The current study included a fading KR schedule as well as an evenly distributed KR schedule with both the 30% and 70% KR frequency conditions. Participants were required to press the response pedal to coincide with the illumination of the last lamp with an anticipation-timing task. Participants who practiced tasks with the 30% evenly distributed KR were more effective in retention for absolute error (AE) than the 30% fading KR group and were more accurate and consistent in retention compared to those who practiced with the 0% KR and the 70% evenly distributed KR. Finally, participants who practiced tasks with the 30% evenly distributed KR were more accurate and consistent in transfer compared to those who practiced tasks without KR (0% KR). The following conclusions were drawn based on the findings in the present study. First, the schedule of KR (when it is presented during practice) may be a factor, in addition to reduced frequency of KR. In addition, practicing tasks with 30% evenly distributed KR shows a tendency ($\underline{p}$ = .06) to yield better retention performance than either a 70% evenly distributed KR and a 30% fading KR schedule. Second, for retention and transfer there is an optimal relative frequency and schedule of KR (30%

evenly distributed KR during acquisition) for learning to response to varying stimuli during an anticipation-timing task. Third, for retention when evenly distributed KR is presented during acquisition a low frequency of KR (30%) is more effective than a high frequency of KR (70%). Fourth, providing less frequent KR does not degrade acquisition performance compared to a higher frequency.

INDEX WORDS: Contextual interference, Reduced frequency of knowledge of results, Fading KR schedule, Evenly distributed KR schedule, Random practice, Anticipation timing

HIGH CONTEXTUAL INTERFERENCE AND REDUCED FREQUENCY OF KNOWLEDGE OF RESULTS (KR): EFFECTS OF FADING AND EVENLY DISTRIBUTED KR ON RETENTION AND TRANSFER

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCATION

Overview

Error detection is the internal ability of learners to detect their own errors when performing a motor skill. Feedback is essential in developing error detection, but the issue is how much and how often, and what type of feedback is necessary? Information feedback can be identified as intrinsic or extrinsic. Intrinsic feedback provides performers with information that is inherent in the performance of a particular movement. It is normally occurring as a consequence of moving. This information is available to the performer from his or her own sensory system (such as vision and proprioception). On the other hand, extrinsic feedback refers to augmented feedback presented to the performer, i.e., added to the intrinsic feedback by a teacher or experimenter.

Error detection is developed during practice when performers recognize their own errors by comparing their own intrinsic feedback to the product goal they produce. Two kinds of information feedback, knowledge of results (KR) and knowledge of performance (KP), give information to the performer about the product and the process goal, respectively. An example of KR, in an anticipation timing test, is the verbal feedback provided in the form of, " early 45 milliseconds." KP refers to information about the movement pattern (the process). For instance, when a performer takes a free-throw shot, the teacher may say, "your upper arm did not fully extend." These types of feedback refer to the two goals performers are attempting to meet when producing a movement, a process (KP) and a product (KR) goal.

Feedback and error detection are studied in a number of fields, including motor learning and control (Adams, 1971; Sherwood, 1996); cognitive psychology (Larigauderie, Gaonac'h, & Lacroix 1998); cognitive neuroscience (Miltner, Braun, & Coles, 1997); brain science (Flament, & Ebner, 1996), and computer science. Evidence obtained from the above fields demonstrates the existence of an error detection mechanism in which a comparison is made between the performer's intrinsic feedback and the product goal achieved. Following the administration of KR, Miltner, Braun and Coles (1997) examined human event-related brain potentials, measurements of the voltage changes in the brain to detect and / or infer various phenomena involved in brain activities. Their findings provide experimental evidence for the existence of a neural system that implements the error detection process. Flament and Ebner (1996) observed that cerebellar activity was highest when movement errors occurred and cerebellar activity decreased as errors decreased and performance improved. Their findings and others indicate that the cerebellum is involved in processing feedback and error detection.

How are feedback and error detection linked? Schmidt and White (1972) demonstrated that a positive correlation between actual error and the participant’s estimation increased as practice continued, and they concluded that error detection ability develops with practice. Adams (1971) identified the importance of intrinsic feedback and error detection in learning motor skills. Adams believed that error detection plays a central role in motor learning. In his closed-loop theory of motor learning, Adams identified a "perceptual trace." According to Adams, performers compare the intrinsic feedback received about the process (KP) with the memory of the movement that produced the product goal (the perceptual trace). If the KP does not match the memory of the movement, then an error is detected. The strength of the comparison is predicted to increase as a function of practice (i.e., the number of comparisons made between intrinsic KP and the perceptual trace). Thus, we can postulate according to Adams, that for learning to occur performers use intrinsic feedback to detect errors by making a comparison between KP and the perceptual trace.

Following Adams' theory, Schmidt (1975) developed his schema theory of motor learning and also included feedback and error detection as an essential aspect of motor learning. Schmidt identified the recognition schema, an internal referent or a template of the specific motor plan that achieved the product goal in previous attempts. The recognition schema (Schmidt) is similar to the perceptual trace (Adams) and is dependent on feedback to develop. To form the recognition schema, Schmidt stated that both intrinsic and extrinsic feedback are essential during practice. Both theorists Adams and Schmidt agree on the important role of feedback in the development of error detection. Adams believed intrinsic feedback is critical and Schmidt postulated that both intrinsic and extrinsic feedback were important to learning and developing an internal error detection mechanism.

Recent investigators (Wulf & Schmidt, 1994), in contrast to Adams and Schmidt, have investigated reduced extrinsic KR and found surprising results. Wulf and Schmidt believed that reduced extrinsic feedback forces the learner to rely on intrinsic feedback which assists in the development of error detection. These findings challenge the classical viewpoint of the role of feedback, which is that frequent extrinsic feedback facilitates motor learning and is necessary to develop error detection abilities. Some extrinsic feedback would seem to be necessary in order to evaluate intrinsic feedback and provide a standard of goal attainment. However, frequent extrinsic KR may distract performers from processing intrinsic feedback and these negative effects are seen in retention and transfer tests.

Based on empirical evidence, explanations have emerged on how reduced extrinsic feedback may facilitate learning (Schmidt, 1991). One explanation is that frequent feedback distracts, or even blocks completely, critical postresponse information processing activities that would occur if feedback was not provided on a particular trial (Schmidt, Young, Swinnen, & Shapiro, 1989). That is, frequent feedback might interfere with the learner's analysis of intrinsic feedback, preventing the development of an internal error detection mechanism. Such internal error detection is most important for performance in retention and transfer, particularly since extrinsic information feedback is withdrawn during retention and transfer. According to the proactive hypothesis (Wulf & Schmidt, 1994), frequent feedback produces excessive variability during practice. Too frequent extrinsic KR can produce excessive modifications from trial to trial and also may prevent processing intrinsic feedback that is so necessary to develop error detection. Moreover, internal error detection is critical to performance on memory and transfer tests when KR is not administered.

Reduced extrinsic feedback has been studied with contextual interference practice schedules. Contextual interference refers to the effects of practicing multiple tasks on memory and transfer tests. Contextual interference studies have 3 phases: acquisition (practice), retention (a memory test of the tasks practiced) and transfer (performance on a novel but similar task). Typically, two practice schedules are administered during the acquisition phase. In a high contextual interference condition, i.e., random practice schedule (RA), three tasks are presented in random order (ABCCABCAB…). Participants in a blocked practice schedule (BL) (low contextual interference) complete a block of trials of one task prior to practicing another (AAA…, BBB…, CCC…). Del Rey and Shewokis (1993) using summary feedback (a form of reduced KR), demonstrated that participants in a high contextual interference condition benefited in transfer from practicing timing tasks with reduced KR. Based on participants' verbal reports, Del Rey and Shewokis reasoned that reduced extrinsic KR facilitated the development of error detection for RA participants. Moreover, using bandwidth feedback (feedback given to performers within a certain error range only), Sherwood (1996) concluded that his participants in a high contextual interference (RA) condition who received bandwidth feedback in acquisition developed better spatial error detection ability when compared to BL, as measured in retention. Also, Wulf (1992) presented 67% KR or 100% KR to RA and BL groups. For 67% KR groups, KR was evenly distributed over 90 trials and was not provided on every third trial. The results of her experiment demonstrated that both reduced frequency of KR and high contextual interference (RA) enhanced performance in retention. Thus, reduced extrinsic feedback in practice was beneficial in retention to these participants practicing tasks in a high contextual interference condition as compared to BL participants.

Both Del Rey and Shewokis and Sherwood used the elaboration hypothesis (Shea & Zimny, 1983) to understand how reduced feedback for RA participants facilitated the development of their error detection. Given the order of presentation for a high contextual interference condition, i.e., on each trial a new task is presented, they argued that frequent extrinsic feedback was a distraction to RA performers during practice because KR about the previous trial could not be used to modify the current response. Frequent extrinsic feedback not only distracts RA performers in preparation of the next response, but also interrupts performers from elaborative and distinctive processing. Shea and Zimny (1983) developed the elaboration hypothesis to explain why RA is a more effective practice schedule compared to BL for retention and transfer tasks. Elaborative processing is a result of comparisons made across tasks (intertask processing) during RA practice. Thus, reduced extrinsic feedback removes the distraction that irrelevant feedback produces and frees participants to focus on their own intrinsic feedback to distinguish differences and similarities between tasks. In effect, reduced KR enhances intertask processing. It is nearly impossible for RA participants in a 100% KR condition to process their intrinsic feedback when extrinsic feedback is provided immediately following the completion of each response. Therefore, elaborative processing is degraded for RA participants in a frequent extrinsic feedback condition. In addition, relying on intrinsic feedback is what is essential for performance in retention and transfer because no extrinsic KR is provided. Thus, benefits would accrue to participants in a high contextual interference condition in retention and transfer when reduced KR is provided during acquisition, because these participants will learn to rely on intrinsic feedback which is necessary in memory tests and in performing transfer tasks.

Relying on intrinsic feedback enables RA participants to acquire information from multiple sensory modalities (e.g., proprioceptive and visual), whereas extrinsic feedback gives information usually about the product goal, the outcome of the movement. Intrinsic feedback provides information both about the outcome of the movement but more important, about the process, the movement itself. By comparing and contrasting intrinsic feedback from the movement's execution, participants in RA can identify similarities and differences among the movements produced and consequently develop distinctive memory representations of movements made. The benefit of such increased processing of the movement and the product goal will appear in later retention and transfer tests. Relying on intrinsic feedback during acquisition trials matches the context in retention and transfer tests when extrinsic KR is not provided and the performer must rely on previously developed internal error detection.

In the literature of reduced frequency of KR, two types of schedules are employed in manipulating reduced frequency of KR, i.e., an evenly distributed KR schedule and a fading KR schedule. An evenly distributed KR schedule requires that KR be evenly distributed across practice trials. In contrast, in a fading KR schedule, KR is presented more often during initial practice and is gradually reduced. Winstein and Schmidt (1990) conducted a series of experiments to study reduced frequency of KR with a constant practice schedule, which is practicing the same task over all practice trials. In their Experiment 1, there were two KR (relative frequency) acquisition conditions, 100% and 33%. Participants in the 100% KR condition received KR after each trial, whereas participants in the 33% KR group received KR after two out of every six trials. Although there were no significant effects between the two relative frequency conditions, the 33% KR condition tended to be slightly more accurate than 100% KR in retention. In their Experiment 2 and Experiment 3, the design was slightly different from Experiment 1. In contrast to Experiment 1, where the KR was evenly distributed over the practice trials in the 33% KR condition, a fading schedule was applied and relative frequency of KR was 50% instead of 33%. Specifically, the relative frequency across 8-trial blocks was gradually decreased from 100% to 25% over all practice trials. On both Experiment 2 and Experiment 3, the 50% fading KR group demonstrated a significantly lower error in retention, compared to 100% KR. Winstein and Schmidt argued that a fading schedule might prevent dependence on extrinsic feedback in later practice and may be an effective way to manipulate reduced frequency of KR for motor learning.

However, in the Winstein and Schmidt's study the effects of a fading KR schedule were confounded with reduced frequency of KR. Thus, the better performance for the fading KR schedule compared to 100% KR in retention could not be attributed to the fading KR schedule alone. It could have been the results of practicing the task with less KR. Nicholson and Schmidt (1991) explored the issue of schedule of KR further by comparing a fading KR group with two other 50% KR groups in a constant practice order. These two 50% KR groups received evenly distributed KR. One group had KR on alternating trials; the other received alternating 5-trial KR and no-KR blocks. The results of their study revealed that there were no significant differences in retention among the three 50% groups. But the three 50% KR groups performed better than the 100% KR group in retention, hinting that the schedule of KR (i.e., when KR is presented) might not be a factor when considering the effects of reduced frequency of KR compared to the actual amount of reduced KR administered.

These previous studies have important implications for further research: 1) Given the differential results of 33% KR and 50% KR in Winstein and Schmidt, it can be reasoned that there may be an optimal relative frequency to maximize retention and transfer. Given the inconsistent results reported in Winstein and Schmidt and Nicholson and Schmidt who used the fading KR schedules, it is unknown if the schedule of KR is a factor in manipulating the effects of reduced frequency of KR. Future research will be needed to clarify this issue (Winstein & Schmidt, 1990). It is premature to conclude that reduced frequency of KR is an effective way to enhance performance in retention. However, it may be that only a certain range of relative frequency of KR may be effective. Moreover, the effects of KR schedule may interact with frequency of KR. In other words, two factors are relevant in evaluating the efficacy of reduced frequency of KR in retention and transfer: frequency and schedule. Thus, there might be an optimal relative frequency and schedule of KR that is effective in retention and transfer.

Therefore, both schedule and frequency were factors of investigation in the current study. Three relative frequency groups, 0% KR, 30% KR and 70% KR were administered to RA participants. However, seventy percent KR may be still too high for RA participants, distracting participants from processing intrinsic feedback. In contrast to the 70% KR, the 0% KR may be too low, not providing the minimum amount of KR for RA participants to develop an internal error detection mechanism. Both intrinsic and extrinsic feedback are needed according to Schmidt's schema theory in order to develop error detection. To further investigate the issue of KR schedule and compare our findings to Winstein and Schmidt (1990) and Nicholson and Schmidt (1991), two KR schedules were administered in the current study: an evenly distributed KR schedule (KR is evenly distributed across all practice trials) and a fading KR schedule (more KR during the initial practice is presented and gradually decreased over practice schedule). Thus, five

KR groups were formed: 0% KR, 30% fading KR, 70% fading KR, 30% KR (evenly distributed) and 70% KR (evenly distributed). Our point of view on reduced frequency of KR is that enough KR must be administered, not too much nor too little to develop effective internal error detection for RA participants in order to perform tasks presented in retention and transfer. However, the positive effects of reduced frequency of KR may be degraded in retention and transfer if the schedule of KR interferes with processing of intrinsic feedback. The issue with schedule of KR is when is KR more effective to be presented. In the current study, the 30% KR (evenly distributed) was expected to maximize the effect of reduced frequency of KR in retention and transfer because participants can take advantage of both intrinsic and extrinsic feedback over practice trials. However, the 30% fading KR would not be as effective in that RA participants receive too much KR during early practice trials and receive too little KR during later practice. Using three relative frequencies of KR with both fading and an evenly distributed KR schedule will yield information not only about optimal relative frequency, but the importance of the schedule of KR (i.e., when the KR is presented) during practice. Thus, the 30% fading KR and the 70% fading KR groups where feedback is given more often in the initial practice trials and gradually decreases were compared to the 30% KR and the 70% KR (evenly distributed) in retention and transfer to determine the effects of frequency of KR and schedule of KR for participants practicing tasks in RA.

Purpose of the Study

The purpose of the present study was to compare the effects on retention and transfer of a fading KR and an evenly distributed KR condition in a high contextual interference practice order. The literature already indicates the benefits of practicing tasks with reduced KR for participants in RA. Our assumption in administering reduced KR is that there is an optimal relative frequency to maximize the effects of reduced frequency of KR. Thus 0% KR, 30% KR and 70% KR were included to determine if there is an optimal range of relative frequency of KR for RA participants in practicing timing tasks. Participants in the 30% KR condition were expected to be free during practice to process their intrinsic, normally-occurring KR, which is so crucial for performance in retention and transfer. The current study included a fading KR schedule as well as an evenly distributed KR schedule with both 30% and 70% conditions, which removed the confounding effects found in the previous literature of relative frequency of KR and the schedule of KR. This study enabled us to clarify the effects of the schedule of KR, independent of relative frequency of KR. Our findings shed light on both the optimal relative frequency of KR and the schedule of KR (i.e., when KR is presented during practice) and their interaction as factors in retention and transfer performance.

Significance of the Study

The investigation of reduced frequency of KR has generally concluded that reduced frequency of KR is beneficial for RA participants in retention and transfer. But the inconsistent findings in the literature suggest the effects of reduced frequency of KR may be limited to a certain range of relative frequency and interact with the schedule of KR.

Previous studies have confounded schedule with reduced frequency of KR. By including a 0%, 30% and 70% relative frequency of KR on both evenly distributed KR and fading KR, the present study extends previous literature, e.g., Winstein and Schmidt (1990), Wulf (1992), and Del Rey and Shewokis (1993) by improving the experimental design. Two different schedules of KR allowed analysis of schedule of KR as a factor in manipulating the effects of reduced frequency of KR. We will thus be able to answer questions about the optimal relative frequency of KR (i.e., opening up discussions of the balance between intrinsic and extrinsic KR) on RA participants, as well as any effects in retention and transfer of when extrinsic KR should be administered during practice. Therefore, this study makes an important contribution both theoretically as well as methodologically by improving the design to control for effects of schedule separate from reduced frequency of KR during practice.

Hypotheses

Dependent variables were absolute errors (AE), variable error (VE) and constant error (CE). Each one provides different information about performance. Absolute error provides the overall magnitude of error. Constant error gives information on subjects' bias as early or late. Variable error, as a measure of consistency, is computed to evaluate subjects' variability around mean CE.

Specifically, the following hypotheses during acquisition, retention, and transfer were tested in order to investigate the purpose of the present study.

Acquisition

1. Participants in the 30% evenly distributed KR group will be more accurate and consistent for all dependent measures compared to the 0% KR group. Empirical evidence shows that a certain minimum amount of extrinsic KR is necessary to provide a standard of goal attainment. Therefore, the 0% KR group is expected to perform with more error and variability than the 30% evenly distributed KR group.
2. Participants in the 30% evenly distributed KR group compared to the 70% evenly distributed KR group will be more accurate and consistent for all dependent measures because participants practicing tasks with the 70% KR in RA will be distracted from processing their intrinsic feedback and therefore, this will negatively affect their performance.
3. Participants in the 30% fading KR group compared to participants practicing tasks with the 70% fading KR will be significantly more accurate for all dependent measures because the 70% fading KR group will receive too much KR distracting them from processing their intrinsic feedback, especially in early practice. Particularly because most of their KR will be presented in early practice, these participants may not develop an accurate standard of error.
4. Participants in the 30% evenly distributed KR will be more accurate and consistent than the 30% fading KR group for all dependent measures. The former group will experience optimum KR frequency. Participants practicing in the 30% fading KR group will receive too much extrinsic KR in early practice. Also, extrinsic KR about the previous trial will be distracting for RA and interrupt processing intrinsic KR for the fading schedule participants.

Retention and Transfer

1. For all dependent measures, participants who practiced the tasks with the 30% evenly distributed KR will be more accurate and consistent than those practicing tasks with the 0% KR. Some extrinsic KR is necessary to develop error detection by interpreting intrinsic KR. Since extrinsic KR is not provided in retention and transfer, performers are relying on internal error detection to respond.
2. For all dependent measures, participants who practiced the tasks with the 30% evenly distributed KR will be more accurate and consistent compared to those practicing tasks with the 70% evenly distributed KR. Too much KR during acquisition will distract participants from processing their intrinsic feedback, and thus negatively affect development of internal error detection necessary in retention and transfer.
3. For all dependent measures, participants who practiced the tasks with the 30% fading KR will be more accurate than those who practiced the tasks with the 70% fading KR. The 70% fading KR group will have received too much KR, distracting them from processing intrinsic feedback in early practice so necessary for internal error detection and performance in no KR retention and transfer tests.
4. For all dependent measures, participants practicing tasks with the 30% evenly distributed KR will be more accurate and consistent than those practicing tasks with the 30% fading KR. Practicing tasks with the 30% fading KR will result in too much KR in the early practice which is when processing intrinsic feedback is critical for developing internal error detection.

Definition of Terms

Absolute error (AE) provides the overall magnitude of error without regard to the direction of criterion. It reflects overall accuracy of performance.

Blocked practice (BL) is a practice schedule that a block of trials of one task is completed prior to another (e.g., AAA…, BBB…, CCC…).

Contextual interference is created when multiple similar but different tasks are performed. High contextual interference (random practice schedule) is created by practicing multiple tasks in a random order, which hinders acquisition performance but enhances learning in terms of retention and transfer performance compared to BL. Low contextual interference (BL) is produced by completing one block of trials of one task before exposure to another task.

Constant error (CE) gives information on both amount and direction of error. It indicates subjects' bias as early or late.

Error detection is the internal ability of learners to detect their own errors when performing a motor skill.

Extrinsic feedback refers to augmented feedback presented to the performer. It is considered to add to the intrinsic feedback by a teacher or experimenter.

Evenly distributed KR schedule requires that KR be evenly distributed across practice trials.

Fading KR schedule is KR that is given more in the initial practice trials and tapers off toward the end of practice.

Intrinsic feedback provides performers with information that is inherent in the performance of a particular movement from visual and proprioceptive sources.

Knowledge of performance (KP) refers to information about the movement pattern (the process).

Knowledge of results (KR) is information about the outcome of the movement (the product).

Random practice (RA) refers to a practice schedule in which multiple tasks are presented in random order and no task is presented more than twice consecutively (e.g., ABCCABCAB…).

CHAPTER 2

REVIEW OF LITERATURE

This chapter reviews the literature on contextual interference, information feedback and summarizes the relevant literature reviewed.

Contextual Interference

The origin of contextual interference can be traced to the research of Battig (1966) who provided the original evidence for what he initially called “ intratask interference.” Battig noted a paradox existing among a number of verbal learning studies where multiple tasks were presented. He identified that intertask facilitation (benefits in transfer) was produced by intratask interference (practicing multiple tasks). He was convinced (1972) that the high levels of between-task processing (i.e. intratask interference) usually led to poor acquisition performance, but resulted in positive effects in retention and transfer performance (intertask facilitation). He argued that when similar tasks must be learned and the tasks themselves are particularly difficult or are presented with high interference, the result of retention would be often better than tasks learned under low interference conditions (Battig, 1979). Later, Battig (1979) changed the term intratask interference to contextual interference, because contextual interference reflected the important roles of contextual factors, like the order of task presentation that produced interference, not just the multiple tasks themselves. Hence, the practice schedule (the order of task presentation) as well as the task were considered potential variables of interference that did influence learning.

According to Battig (1979), a random practice schedule (RA) creates high contextual interference, since participants perform multiple tasks in a random order but no task will be presented consecutively more than twice. In contrast, a blocked practice schedule (BL) creates low contextual interference since participants complete all trials of one task prior to exposure to next. RA degrades acquisition performance but enhances performance in retention and transfer tests. However, participants in BL demonstrate superior performance during acquisition but poorer performance during retention and transfer than those in RA. Battig proposed that, under high contextual interference, these similar tasks could undergo an elaborative and distinctive processing in that multiple items can be compared and contrasted simultaneously because in RA a new task is presented on every trial. Elaborative and distinctive processing facilitates the memory of tasks to be learned; therefore results in better retention and transfer performance for RA participants. On the contrary, under low contextual interference, only one task resides in working memory for a block of trials, so elaborative and distinctive processing cannot be performed. Working memory is the processes and structures that involve holding information and simultaneously using that information to solve a problem, make a decision, or learn new information (Craik & Jennings, 1992). Thus, according to Battig it is not surprising that participants in BL demonstrate poorer performance in retention and transfer because the critical differences between tasks are not learned during acquisition.

Contextual interference had not received attention from researchers in motor learning until Shea and Morgan (1979) provided experimental evidence and bridged the gap between the verbal and motor domain. Shea and Morgan's results supported the contextual interference effects found with verbal skills. That is, participants who practiced with a low contextual interference schedule (BL participants) had superior acquisition performance and lower retention and transfer scores, while the RA group that performed under high contextual interference condition was reversed, viz., RA participants were more accurate than BL in retention and transfer.

Since 1979 contextual interference has been the focus of many motor learning studies, and a large number of studies have reported its effects and generalizability. The tasks used in contextual interference research can be categorized into laboratory tasks, applied tasks and sport skills. Two types of tasks have been administered in the laboratory. They are multi-segment movement tasks, such as the barrier knock-down task used by Shea and Morgan (1979), and the coincident anticipation timing task, such as the one used by Del Rey and her colleagues in several studies beginning in 1982. For the multi-segment movement task, participants are required to move as fast as possible through a certain movement pattern or through a certain pattern sequence but in a criterion movement time (Gabriele, Hall, & Lee, 1989; Wulf, & Lee, 1993). The results of this type of task have consistently shown the benefit of RA in both retention (Lee, & Magill, 1983; Poto, 1988; Shea, & Zimny, 1988) and transfer (Shea & Morgan, 1979; Gabriele et al., 1989). This anticipation timing task is a popular task used in the laboratories. Retention performances (Del Rey, 1982, 1989; Del Rey, 1987) and transfer performances (Del Rey, et al. 1983; Del Rey, 1989) show benefits of RA over BL. The second category of experimental tasks are found in a number of applied studies, such as badminton serves (Goode, & Magill, 1986; Wrisberg & Liu, 1991); rifle shooting (Boyce, & Del Rey, 1990); volleyball skills (Bortoli, Robazza, Durigon, & Carra, 1992); kayaking skills (Smith, & Davies, 1995); and baseball batting (Hall, Domingues, & Cavazos, 1994).

To address why RA contributes more to retention and transfer performance than BL, three hypotheses have been developed to provide theoretical explanations. An interpretation is offered with the action-plan reconstruction hypothesis (Lee & Magill, 1985). According to this view, during practicing under high contextual interference or RA, an action-plan or motor program for a particular task (Task A) is forgotten when a new task is presented on the following trial (Task B or C). The next attempt at Task A requires the performer to reconstruct the action-plan or motor program for Task A again because he or she has forgotten the solution to the problem. This forced reconstruction based on forgetting the action plan due to order of presentation is beneficial for RA participants because in retention and transfer reconstruction of action plan is what is required. On the other hand, participants in BL do not engage in reconstruction of the action-plan since the solution is still available in working memory from trial to trial because the same task is presented over a block of practice trials.

The action-plan reconstruction hypothesis was developed from investigations in the verbal domain on the spacing of repetitions effect (Jacoby, 1978). Jacoby (1978) suggested that repeating the processing to solve a problem facilitated retention and transfer as compared to just remembering a solution. That is, if the solution of a specific problem is still available in working memory when the problem is presented again, then only the solution will be repeated rather than processing activities. During practice, when a solution for a particular problem is forgotten, one has to process again to arrive at the solution. Thus, forgetting forces the repetition of processing activities which enhance retention and transfer. Lee and Magill (1985) proposed that the contextual interference effect (RA benefits in retention and transfer compared to BL) might be due to this spacing effect during performance of the practice tasks for RA participants.

Retroactive inhibition holds a different view on the contextual interference effect. Unlike the action-plan reconstruction hypothesis, retroactive inhibition focuses on the disadvantages of BL, instead of the benefits of RA. Retroactive inhibition refers to the poor retention performance of a task as result of interpolation of another activity between the original learning and a retention task (Brady, 1998). Meeuwsen (1987) claimed that the action-plan reconstruction hypothesis is inappropriate in explaining the contextual interference effect. In his first two experiments, he failed to find support for action-plan reconstruction. In his third experiment, Meeuwsen gave an immediate retention test to BL after each trial block. The results showed that the immediate retention group had superior retention performance compared to the typical BL where the retention test was given only after all practice trials were administered. Meeuwsen argued that the poorer retention performance of the typical BL compared to the immediate retention BL might be due to retroactive inhibition. On each trial block a new task is presented so that the retention test presented on the last task right after that task was practiced would enhance retention compared to a retention test given after all tasks were practiced. Meeuwsen's order of testing for the immediate retention group removed the effects of retroactive inhibition.

Following the study of Meeuwsen (1987), Poto (1988) suggested that the blocked order had a negative influence on retention performance, compared to RA, because the structure of BL produced retroactive inhibition. For instance, if tasks are presented in order ABC during acquisition, then A is tested in retention first. Retroactive inhibition will influence retention of task A because of the interpolation of task B and C before the retention test. In a series of experiments by Davis (1988), the findings indicated that the farther from retention test a task was practiced, the poorer the retention performance would be. The retroactive inhibition explanation is supported by several studies (Del Rey, Liu, & Simpson, 1994; Shea & Titzer, 1993).

Alternatively, the benefits of RA practice schedule over BL were explained by Shea and Zimny (1983) in the elaboration hypothesis. Shea and Zimny proposed that practicing in RA creates intertask processing (between-task processing). High contextual interference engages participants in a high degree of intertask processing which in turn makes memmorability of the representations more distinctive. During RA practice, multiple tasks are in working memory, which allows participants to compare and contrast features of tasks. Shea and Zimny (1988) provided evidence that participants in RA made more comparisons across tasks as compared to BL participants who described each task individually. The elaboration hypothesis relies heavily on the existence of two different processing modes, intratask and intertask processing. Under BL, the learners rely almost exclusively on intratask processing or within-task analysis because only one task resides in working memory during practice trials. In contrast, due to the order of task presentation on RA, the learner undergoes intertask processing. Identifying distinguishing features and similar elements across tasks has been shown to be helpful to RA participants in retention and transfer compared to BL.

In interpreting the effect of reduced frequency of KR on RA participants, Del Rey and Shewokis (1993) and Sherwood (1996) used the elaboration hypothesis to explain the advantage of reduced frequency of KR for RA participants. Given the order of presentation for RA, i.e., on each trial a new task is presented, they argued that frequent extrinsic feedback was a distraction to RA performers because KR about the previous trial could not be used to modify the current response. Frequent extrinsic feedback not only distracts RA performers in preparation of the next response, but also interrupts performers from elaborative and distinctive processing. Since elaborative processing is a function of comparisons made across tasks (intertask processing), providing extrinsic feedback after each trial for RA disrupts performers from a focus on intrinsic feedback. It is nearly impossible for RA participants in 100% KR to process their intrinsic feedback when extrinsic feedback is provided immediately following the completion of the movement. Moreover, relying on intrinsic feedback is what is essential for performance in retention and transfer because no extrinsic KR is provided. Thus, benefits would accrue to RA participants in retention and transfer when reduced KR is provided during acquisition, because these participants will learn to rely on intrinsic feedback which is necessary in recall and in performing transfer tasks.

In an investigation of effects of reduced frequency of KR on participants in high contextual interference, Wulf (1992) manipulated both RA and BL to examine reduced frequency of KR. The participants’ task was to produce three pre-determined goal movement patterns. KR was presented in 67% or 100% of the practice trials to both RA and BL groups. For 67% KR condition, KR was evenly distributed throughout the practice and participants did not receive KR on every third trial. Her findings supported that reduced relative frequency of KR and RA enhanced GMP learning (learning different movements). Wulf's two random groups (67% KR and 100% KR) were more accurate than the two blocked groups for movements that share the same GMP in immediate and delayed retention.

Winstein and Schmidt (1990) conducted a series of experiments to study reduced frequency of KR with a constant practice schedule. In their Experiment 1, there were two KR relative frequency acquisition conditions, 100% and 33%. Participants in the 100% KR condition received KR after each trial, whereas participants in the 33% KR group received KR after two out of every six trials. Their results indicated that there were no significant effects between the two relative frequency conditions in retention. However, in their Experiment 2 and Experiment 3, the design was slightly different from Experiment 1. In contrast to Experiment 1, where the KR was evenly distributed over the practice trials in the 33% KR condition, a fading schedule was applied and relative frequency of KR was 50% instead of 33%. Specifically, the relative frequency was gradually decreased from 100% to 25% over practice. In both Experiment 2 and Experiment 3, the 50% fading KR group demonstrated significantly less error in retention compared to 100% KR. However, in the Winstein and Schmidt’s study the effects of a fading KR schedule were confounded with reduced frequency of KR. Thus, the better performance in retention for the fading KR schedule compared to 100% KR could not be attributed to the fading KR schedule alone. It could have been the results of practicing the tasks with less KR. These findings bring up the following question: what type of schedule of reduced frequency of KR (i.e., evenly distributed or fading) is more effective for participants in high contextual condition? By holding the percentage of reduced KR constant across schedules, we intend to answer this question.

To separate the effects of reduced frequency of KR and schedule of KR, three reduced KR groups (i.e., 0%, 30% and 70%) were created in the present study. Both evenly distributed and fading KR schedules were compared at the same percentage of KR to remove the confounding of schedule of KR and frequency of KR found in Winstein and Schmidt's study. All 4 KR groups were compared to a group that did not receive KR (0% KR). The high frequency of KR (e.g., 70% frequency of KR) is expected to encourage participants' reliance on extrinsic KR and thus, to interfere with processing intrinsic feedback which is necessary to develop internal error detection. For the reduced frequency of KR (i.e., 30%) condition, the 30% fading KR group is expected to perform with more error in retention and transfer than the evenly distributed KR group because participants in the 30% fading KR will receive too much KR in the early practice which will distract them from processing intrinsic feedback and negatively influence the formation of internal error detection. All groups will practice in a RA order.

To summarize the literature in contextual interference, high contextual interference (RA) is created by practicing multiple tasks in a random order. This practice schedule hinders acquisition performance but enhances learning in terms of retention and transfer compared to BL. The action-plan reconstruction hypothesis (Lee & Magill, 1985), the retroactive inhibition hypothesis (Meeuwsen, 1987) and the elaboration hypothesis (Shea & Zimny, 1983, 1988) have been developed to explain contextual interference effects in retention and transfer. In a contextual interference paradigm, KR is usually presented after each trial and immediately following the completion of movement. Recently, a number of studies (Wulf, 1992; Del Rel and Shewokis, 1993; Sherwood, 1996) have demonstrated that reduced frequency of KR is beneficial for RA participants. The reason may be that reduced KR gives RA participants the opportunity to process their intrinsic feedback, which contributes to their elaborative processing and yields benefits in retention and transfer tests compared to those RA participants who have 100% KR during practice. However, previous research has confounded the effects of reduced frequency of KR with schedule of presentation of KR.

Information Feedback

Information feedback is identified as one of the most critical factors for motor learning because the type of the information, the amount of it, and when it is provided all have influence on performance and learning. Information feedback refers to information produced by movement that is available to the learner during or after the action (Schmidt, & Lee, 1999) and originates from two sources: intrinsic feedback (sometimes called inherent or internal feedback) and extrinsic feedback (also called augmented feedback). Intrinsic feedback provides performers with information normally occurring as a consequence of moving. This information is available to the performer from his or her own sensory system (such as vision and proprioception). On the other hand, extrinsic feedback refers to augmented feedback presented to the performer, added to the intrinsic feedback usually by a teacher or experimenter. Information feedback can also refer to information about the goal of the movement or the movement itself: knowledge of results

(KR) and knowledge of performance (KP). KR is information referring to the outcome of the movement (the product). KP is defined as information about the movement pattern.

Adams (1971) identified the importance of intrinsic feedback and error detection in learning motor skills. Adams believed that error detection plays a central role in motor learning. In his closed-loop theory of motor learning, Adams identified a "perceptual trace." According to Adams, performers compare the intrinsic feedback received about the process (KP) with the memory of the movement that produced the product goal (the perceptual trace). If the KP does not match the memory of the movement, then an error is detected. The strength of the comparison is predicted to increase as a function of practice (i.e., the number of comparisons made between intrinsic KP and the perceptual trace). Thus, we can postulate according to Adams, that for learning to occur performers use intrinsic feedback to detect errors by making a comparison between KP and the perceptual trace.

Following Adams' theory, Schmidt (1975) developed his schema theory of motor learning and also included feedback and error detection as an essential aspect of motor learning. Schmidt identified the recognition schema, an internal referent or a template of the specific motor plan that achieved the product goal in previous attempts. The recognition schema (Schmidt) is similar to the perceptual trace (Adams) and is dependent on feedback to develop. To form the recognition schema, feedback is essential during practice. Both theories (Adams' & Schmidt's theories of motor learning) agree on the important role of feedback in the development of error detection. Adams relied on intrinsic feedback as critical and Schmidt believed both intrinsic and extrinsic feedback were important to learning and developing an internal error detection mechanism.

The traditional perspective on extrinsic feedback (Adams, 1971; Bilodeau, Bilodeau, & Schumsky, 1959) has been that providing more precise, frequent, and immediate post-response KR during acquisition facilitates motor learning. However, in the past few years, a number of studies have manipulated extrinsic feedback and demonstrated that reducing the frequency of KR does not degrade motor learning, and may even enhance motor learning. Wulf and Schmidt (1994) believed that reduced extrinsic feedback forces the learner to rely on intrinsic feedback which assists the development of error detection. These findings challenge the classical viewpoint of the role of feedback, which is that frequent extrinsic feedback facilitates motor learning and is necessary to develop error detection abilities. Some extrinsic feedback would seem to be necessary in order to evaluate intrinsic feedback and provide a standard of goal attainment. However, frequent extrinsic KR may distract performers from processing intrinsic feedback. Studies that have manipulated the amount and frequency of KR have used bandwidth KR; summary KR; average KR; KR delay; and reduced frequency of KR.

Bandwidth KR refers to the administration of KR only when errors in performance exceed predetermined boundaries of correctness. Thus, with this approach, no KR will be provided to the learner if the performance error lies within a given error range and only will be presented when the performance error is outside the bandwidth. The bandwidth KR method was first developed by Sherwood. In an early experiment (1988), participants performed a rapid elbow flexion movement within a goal of 200 ms. A control group received their movement time performances as KR after each trial. In two other groups, movement time KR was provided only if the performance was outside the range of the movement time goal (±5% or ±10%). There was a practice or acquisition phase followed by retention and transfer tests. Although there were no significant differences between groups in acquisition, bandwidth KR facilitated significantly better performance on a no-KR retention test as compared to 100% KR. Again using a bandwidth schedule, for RA and BL Sherwood (1996) used 24 participants, randomly assigned to either RA or BL. The task in Sherwood's experiment was to make a rapid lever reversal movement in 225 ms. During acquisition, his BL was more accurate compared to RA as expected. However, on the no-KR retention test, a reversal occurred. RA was more accurate than the BL. Sherwood attributed the benefits of random practice to elaborative processing (Shea & Zimny, 1983) or intertask processing. Even with bandwidth KR RA participants had better memory than BL.

An alternative method for reducing KR, summary KR, was developed by Lavery (1962). KR was withheld for a number of trials until the last trial had been completed. For example, in a 10-trial summary KR condition, the participant would perform 10 trials before receiving KR on all preceding trials. In Lavery's study, three feedback conditions were administered in constant practice. One condition was given KR after each trial. The second condition received KR after each trial and the third group used both: a 20-trials summary KR that received KR after every 20 trials and 100% KR after each trial. The findings revealed that during acquisition (practice phase) the 20-trials summary group performed worse than the 100% KR group and the group receiving both types of KR. However, when retention performance was evaluated across KR groups, the summary KR group was more accurate than the two other KR groups. Thus, it was concluded that summary KR was more effective for learning as measured in retention than his other KR conditions. Lavery concluded that providing KR after each trial seemed to be detrimental to retention. Less KR enabled participants who practiced in a constant order to process intrinsic feedback on each trial and therefore develop error detection.

Schmidt and co-workers tried to extend Lavery's work (Schmidt, Swinnen, Young, & Shapiro, 1989) by investigating the optimal summary length. In their experiments participants were asked to perform a simple arm movement in a specified goal time. Summary KR was provided in lengths of 1, 5, 10, and 15 trials. For the simple task, the results of the study demonstrated that the group received 15-trial summary was the most accurate in retention. They concluded that the longest summary KR produced the most effective learning for their simple task as measured in retention and least learning occurred in the immediate KR group. Retention and transfer are thought to be better measures of permanent learning compared to performance practice or acquisition trials.

Later, Schmidt et al. (1990) asked participants to learn a more difficult coincident - timing task with a design similar to the 1989 investigation. The results indicated for the more complex task that the 5-trial summary group (the shorter summary length) was best in retention, followed by 1-, 10-, and 15-trial groups. These data show that the optimal length of summary KR may interact with task complexity. Longer summary lengths were more effective for simple movements and shorter summary lengths are more effective for complex movement.

Del Rey and Shewokis (1993) investigated summary KR with timing tasks in a multitask learning experiment using BL and RA in a contextual interference paradigm. In acquisition, KR for each trial was provided in graphic form (with constant error and trial number as axes) after each trial, after every 5 or 10 trials. For the 100% KR group, the graph was shown to subjects after each trial, with the one previous score plotted. Subjects in KR5 and KR10 were presented with a graph that plotted all preceding 5 or 10 trials' scores. Subjects performed the tasks in a RA or BL practice schedule. In comparing the transfer performances of RA subjects, performance in KR10 condition was more accurate than that of those who received 100% KR (for variable error). The results of the study supported the use of longer summary KR lengths in acquisition for subjects learning task in RA. On the contrary, in the 100% KR for BL subjects, their performances were more accurate if they received KR after each trial compared with RA. Therefore, tasks with less frequent feedback in acquisition were beneficial for RA in transfer compared to 100% KR for those same subjects. These results support the notion that less frequent feedback yields processing advantages for RA. Thus, based on the work of Schmidt and colleagues previously discussed, a link between RA, reduced extrinsic feedback and elaborative processing were made. Reduced extrinsic feedback seems to facilitate the comparisons and contrasts made between tasks for RA.

An interesting variation of the summary KR method is termed average KR. Rather than providing summary KR after a series of trials, the averaged performances of several trials is presented to the participant as KR. In Yao, Fischman, and Wang's (1994), two conditions were manipulated. One was given averaged KR as mean error over 5 or 15 trials. The other condition was provided summary KR after every trial, 5 trials, and 15 trials. In a no-KR retention test, the 5-trial averaged KR group showed the smallest error and the immediate group was the poorest.

To compare the effectiveness of average KR with summary KR, Weeks and Sherwood (1994) conducted an experiment where KR was given either after every trial, after the completion of 5 trials in form of averaged KR, or in the form of summary KR. The data from both immediate retention and delayed retention suggested that the performance was similar for both averaged KR and summary KR groups. Both groups performed significantly better in immediate and delayed retention than the group receiving KR after every trial.

In addition, studies that have manipulated KR frequency have revealed that reduced frequency of KR during acquisition is beneficial for long-term retention compared to a condition in which KR is provided after each trial. Winstein and Schmidt (1990) conducted a study that investigated the effects of reduced frequency of KR in constant practice (one task performed for all acquisition trials). The task for participants was to move a lever to produce a goal movement pattern in 800 ms. In their Experiment 1, there were two KR relative frequency acquisition conditions, 100% and 33%. Participants in the 100% KR condition received KR after each trial, whereas participants in the 33% KR group received KR after two out of every six trials. Although there was no significant effects between the two relative frequency conditions, the 33% KR condition tended to be slightly more accurate than 100% KR in retention. In their Experiment 2 and Experiment 3, the design was slightly different from Experiment 1. In contrast to Experiment 1, where the KR was evenly distributed over the practice trials in the 33% KR condition, a fading schedule was applied and relative frequency of KR was 50% instead of 33%. Specifically, the relative frequency across 8-trial blocks was gradually decreased from 100% to 25% over practice. This is a fading KR schedule and is based on the idea that participants need more feedback in the early practice stages than in later practice stage. For this reason, KR was presented frequently in early practice stage and then KR was gradually decreased. On both Experiment 2 and Experiment 3, the findings revealed that during the no-KR delayed retention test, the 50% fading KR group performed significantly more accurate than the 100% KR group. Winstein and Schmidt concluded that reduced frequency of KR enhanced learning compared to providing KR after each trial. Thus, the fading schedule seems to be an effective way to manipulate reduced frequency of KR for motor learning. Sparrow and Summers (1992) provided supporting evidence. Their groups receiving reduced frequency of KR outperformed groups receiving KR on every trial. These findings were replicated in a set of studies (Nicholson & Schmidt, 1991; Vander Linden, Cauraugh, & Greene, 1993; Winstein, Pohl, & Lewthwaite, 1994). Nicholson and Schmidt (1991) used the same task as Winstein and Schmidt (1990) in their experiments and demonstrated on their delayed retention test that 3 different reduced frequency KR groups outperformed the group receiving 100% KR.

In addition, frequent KR produces variable acquisition performance when the same task is performed over practice trials and prevents the participant from learning a stable movement (Wulf & Schmidt, 1994; Lai & Shea, 1998). According to the proactive hypothesis, frequent feedback produces excessive variability during practice. Too frequent KR can produce excessive modifications from trial to trial. In the short term, the performer may benefit from the frequent KR from trial to trial to keep the behavior close to the goal, but ultimately degrades learning when KR is removed.

Some studies on the benefits of reduced frequency of KR also investigated RA (Wulf, Schmidt, & Deubel, 1993; Wrisberg & Wright, 1997; Lai & Shea, 1998) and constant practice (Nicholson & Schmidt, 1991; Vander Linden et al., 1993; Lai & Shea, 1999). Their findings revealed that reduced frequency of KR was beneficial for RA participants in retention, but had inconsistent findings on reduced frequency of KR for participants in constant practice. Constant practice involves the repetitions of single task over practice trials. However, studies that compare random and blocked practice schedules are few. One study conducted by Wulf (1992) has manipulated both RA and BL to examine reduced frequency of KR. The participants' task was to produce three pre-determined goal movement patterns. KR was presented in 67% or 100% of the practice trials to random or blocked groups. For 67% KR condition, KR was evenly distributed throughout the practice and participants did not receive KR on every third trial. Wulf also separated learning into learning of a generalized motor program (GMP) (different movements) and learning of movement parameters (similar movements or the same GMP). Similar movements that share common invariant characteristics, such as the relative time, the relative force, and the sequence of actions, are thought to be controlled by the same generalized motor program (GMP) and involve only parameter modifications when movements are controlled by the same generalized motor program. Modification of parameters (e.g., absolute time or absolute force) is thought of as parameter learning. Learning different movements where both relative timing and force are different are referred to as movements controlled by different GMPs. Her findings supported that reduced relative frequency of KR and RA enhanced GMP learning (different movements). Wulf's two random groups (67% KR and 100% KR) were more accurate than the two blocked groups for movements share the same GMP in the immediately and delayed retention. Thus, reduced frequency of KR and RA during practice were more beneficial in retention for parameter learning compared to the BL group who received reduced KR.

In a recent study, Wrisberg and Wulf (1997) used a similar task as Wulf (1992) with 67% and 100% frequency of KR. But their 67% KR schedule was slightly different from Wulf's (1992). In their study, KR was randomized to present on 60 of the 90 trials with the restriction that each amplitude was given 10 no-KR trials. Their results showed that no group differences in acquisition and in a no-KR retention test. Thus, further research is needed to clarify whether reduced frequency of KR is beneficial to learning and what type of reduced frequency of KR (e.g., evenly distributed KR or fading KR) is more effective for participants in a high contextual interference condition. It is hypothesized in the present study that RA participants in reduced frequency of KR with an evenly distributed KR will enhance retention and transfer because these participants can take both intrinsic and extrinsic feedback to compare and contrast the critical features of tasks and acquire more detailed knowledge about differences between tasks, which may result in better transfer and retention for these participants than RA participants who practice with high frequency of KR (e.g., 100% KR).

In summary, recent research on feedback has demonstrated that reducing the frequency of KR does not degrade motor learning, and may even enhance motor learning as measured in retention and transfer tests, especially for RA. The manipulation of reduced frequency of KR includes bandwidth KR; summary KR; averaged KR; KR delay; and reduced frequency of KR. Two major types of schedules employed in manipulating reduced frequency of KR are an evenly distributed KR schedule and a fading KR schedule. Reduced frequency of KR for RA participants will free participants to focus on their own intrinsic feedback during practice which is beneficial in retention and transfer.

Summary of Literature Review

Contextual interference refers to the effects of practicing multiple tasks on memory and transfer tests. High contextual interference (RA) is created by practicing multiple tasks in a random order which hinders acquisition performance but enhances learning in terms of retention and transfer, compared to BL. Recently, a number of studies (Wulf, 1992; Del Rel & Shewokis, 1993; Sherwood, 1996) have demonstrated that reduced frequency of KR is beneficial for RA participants. The reason may be that reduced KR gives RA participants the opportunity to process their intrinsic feedback which contributes to their elaborative processing and yields benefits in retention and transfer tests compared to those RA participants who have 100% KR during practice. Two major types of schedules employed in manipulating reduced frequency of KR are an evenly distributed KR schedule and a fading KR schedule. Recent studies such as Winstein and Schmidt (1990) in the area of redcued frequency of KR have confounded the effects of KR schedule with reduced frequency of KR. Thus, the issue to be studied is how much feedback is benefical in retention and transfer as well as when should it be presented during practice.

CHAPTER 3

METHOD

This chapter consists of sections that describe the participants, the apparatus and tasks, the design, and procedures which were used in the present study.

Participants

Seventy participants recruited from undergraduate and graduate students enrolled at the University of Georgia participated in the study. The age range was from 18 to 29 years old with a mean of 21.63 ± 1.93. Previous studies (e.g., Del Rey, Wughalter, & Whitehurst, 1982) indicated that prior experience with open skills outside the laboratory (participating in sports skills) influenced retention and transfer on laboratory timing tasks similar to those employed in the current study. It has been found (Del Rey et al., 1982) that the athletes who are experienced in open skills, like basketball, soccer, as examples, bring their expertise into the laboratory and are more accurate than those participants who do not bring this experience to the laboratory. Thus, prior experience outside the laboratory should be accounted for during subject selection. Experience outside the laboratory that might influence performance on laboratory tasks must be identified.

Open skills refer to those skills that are performed in an environment in which the regulatory conditions change from trial to trial. The spatial and temporal features of the environmental input to which the movement must conform in order to be successful are called regulatory conditions. When regulatory conditions change from trial to trial, there is intertrial variability of regulatory conditions present, and skills performed in this condition are called open skills. The spatial features of the timing tasks used in the present study did not change from trial to trial during practice, while the temporal features did. Thus, on each trial a new speed was presented, so that participants had to monitor the temporal changes in the input carefully. This is similar to the processing required in open skill sports though open skill sports are more complex because spatial as well as temporal changes occur during performance.

Prior to participating in this study, participants completed an Activity Questionnaire (Appendix A) to determine their current and past participation in sports including their ability levels in each activity. Based on this information, participants were categorized as experienced or novice participants in open skill sports. Participants were categorized as experienced if they satisfied one of the following criteria: 1) participating in one or more current open skill sports at the intermediate level for the previous 6 months or 2) participated in one or more open skill sports at the intermediate level for 3 years in their past. Sixty participants (out of 70) were classified as experienced in open skilled sports. Most of them were majors in either the Department of Exercise Science or the Department of Physical Education and Sports Studies, were currently active in sports and had a long history of participation. These 60 were randomly assigned to five practice groups and the 10 novice participants were divided evenly into the 5 groups. By doing this, each group was guaranteed to have 12 experienced and 2 novice participants. Thus, homogeneous groups based on experience outside the laboratory were created. All participants were unaware of the purpose of experiment. Each participant was requested to read and sign an informed consent form prior to participating in the study.

Apparatus and Tasks

A Bassin Anticipation Timer (Lafayette Instruments Company), consisting of four 16-lamp runways attached end-to-end, were placed on a table, perpendicular to the participants' seat. There were 65 lamps on the runway and the last lamp was directly in front of the participant's seat. Participants sat on a chair and rested their right foot on the right pedal as the start position. The task was to push the left pedal to coincide with the illumination of last light. When participants heard the verbal signal "Ready," they had to look at the amber warning light, which was the indicator for participants to watch for the movements of the lights to begin. A constant foreperiod of 1.5 seconds was used for all trials. KR was provided to the participant as constant error in form of "early" or "late" in hundredths of a second. If an error score was less than or equal to 10 milliseconds, the verbal feedback given was "perfect." The speeds used in the acquisition and retention phase were 2, 4, and 6 mph (i.e., 53.6 m/min, 107.3 m/min and 160.9 m/min) because the pilot testing showed the strongest relationship between intrinsic feedback and goal attainment at these slower speeds.

Anticipation timing tasks were selected for the experiment for the following two reasons. First, these anticipation-timing tasks have been a popular laboratory task in investigations of contextual interference. Thus, results can be compared to previous investigations. Second, from the pilot testing and previous investigations these specific tasks have strong agreement between intrinsic feedback and goal attainment for participants. In other words, the participants' estimation of error is very close to their actual goal attainment. In a reduced KR study, we wanted to be sure participants were receiving intrinsic feedback that accurate reflected goal attainment.

Design

All participants performed 3 pretest trials and a total of 90 acquisition trials divided into three 30-trial blocks followed by 18 retention and 18 transfer trials. After acquisition, a 15-minute break was administered followed by retention and transfer tests. All participants performed three tasks (2, 4, 6 mph) in a random order with a restriction that no more than two trials of the same task were performed consecutively. KR was administered in three different frequencies (i.e., 0%, 30% and 70% relative frequency) both evenly distributed and fading KR conditions. The 0% KR group served as a control group and would be used as a baseline to be compared to the 30% and the 70% relative frequency in both evenly distributed and fading KR condition. This allowed us to examine if there was an optimal range of frequency within the two KR schedules employed during retention and transfer. The current study included two fading KR groups (a 30% fading KR and a 70% fading KR) and two evenly distributed KR groups (a 30% evenly distributed KR and a 70% evenly distributed KR). This design allowed us to determine the effects of schedule of KR (i.e., when extrinsic KR should be provided) separately from reduced frequency of KR on retention and transfer.

Dependent variables were absolute error (AE), variable error (VE), and constant error (CE). Each provides different error information. Absolute error indicates the overall magnitude of error. Constant error gives information on subject's bias as early or late in responding. Variable error is a measure of consistency and is the standard deviation around subject's average CE.

For all dependent variables, acquisition data were analyzed in 3 analyses. First, a 2 (frequency of KR, i.e., 30% and 70%) × 2 (KR schedule, i.e., evenly distributed KR schedule and fading KR schedule) × 3 (Trial Block, 30 trials each) ANOVA with repeated measures on the last factor was conducted to evaluate the hypotheses established. Second, for evenly distributed KR groups, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) × 3 (Trial Block) ANOVA with repeated measures on the last factor was used to evaluate the hypotheses related to the evenly distributed KR groups. Third, for fading KR schedules similar to above, a 3 (0% KR, 30% fading KR and 70% fading KR) × 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to evaluate the hypotheses related to differences between fading schedules.

For retention and transfer data (AE, CE, & VE), three similar analyses were conducted. Eighteen trials were presented in retention and transfer. First, a 2 (frequency of KR, i.e., 30% and 70%) × 2 (KR schedule, i.e., evenly distributed KR schedule and fading KR schedule) × 3 (Trial Block, 6 trials each) ANOVA with repeated measures on the last factor was conducted to evaluate the hypotheses established. Second, for evenly distributed KR groups, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) × 3 (Trial Block) ANOVA with repeated measures on the last factor was used to evaluate the hypotheses related to an optimal range of frequency of KR. Third, for fading KR schedules similar to above, a 3 (frequency of KR, i.e., 0% KR, 30% fading KR and 70% fading KR) × 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to evaluate the hypotheses related to an optimal range of frequency of KR. Post hoc tests (Tukey HSD test) or t-tests at $\underline{p} < .05$ were conducted for significant main effects and interactions when necessary.

Procedures

Participants were asked to read and signed an informed consent form (Appendix B) and read instructions (Appendix C) until they understood the tasks. The experimenter told them that the task was to push the left pedal to coincide with illumination of the last light. Each trial began with participant sitting on a chair and rested their right foot on the right pedal. Before the testing, participants practiced 3 trials at 4, 2 and 6 mph. After all questions were answered, then 90 acquisition trials were administered. After 30 trials, participants were allowed to take a short break to avoid fatigue. During the acquisition phase, KR was administered to participants in relative frequencies of 0% KR, 30% KR and 70% KR and provided as CE verbally. In the 0% KR condition, after each trial, no KR was provided to participants. In the 30% evenly distributed KR condition, KR was presented 3 times on every 10 trials over the 90 acquisition trials and each speed received the same number of KR trials (i.e., 3 times per speed) over 30 trials. For the 70% evenly distributed KR condition, KR was presented 7 times on every 10 trials over the 90 acquisition trials and each speed received the same number of KR trials (i.e., 7 times per speed) over 30 trials. The number of KR trials and the consistent percentages over trials for the evenly distributed KR conditions are illustrated in Table 1. For the fading KR schedules, three principles were applied in the current study: 1) KR was presented more during initial practice and gradually decreased over all practice trails. 2) Each task (2, 4, 6 mph) received the same number of KR trials (i.e., 10 trials in the 30% fading KR and 21 trials in the 70% fading KR). 3) Two fading KR schedules had the same pattern of presentation of KR. The frequency of KR and the pattern of KR for the two fading schedules are shown in Table 2 and Figure 1. For the 30% fading KR condition, the relative frequency of KR gradually decreased from 60% to 0%. For the 70% fading KR condition, the relative frequency of KR gradually dropped from 100% to 40%. The Figure 1 shows that the two fading groups had the same fading schedule pattern over 90 practice trials.

After the acquisition phase, participants took a 15-minute break, then 18 retention trials and followed by 18 transfer trials at 3, 5 mph were administered. During the retention interval of 15 min, participants were asked strategies they used in acquisition. KR was not provided in both retention and transfer. The speeds for the retention test were the same as during acquisition. In transfer, all participants performed tasks at 3 and 5 mph in RA with the same restriction as acquisition that the same task was performed no more than two continuous trials.

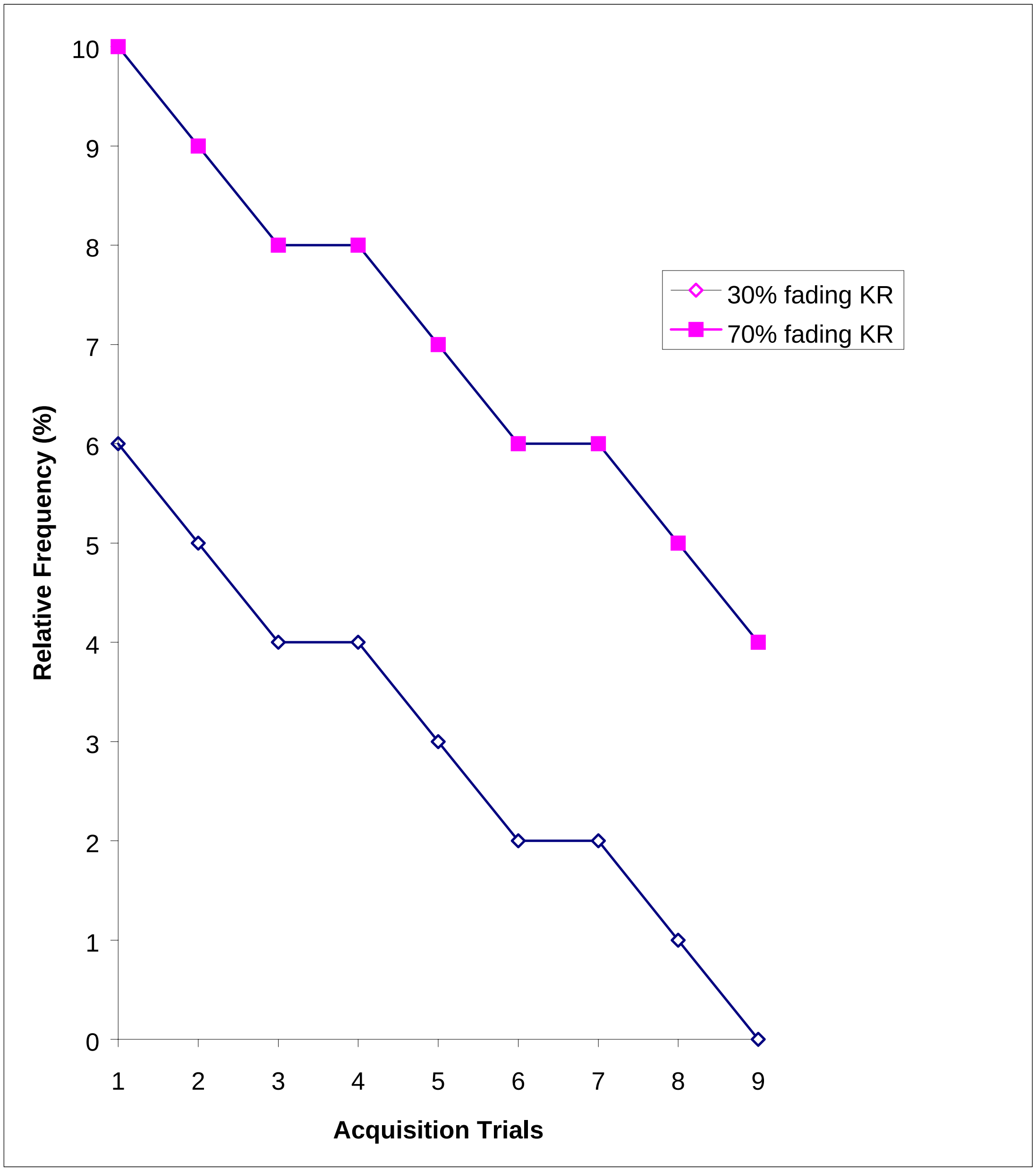
Table 1
The Relative Frequency and the Number of KR Trials for 30% Evenly Distributed KR and 70% Evenly Distributed KR Schedules

	30% evenly distributed KR		70% evenly distributed KR	
Number of Trials	Frequency (%)	Number of KR trials	Frequency (%)	Number of KR trials
1-30	30	9	70	21
31-60	30	9	70	21
61-90	30	9	70	21
Total	30	27	70	63

Table 2

The Relative Frequency and the Number of KR Trials for 30% Fading KR and 70% Fading KR Schedules

	30% fading KR		70% fading KR	
Number of Trials	Frequency (%)	Number of KR trials	Frequency (%)	Number of KR trials
1-10	60	6	100	10
11-20	50	5	90	9
21-30	40	4	80	8
31-40	40	4	80	8
41-50	30	3	70	7
51-60	20	2	60	6
61-70	20	2	60	6
71-80	10	1	50	5
81-90	0	0	40	4
Total	30	27	70	63



<u>Figure 1</u> The pattern of two fading KR schedules

Note: 1 represents trial 1 to trial 10 and 2 represents trial 11 to 20 and so on.

CHAPTER 4

RESULTS

Overview

The purpose of the present study was to compare the effects of reduced frequency of KR on retention and transfer. Two types of reduced frequency of KR were presented, a fading KR schedule and an evenly distributed KR schedule, during practice of timing tasks in a high contextual interference practice order. Reduced frequencies of 30% and 70% were administered in both a fading and evenly distributed schedule over 90 practice trials. A 0% KR practice group was also included to compare to both the 30% and the 70% groups. Hypotheses were established to investigate these conditions and their interaction in retention and transfer.

Three dependent variables were selected to test the hypotheses established: constant error (CE), absolute error (AE), and variable error (VE). The evenly distributed KR groups were compared to the fading KR groups in frequencies of 30% and 70% and both types of schedules of KR were compared to the 0% KR. Three analyses were computed for each dependent variable separately on acquisition, retention and transfer data. The first analysis was a 2 x 2 x 3 ANOVA (Frequency of KR x Schedule of KR x Trial Block) with repeated measures on the last factor. Second, for evenly distributed KR groups, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor. Third, for fading KR schedules the same analyses were computed, a 3 (0% KR, 30% fading KR and 70% fading KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor. The critical level of significance was set at .05 for all analyses. Post hoc tests (Tukey HSD) or t-tests were applied as appropriate when significant main effect and interaction effects were found. The results are presented in the following three phases: acquisition, retention, and transfer.

Acquisition

For CE, AE, and VE, three analyses were conducted. The first analysis was a 2 x 2 x 3 [Frequency of KR (30% and 70%) x Schedule of KR (evenly distributed and fading) x Trial Block, 30 trials in each block] ANOVA conducted with repeated measures on the last factor. These analyses were conducted to determine interaction effects of schedule of KR and reduced Frequency. Second, to compare the 3 KR frequencies for the evenly distributed KR condition, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare reduced frequency of KR (evenly distributed) to the 0% KR. Third, to compare the 3 KR frequencies for the fading KR conditions, a 3 (0% KR, 30% fading KR and 70% fading KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare the fading KR schedules to the 0% KR. Overall means for CE, AE, and VE for each practice schedule over each Trial Block are showed in Table 3.

Constant error (CE):

The 2 x 2 x 3 ANOVA Summary Table is shown in Table 4. A significant Trial Block x Frequency interaction was found, F (2, 104) = 6.388, $p < .05$. This two-way interaction is shown in Figure 2. Post hoc tests indicated that participants in the 30% frequency of KR ($M = 1 \pm 44$ ms) were more accurate than participants in the 70% frequency of KR ($M = 29 \pm 39$ ms) only in Trial Block one. No other interactions nor main effects were found for CE.

The ANOVA Summary Table (Table 5) of the 3 x 3 ANOVA for the evenly distributed KR groups and the ANOVA for the 3 x 3 for the fading KR groups resulted in no significant interaction or main effects.

Thus, for CE at Trial Block one, the 30% frequency of KR groups were more accurate and closer to zero error than the 70% frequency groups ($p < .05$).

Absolute error (AE)

The 2 x 2 x 3 ANOVA Summary Table for AE is shown in Table 4. A significant main effect was found for Trial Block, F (2, 104) = 24.196, $p < .05$. Participants performed most accurate during trial block three ($M = 52 \pm 22$ ms), followed by trial block two ($M = 59 \pm 21$ ms), and then trial block one ($M = 70 \pm 29$ ms). These results

Table 3
Mean Acquisition Error Scores for Frequency Groups and KR Schedules across Trial Block (ms)

Error Source	Acquisition Group	Block 1	Block 2	Block 3	Mean
CE	0% KR	33.4905	19.3619	5.0333	19.2950
	30% even KR	-3.6024	-6.1857	2.7571	-2.3440
	30% fading KR	5.4048	12.0548	9.3167	8.9250
	70% even KR	31.5452	17.7857	14.9690	21.4330
	70%fading KR	26.0405	9.4000	4.1690	13.2030
AE	0% KR	94.2000	61.2095	60.5429	71.9840
	30% even KR	60.7071	54.3857	45.9714	53.6880
	30% fading KR	69.8286	60.8214	53.9548	61.5350
	70% even KR	72.5024	57.6905	53.9452	61.3790
	70%fading KR	78.4262	62.0810	55.5738	65.3600
VE	0% KR	122.0582	67.4405	69.6713	86.3900
	30% even KR	80.3977	70.9503	64.2164	71.8550
	30% fading KR	93.2312	76.7471	71.9070	80.6280
	70% even KR	100.8587	78.6397	68.2677	82.5890
	70%fading KR	107.3559	89.7981	71.1617	89.4390

Table 4
Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Acquisition for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	1	8264.231	2.471	.122
Schedule	1	96.966	.029	.865
Frequency x Schedule	1	3992.300	1.194	.280
Error	52	3345.024		
Trial Block (TB)	2	869.597	2.530	.085
TB x Frequency	2	2196.032	6.388	.002*
TB x Schedule	2	174.405	.507	.604
TB x Frequency x Schedule	2	140.429	.408	.666
Error	104	343.779		
		AE		
Frequency	1	1392.653	1.021	.317
Schedule	1	1468.911	1.076	.304
Frequency x Schedule	1	156.922	.115	.736
Error	52	1364.665		
Trial Block (TB)	2	4666.443	24.196	.000*
TB x Frequency	2	228.941	1.187	.309
TB x Schedule	2	28.464	.148	.863
TB x Frequency x Schedule	2	17.423	.090	.914
Error	104	192.858		

Table 4 (continued)
Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Acquisition for CE, AE, and VE

Source	df	MS	F	p
		VE		
Frequency	1	4010.675	1.229	.273
Schedule	1	2562.994	.786	.380
Frequency x Schedule	1	38.856	.012	.914
Error	52	3262.305		
Trial Block (TB)	2	10069.641	14.730	.000*
TB x Frequency	2	859.868	1.258	.289
TB x Schedule	2	71.588	.105	.901
TB x Frequency x Schedule	2	141.401	.207	.813
Error	104	683.620		

Note. * $p < .05$

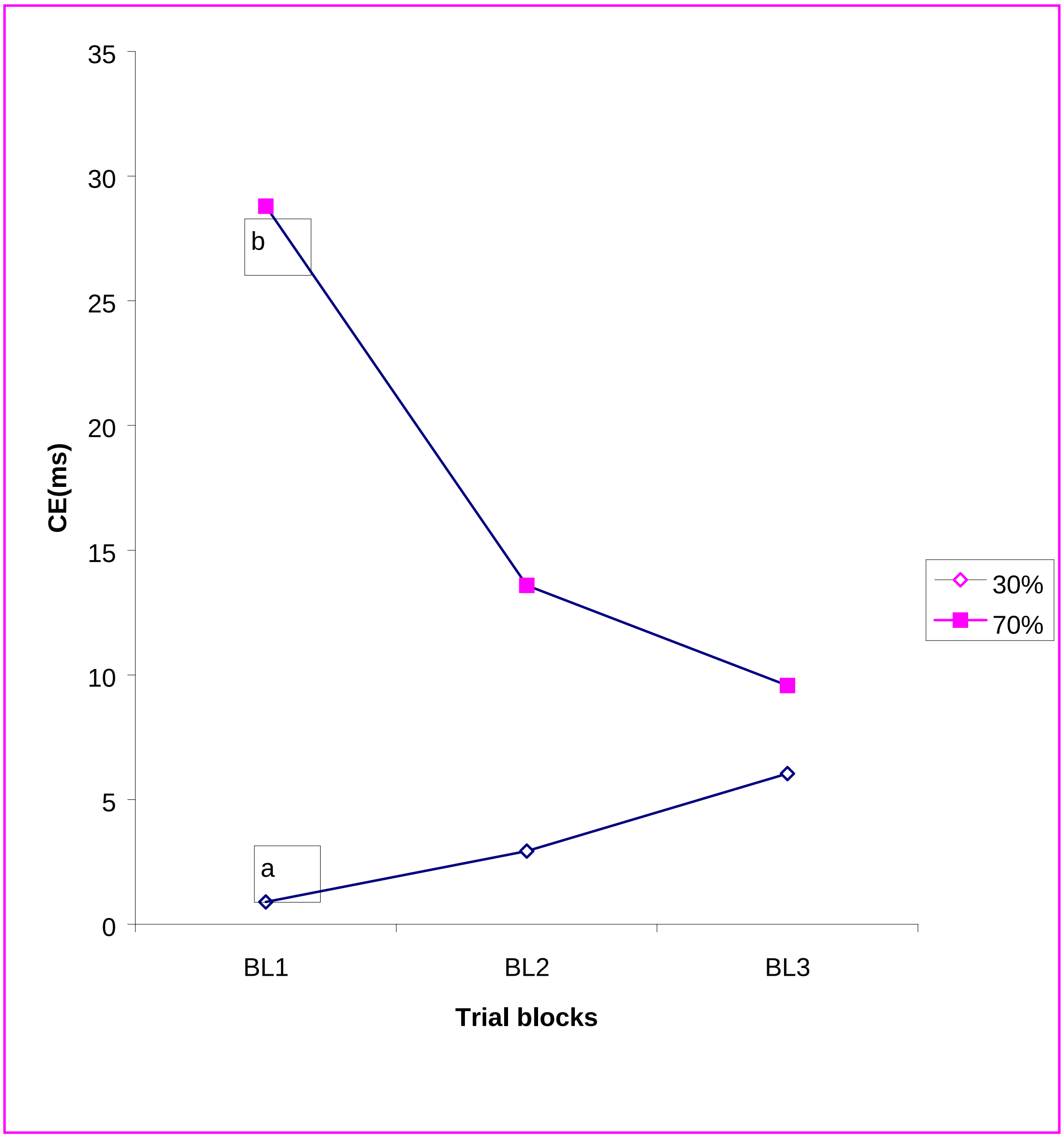


Figure 2. CE acquisition scores as a function of Frequency of KR and Trial Blocks, $p < .05$. Means are not significantly different unless labeled with different letters.

indicated that participants progressively improved their performances over practice trials. No other main effects or interactions exceeded the critical probability level.

In the ANOVA Summary Table found in Table 5 for the evenly distributed KR groups, the 3 x 3 ANOVA indicated that a significant Trial Block x Frequency interaction was found, F (4, 78) = 3.57, p < .05, and is illustrated in Figure 3. Post hoc tests indicated that participants in the 30% evenly distributed KR group (M = 61 ± 24 ms) were more accurate than participants in 0% KR (M = 94 ± 34 ms) in Trial Block one only. In addition, participants in the 0% KR were more accurate in Trial Block two (M = 61 ± 22 ms) and three (M = 61 ± 17 ms) compared to in Trial Block one (M = 94 ± 34 ms) (Figure 3). This interaction explained the significant main effect of Trial Block, F (2, 78) = 29.93, p < .05. Participants performed most accurate during Trial Block three (M = 53 ± 19 ms), followed by Trial Block two (M = 58 ± 21 ms), and then Trial Block one (M = 76 ± 33 ms). These results indicated that participants in the 0% KR progressively improved their performances over practice trials, but were still less accurate (p < .05) at Trial Block one compared to those in the 30% evenly distributed KR. No other main effect or interaction exceeded the critical probability level.

The 3 x 3 ANOVA for the fading KR groups resulted in no significant main effects or interactions.

Variable error (VE):

The 2 x 2 x 3 ANOVA Summary Table for VE is shown in Table 4. A significant main effect was found for Trial Block, F (2,104) = 14.73, p < .05. Participants performed most consistent during Trial Block three (M = 69 ± 33 ms), followed by Trial Block two

Table 5
Summary ANOVA Tables for the Evenly Distributed KR Conditions over 3 Frequency Levels and Trial Blocks in Acquisition for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	2	7267.106	1.754	.186
Error	39	4143.087		
Trial Block (TB)	2	1937.795	2.649	.077
TB x Frequency	4	1147.265	1.568	.191
Error	78	731.612		
		AE		
Frequency	2	3544.530	2.598	.087
Error	39	1364.522		
Trial Block (TB)	2	5892.600	29.927	.000*
TB x Frequency	4	702.226	3.566	.010*
Error	78	196.901		
		VE		
Frequency	2	2386.569	.856	.433
Error	39	2788.272		
Trial Block (TB)	2	13921.755	20.623	.000*
TB x Frequency	4	2130.170	3.156	.019*
Error	78	675.044		

Note. * $p < .05$

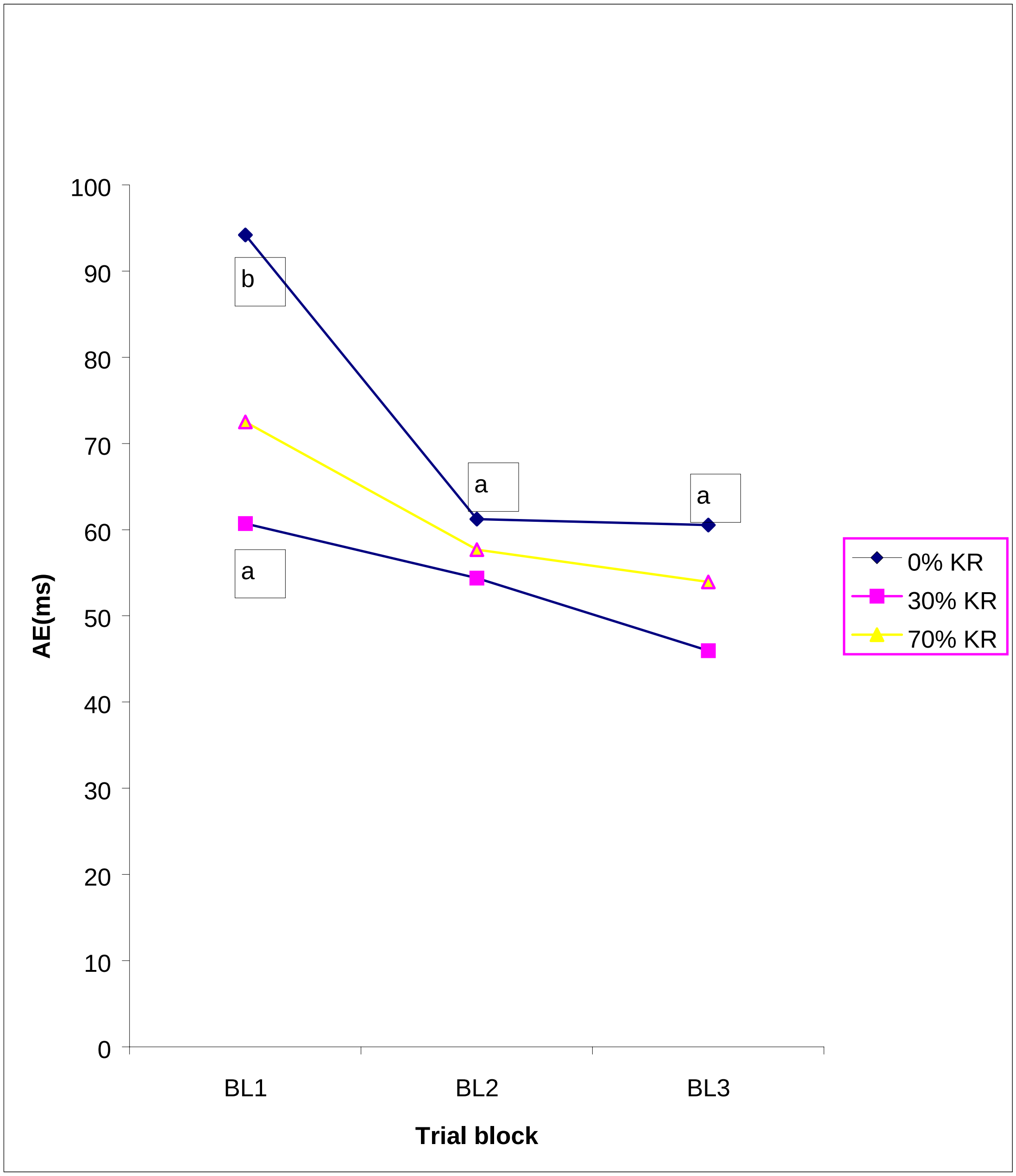


Figure 3. AE means in acquisition as a function of 0%, 30%, and 70% evenly distributed KR over Trial Blocks, $p < .05$. Means are not significantly different unless labeled with different letters.

(M = 79 ± 37 ms), and then Trial Block one (M = 96 ± 46ms). No other main effects nor interactions were significant.

The 3 x 3 ANOVA Summary Table for the evenly distributed KR groups, is presented in Table 5. Similar to AE, a significant Trial block x Frequency interaction was found, F (4, 78) = 3.156, $p < .05$, and is shown in Figure 4. Post hoc tests indicated that similar to AE participants in the 0% KR were more consistent in Trial Block two (M = 67 ± 22 ms) and three (M = 70 ± 29 ms) compared to Trial Block one (M = 122 ± 53 ms) (see Table 5). This interaction explains the significant main effect of Trial Block, F (2, 78) = 20.623, $p < .05$. Participants performed most consistent during Trial Block three (M = 67 ± 29 ms), followed by Trial Block two (M = 72 ± 31 ms), and then Trial Block one (M = 101 ± 50 ms). These results indicated that participants in the 0% KR group performed more consistently over practice trials.

Finally, the last ANOVA for the fading schedules resulted in no significant interactions or main effects.

Summary of Acquisition Analyses

Illustrated in Figure 2 for CE, participants in both 30% KR conditions (combined) were more accurate overall than participants in the 70% KR conditions but only during Trial Block one. Thus, less KR regardless of schedule resulted in more accuracy during the first 30 trials. Differences between amount of KR did not extend throughout practice.

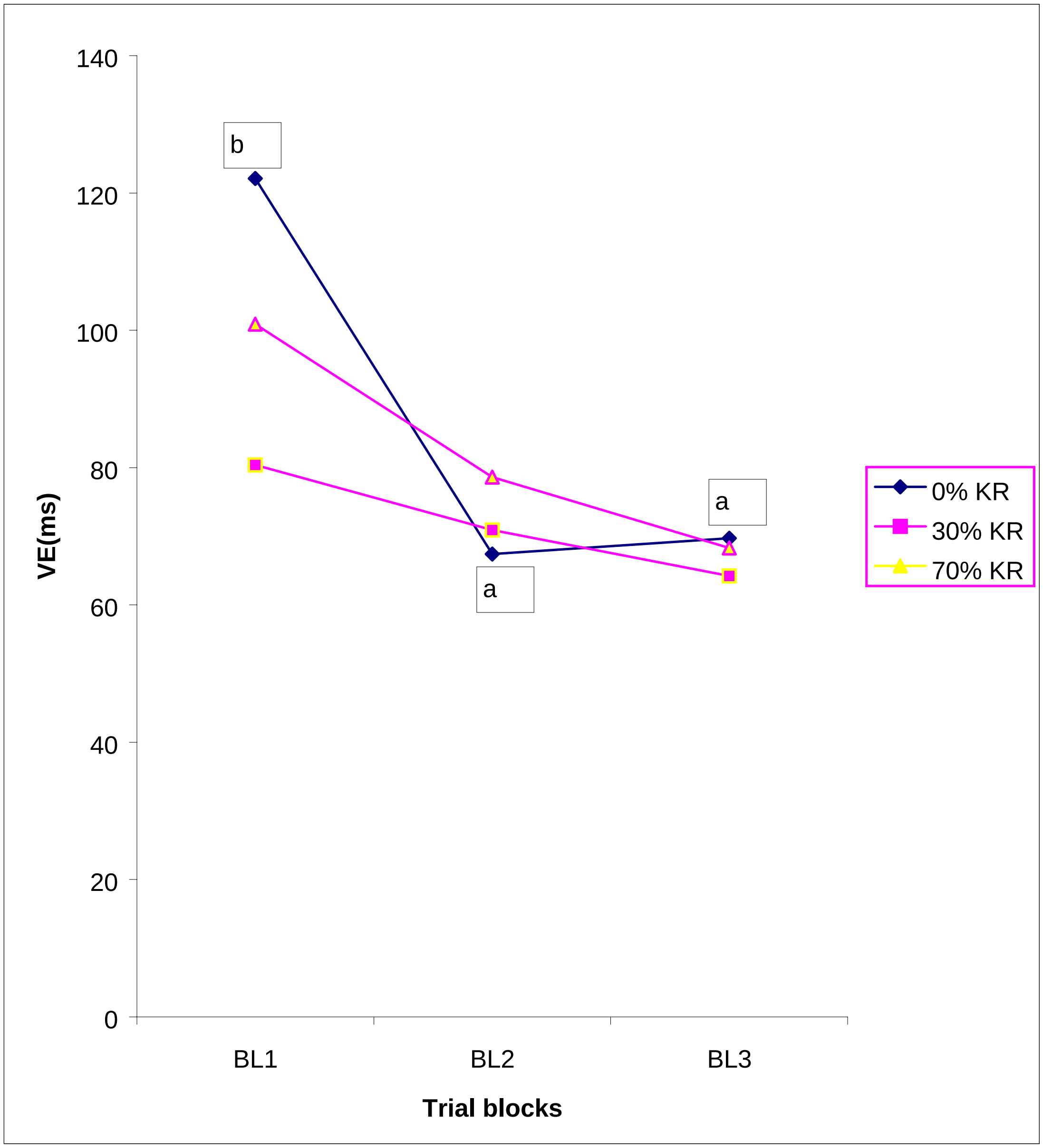


Figure 4. VE scores in acquisition for evenly distributed KR and 0% KR groups over Trial Blocks, $p < .05$. Means are not significantly different unless labeled with different letters.

The results for AE indicated that participants in the 0% KR progressively improved their performances over practice trials, but were still less accurate ($p < .05$) at Trial Block one compared to those in the 30% evenly distributed KR.

Participants who practiced tasks in the 0% KR not only improved their accuracy (AE) over practice, but also became more consistent (VE) throughout practice as well.

Retention

There were 18 trials administered in retention, 6 for each of 3 task divided into three trial blocks. Three analyses were conducted. The first analysis was a 2 x 2 x 3 [Frequency of KR (30% and 70%) x Schedule of KR (evenly distributed and fading) x Trial Block] ANOVA conducted with repeated measures on the last factor. These analyses were conducted to determine interaction effects of schedule of KR and reduced Frequency. Second, to compare the evenly distributed KR conditions, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare evenly distributed to the 0% KR. Third, to compare the fading KR conditions, a 3 (0% KR, 30% fading KR and 70% fading KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare these KR groups to the 0% KR. Overall CE, AE, and VE means for each practice schedule over each Trial Block are showed in Table 6.

Constant error (CE):

The ANOVA Summary Table for the 2 x 2 x 3 ANOVA is shown in Table 7. A significant Trial Block x Frequency interaction was found, $F(2, 104) = 3.83$, $p < .05$, and

Table 6
Mean Retention Error Scores for Frequency Groups and KR Schedules across Trial Block (ms)

Error Source	Acquisition Group	Block 1	Block 2	Block 3	Mean
CE	0% KR	-3.2024	-7.4762	-4.7738	-5.1510
	30% even KR	-7.0952	-9.8333	-2.6310	-6.5200
	30% fading KR	-9.6071	-12.8929	-8.7976	-10.4330
	70% even KR	30.3214	18.2976	8.0238	18.8810
	70%fading KR	14.3690	3.1548	-15.2381	.7620
AE	0% KR	63.8214	63.7143	68.1548	65.2300
	30% even KR	40.6905	37.9048	41.9167	40.1710
	30% fading KR	56.1310	60.2262	52.1071	56.1550
	70% even KR	70.4881	59.1786	59.0476	62.9050
	70%fading KR	75.1071	62.3214	40.0476	59.1590
VE	0% KR	78.3852	76.4057	78.8247	77.8720
	30% even KR	57.2739	44.9102	50.4914	50.8920
	30% fading KR	69.6250	58.0972	58.6922	62.1380
	70% even KR	92.5076	70.2937	70.1595	77.6540
	70%fading KR	97.7688	77.8975	66.6848	80.7840

Table 7
Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Retention for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	1	14061.720	4.813	.033*
Schedule	1	5096.677	1.744	.192
Frequency x Schedule	1	2119.114	.725	.398
Error	52	2921.791		
Trial Block (TB)	2	1943.893	2.471	.089
TB x Frequency	2	3011.671	3.829	.025*
TB x Schedule	2	143.682	.183	.833
TB x Frequency x Schedule	2	23.519	.030	.971
Error	104	786.560		
		AE		
Frequency	1	6955.720	6.238	.016*
Schedule	1	1572.595	1.410	.240
Frequency x Schedule	1	4087.431	3.666	.061
Error	52	1114.998		
Trial Block (TB)	2	2130.523	2.970	.056
TB x Frequency	2	1685.893	2.350	.100
TB x Schedule	2	1188.441	1.657	.196
TB x Frequency x Schedule	2	296.043	.413	.663
Error	104	717.376		

Table 7 (continued)

Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Retention for CE, AE, and VE

		VE		
Frequency	1	21649.209	9.971	.003*
Schedule	1	2170.152	1.000	.322
Frequency x Schedule	1	691.660	.319	.575
Error	52	2171.192		
Trial Block (TB)	2	5507.611	2.940	.057
TB x Frequency	2	1116.360	.596	.553
TB x Schedule	2	253.303	.135	.874
TB x Frequency x Schedule	2	35.240	.019	.981
Error	104	1873.409		

Note. * $p < .05$

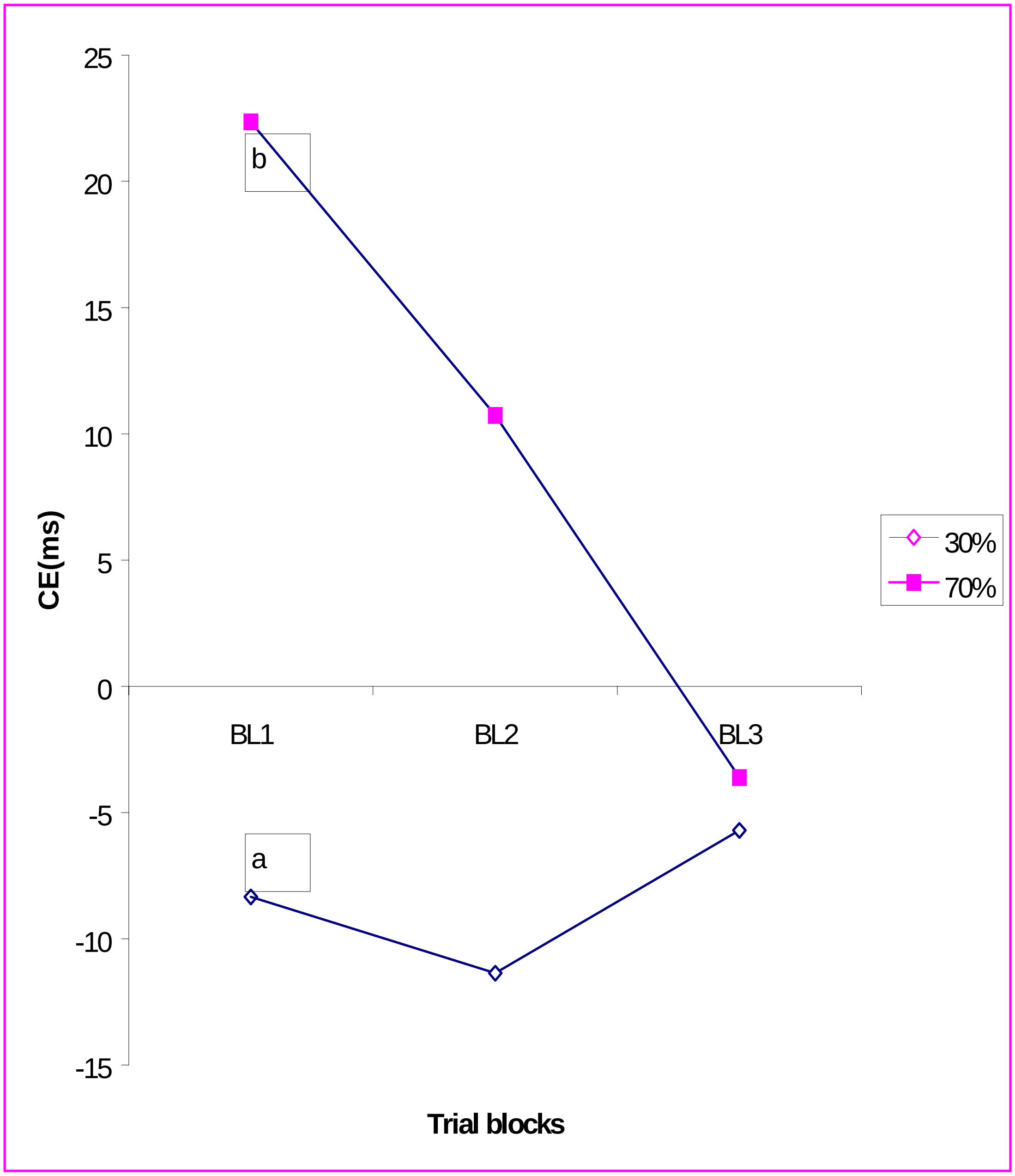


Figure 5. CE in retention as a function of Frequency of KR and Trial Blocks, $p < .05$.

Means are not significantly different unless labeled with different letters.

is shown in Figure 5. Post hoc tests indicated that participants in the 30% frequency of KR ($\underline{M}$ = -8 ± 31ms) were earlier and more accurate than participants in the 70% frequency of KR ($\underline{M}$ = 22 ± 56 ms) in Trial Block one only. Also, this interaction explained the main effect of Frequency of KR that was found, $\underline{F}$ (1, 52) = 4.813, $\underline{p}$ < .05, indicating that participants who practiced tasks with 30% KR ($\underline{M}$ = -8 ± 30 ms) performed more accurate than those who practiced tasks with the 70% KR ($\underline{M}$ = 10 ± 33 ms). No other main effects nor interactions were reached significance.

The 3 x 3 ANOVA Summary Table for CE (Table 8) for evenly distributed KR and fading KR failed to show any main effects or interactions between Frequency of KR and Trial Block.

Absolute error (AE):

The ANOVA Summary Table for the 2 x 2 x 3 ANOVA is shown in Table 7. A near significant interaction of Frequency x Schedule ($\underline{p}$ = .06) was found and is shown in Figure 6. The t-test indicated that participants who practiced tasks with the 30% evenly distributed KR ($\underline{M}$ = 40 ± 13 ms) were more accurate ($\underline{p}$ = .025) than those who practiced with the 30% fading KR ($\underline{M}$ = 56 ± 22 ms) and those who practiced tasks with the 70% evenly distributed KR ($\underline{M}$ = 63 ± 18 ms). These results support that 30% KR was more effective for RA participants for AE in retention compared to the 70% KR. The important findings of the study ($\underline{p}$ = .06) are depicted in Figure 6. The 30% evenly distributed KR schedule shows a tendency to be more effective in improving accuracy in retention compared to a 30% fading KR schedule. Second, for the evenly distributed KR groups, the 30% evenly distributed KR schedule shows a tendency to be more effective in facilitating retention performance compared to the 70% evenly distributed KR schedule.

Table 8
Summary ANOVA Tables for the Evenly Distributed KR Conditions over 3 Frequency Levels and Trial Blocks in Retention for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	2	8572.196	3.032	.060
Error	39	2827.388		
Trial Block (TB)	2	574.808	.977	.381
TB x Frequency	4	709.683	1.206	.315
Error	78	588.229		
		AE		
Frequency	2	8051.594	9.880	.000*
Error	39	814.968		
Trial Block (TB)	2	237.642	.455	.636
TB x Frequency	4	257.631	.493	.741
Error	78	522.641		
		VE		
Frequency	2	10109.149	5.563	.007*
Error	39	1817.088		
Trial Block (TB)	2	1727.816	1.189	.310
TB x Frequency	4	574.467	.395	.811
Error	78	1453.409		

Note. * $p < .05$

The ANOVA Summary Table in Table 8 for the evenly distributed groups, the KR 3 x 3 (Trial Block) indicated a significant main effect of frequency of KR, F (2, 39) = 9.88, $p < .05$. Post hoc tests indicated that participants who received the 30% evenly distributed KR (M = 40 ± 13 ms) were more accurate than those who received the 0% KR (M = 65 ± 18 ms) and the 70% evenly distributed KR (M = 63 ± 18 ms). No other main effects nor interactions were significant.

The last 3 x 3 ANOVA for the fading KR schedules resulted in no significant main effects or interactions.

Variable error (VE)

The ANOVA Summary Table in Table 7 for the 2 x 2 x 3 ANOVA indicated a significant main effect for frequency of KR, F (1, 52) = 9.97, $p < .05$. Participants in the 30% KR performed more consistent (M = 57 ± 21 ms) than those in the 70% KR (M = 79 ± 31 ms). No other main effects nor interactions were significant.

The 3 x 3 ANOVA Summary Table for the evenly distributed KR groups (Table 8) indicated significant main effect of frequency of KR, F (2, 39) = 5.563, $p < .05$. Post hoc tests indicated that participants in the 30% evenly distributed KR performed most

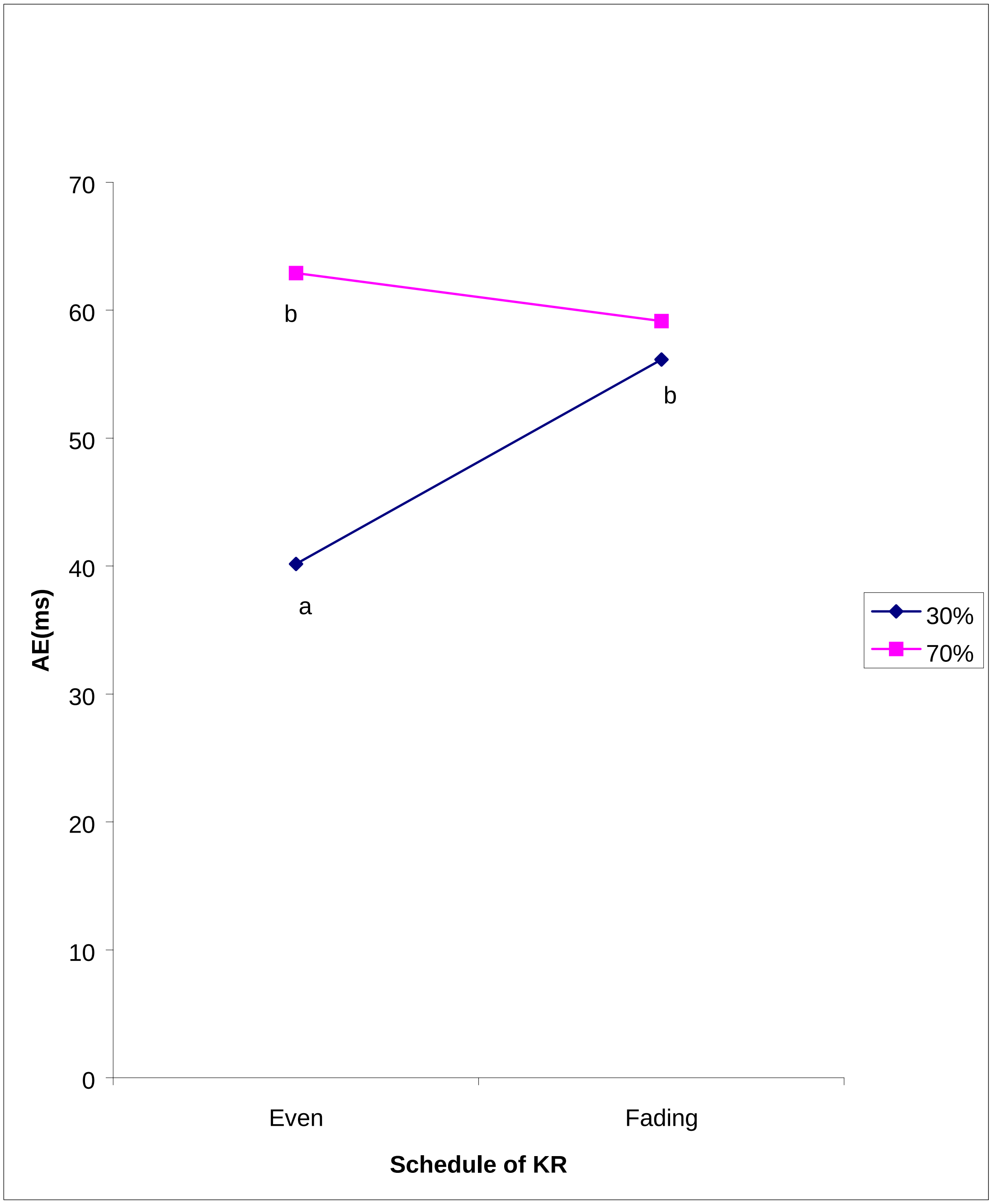


Figure 6. AE in retention as a function of KR Schedule and Frequency of KR, $p = .06$. Means are not significantly different unless labeled with different letters.

consistent (M = 51 ± 18 ms) compared to the 0% KR (M = 78 ± 24 ms) and the 70% evenly distributed KR (M = 78 ± 30 ms). No other main effects nor interactions were significant.

The final 3 x 3 VE ANOVA for fading KR schedules resulted in no significant interactions or main effects.

Summary of Retention Analyses

Two important findings for AE are illustrated in Figure 6. First, participants who practiced tasks in the 30% evenly distributed KR were more accurate in retention for AE than those who practiced tasks with the 30% fading KR. This finding indicated that schedule of KR may be a factor in the effects of reduced frequency of KR. Second, participants who practiced tasks with the 30% evenly distributed KR were more accurate in retention than those who practiced tasks with the 70% evenly distributed KR, suggesting that low frequency of KR is beneficial for RA participants compared to a higher frequency of KR.

Moreover, comparing the evenly distributed schedules to the 0% KR for AE also, participants who practiced tasks with the 30% evenly distributed KR were not only more accurate (AE) than those who practiced tasks with the 70% evenly distributed KR and the 0% KR, but more consistent than those who practiced tasks with the 70% evenly distributed KR and the 0% KR. These results suggest that practicing with the 30% evenly distributed KR is more effective in facilitating retention compared to practicing with the

70% evenly distributed KR and 0% KR, supporting the hypothesis that there is an optimal relative frequency of KR for RA participants.

Participants who practiced with the 30% KR, regardless of schedule, were more accurate (CE) than those practicing with the 70% KR. But this trend was found in Trial Block one only and did not extend throughout practice. In addition, the 30% KR groups, overall, demonstrated more consistent performance compared to the 70% KR groups. Thus, regardless of schedule the 30% KR was more effective in enabling RA participants to reduce error and perform consistent in retention compared to the 70% frequency of KR.

Transfer

There were 18 trials administered in transfer, 6 for each of tasks. The speeds used in transfer were 3, 5 mph. Eighteen trials were divided into three trial blocks. Three analyses were conducted. The first analysis was a 2 x 2 x 3 [Frequency of KR (30% and 70%) x Schedule of KR (evenly distributed and fading) x Trial Block] ANOVA conducted with repeated measures on the last factor. These analyses were conducted to determine interaction effects of schedule of KR and reduced Frequency. Second, to compare the evenly distributed KR conditions, a 3 (0% KR, 30% evenly distributed KR and 70% evenly distributed KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare evenly distributed KR schedules to the 0% KR. Third, to compare the fading KR conditions, a 3 (0% KR, 30% fading KR and 70% fading KR) x 3 (Trial Block) ANOVA with repeated measures on the last factor was conducted to compare fading schedules to the 0% KR. Overall means for CE, AE, and VE for each practice schedule over each Trial Block are showed in Table 9.

Constant error (CE)

The Summary Table for the 2 x 2 x 3 ANOVA is shown in Table 10. A significant Trial Block x Frequency interaction was found, F (2, 104) = 3.107, and is illustrated in Figure 7. Although Post hoc tests failed to find any significance, the 30% KR was more accurate than the 70% KR at Trial Block three. No other main effects nor interactions were achieved at $p < .05$.

The 3 x 3 ANOVA Summary Tables (Table 11) for the evenly distributed KR groups and fading KR groups failed to show any main effects or significant interactions.

Absolute error (AE):

For the 2 x 2 x 3 ANOVA shown in Table 10, no main effects nor interactions were exceeded the critical level.

In Table 11, the 3 x 3 ANOVA Summary Table for evenly distributed KR schedules is presented. A significant main effect of frequency of KR was found, F (2, 39) = 6.399, $p < .05$. Post hoc tests indicated that participants in the 30% evenly distributed KR ($M = 40 \pm 14$ ms) were more accurate in transfer than those who practiced without KR (0% KR) ($M = 68 \pm 31$ ms). Also, a tendency ($p = .06$) was found between 30% evenly distributed KR ($M = 40 \pm 14$ ms) and the 70% evenly distributed KR ($M = 49 \pm 16$ ms), indicating that the 30% evenly distributed KR was more effective for RA participants compared to the

Table 9
Mean Transfer Error Scores for Frequency Groups and KR Schedules across Trial Block (ms)

Error Source	Acquisition Group	Block 1	Block 2	Block 3	Mean
CE	0% KR	-.7976	10.9881	-.3214	3.2900
	30% even KR	8.5000	4.4405	2.3333	5.0910
	30% fading KR	-2.9524	-8.7738	-6.5119	-6.0790
	70% even KR	14.9881	23.0833	20.1190	19.3970
	70% fading KR	-16.0952	-9.6310	12.6310	-4.3650
AE	0% KR	63.3929	82.0833	59.8690	68.4480
	30% even KR	39.5476	40.2262	39.1905	39.6550
	30% fading KR	54.8095	61.3452	49.9167	55.3570
	70% even KR	45.7500	52.8214	48.8333	49.1350
	70% fading KR	48.4762	46.3929	49.5595	48.1430
VE	0% KR	64.9028	101.9956	54.9126	73.9370
	30% even KR	43.7616	42.8532	47.8860	44.8340
	30% fading KR	57.1229	61.7048	52.0327	56.9530
	70% even KR	48.6159	55.5267	47.6017	50.5810
	70% fading KR	59.6595	60.1204	60.3421	60.0410

Table 10
Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Transfer for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	1	2694.671	.786	.379
Schedule	1	12812.964	3.736	.059
Frequency x Schedule	1	1664.671	.485	.489
Error	52	3429.486		
Trial Block (TB)	2	573.176	1.066	.348
TB X Frequency	2	1670.254	3.107	.049*
TB X Schedule	2	918.140	1.708	.186
TB X Frequency X Schedule	2	510.730	.950	.390
Error	104	343.779		
		AE		
Frequency	1	53.909	.049	.825
Schedule	1	2272.131	2.076	.156
Frequency x Schedule	1	2926.397	2.673	.108
Error	52	1094.733		
Trial Block (TB)	2	190.506	.568	.568
TB X Frequency	2	133.692	.399	.672
TB X Schedule	2	37.377	.111	.895
TB X Frequency X Schedule	2	314.829	.939	.394
Error	104	335.367		

Table 10 (continued)

Summary ANOVA Tables for Frequency of KR x Schedule of KR x Trial Blocks Data in Transfer for CE, AE, and VE

		VE		
Frequency	1	819.611	.547	.463
Schedule	1	4889.411	3.265	.077
Frequency x Schedule	1	74.328	.050	.825
Error	52	1497.598		
Trial Block (TB)	2	161.015	.226	.798
TB x Frequency	2	13.689	.019	.981
TB x Schedule	2	58.595	.082	.921
TB x Frequency x Schedule	2	457.227	.643	.528
Error	104	710.882		

Note. * p <.05

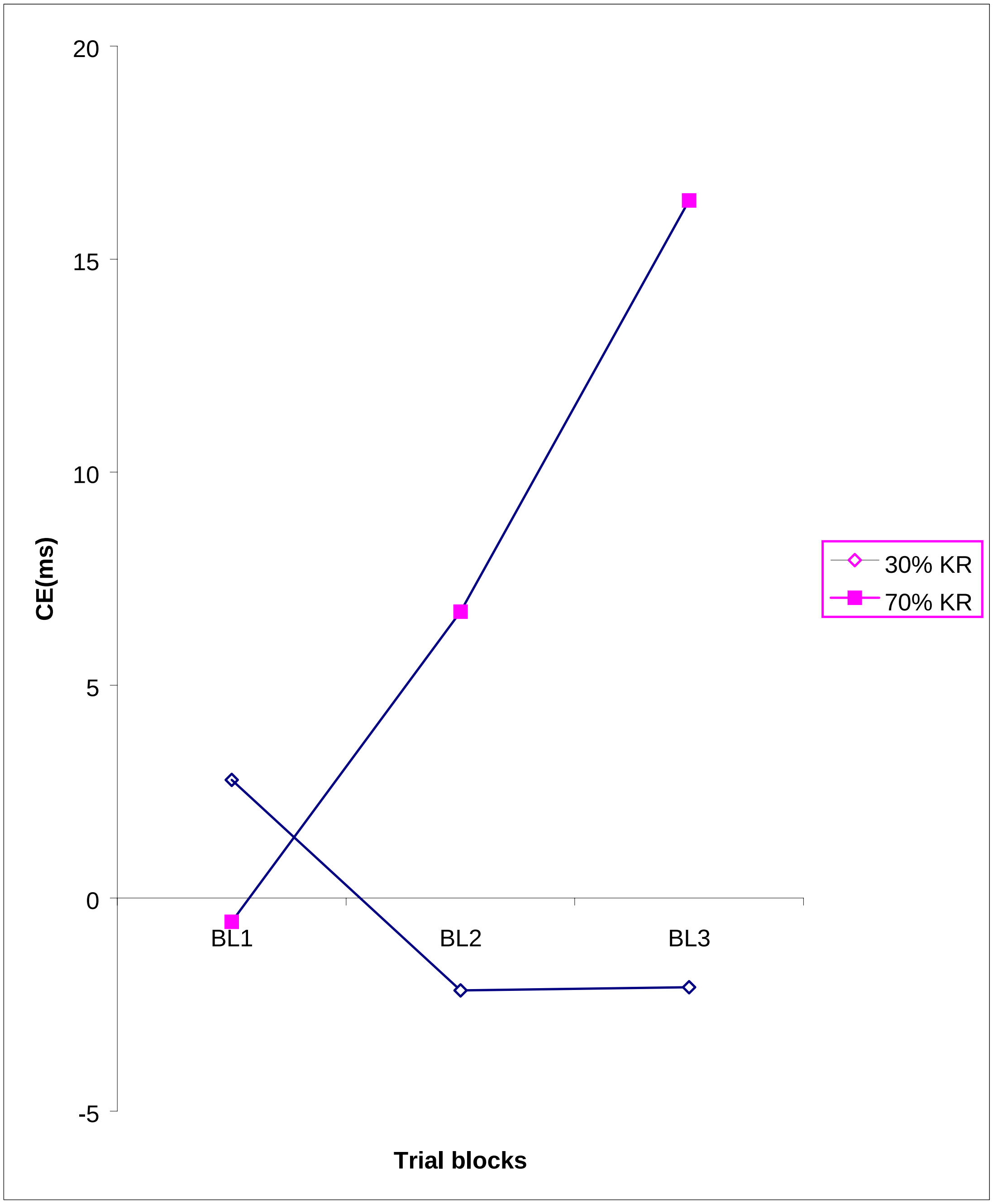


Figure 7. CE transfer scores as a function of Frequency of KR and Trial Blocks, $p < .05$.

Table 11
Summary ANOVA Table for the Evenly Distributed KR Conditions over 3 Frequency Levels and Trial Blocks in Transfer for CE, AE, and VE

Source	df	MS	F	p
		CE		
Frequency	2	3271.343	.720	.493
Error	39	4545.934		
Trial Block (TB)	2	403.640	.529	.591
TB x Frequency	4	295.914	.388	.817
Error	78	763.280		
		AE		
Frequency	2	9043.711	6.339	.004*
Error	39	1426.676		
Trial Block (TB)	2	1121.282	2.315	.105
TB x Frequency	4	527.046	1.088	.368
Error	78	484.296		
		VE		
Frequency	2	9978.688	4.516	.017*
Error	39	2209.735		
Trial Block (TB)	2	3423.820	2.519	.087
TB x Frequency	4	2776.538	2.043	.096
Error	78	1359.064		

Note. * $p < .05$

0% KR and the 70% evenly distributed KR. No other main effects nor interactions were significant.

The last ANOVA for AE, the 3 x 3 for the fading KR schedules resulted in no significant main effects or interactions.

Variable error (VE):

The 2 x 2 x 3 ANOVA Summary Table (Table 10) indicated an F (1, 52) = 3.26, p = .07 for schedule of KR. The evenly distributed KR groups tended to be more consistent than those who practiced in the fading schedule. No other main effects nor interactions were found.

The 3 x 3 ANOVA Summary Table (Table 10) for the evenly distributed KR groups showed a significant main effect of frequency of KR, F (52, 39) = 4.52, $p < .05$. Post hoc tests indicated that participants in the 30% evenly distributed KR (M = 45 ± 19 ms) were more consistent than those in the 0% KR (M = 74 ± 36 ms). This indicated that the 30% evenly distributed KR was more effective for RA participants compared to the 0% KR. No other main effects nor interactions were found.

The last 3 x 3 ANOVA for VE for fading KR schedules resulted in no significant interactions or main effects.

Summary of Transfer Analyses

For AE and VE, participants in the 30% evenly distributed KR condition performed more accurate and consistent in transfer than those who practiced tasks in either 0% KR or the 70% evenly distributed KR (only for AE). These results paralleled AE and VE effects in retention. It also supported the hypothesis that there was an optimal range of frequency of KR for RA participants at the 30% evenly distributed KR.

For CE, although there are not significant difference between 30% KR and 70% KR, the 30% KR tends to be more accurate than the 70% KR at Trial Block three.

Summary of the Results

An important finding in the current study is that there is significant difference between the 30% evenly distributed KR and the 30% fading distributed KR for AE in retention. Participants who practiced tasks with the 30% evenly distributed KR (M = 40 ± 13 ms) were superior in retention than those who practiced tasks with the 30% fading KR (M = 56 ± 22 ms). The results demonstrate that the schedule of KR may be a factor in the effects of reduced frequency of KR for RA participants.

The second important finding in the current study is that participants practicing with the 30% evenly distributed KR were more accurate and consistent in retention than those who practiced tasks in the 0% KR. Thus, the 30% evenly distributed KR, as hypothesized is more effective for RA participants in facilitating accuracy and consistency of retention compared to the 0% KR. Furthermore, the 30% evenly distributed KR not only enhanced RA performance in the memory test, but facilitated their performance in learning novel tasks. This is supported by the AE and VE results in transfer.

The third important finding in the current study is that participants practicing tasks with the 30% evenly distributed KR were more accurate and consistent in retention than those who practiced tasks with the 70% evenly distributed KR. Thus, the 30% evenly distributed KR as hypothesized is more effective for RA participants in facilitating accuracy and consistency of performance compared to the 70% evenly distributed KR, supporting the hypothesis that too much extrinsic KR is detrimental for RA. In all, the findings in retention and transfer support that there is an optimal relative frequency of KR for RA.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Discussions

The purpose of the present study was to compare the effects on retention and transfer of a fading KR and an evenly distributed KR condition practiced in a high contextual interference (RA) practice order. The literature already indicated the benefits of practicing tasks with reduced KR for participants in RA. However, the differential relative frequencies of KR used in previous studies have indicated that not all reduced frequencies of KR were effective. The assumption in the present study for reduced KR is that there is an optimal relative frequency to maximize the effects of reduced frequency of KR. Thus, it was hypothesized that participants in the 30% KR (evenly distributed throughout 90 practice trials) were expected to be free during practice to process their intrinsic KR and thus, would be more accurate and consistent in retention and transfer than those participants who practiced tasks with the 0% KR and the 70% KR. Moreover, since the current study included a fading KR schedule as well as an evenly distributed KR schedule (in both 30% and 70% conditions), the confounding effects found in the previous literature of relative frequency of KR and schedule of KR were absent. The effects of the schedule of KR in the present study could be investigated independent of any effects provided by reduced KR. Participants who practiced tasks with the 30%

evenly distributed KR were hypothesized to remember the tasks and transfer their knowledge to novel tasks better than those who practiced tasks with the 30% fading KR. Results from the present study provided evidence to support this hypothesis and will be explored with other findings in this chapter.

The first result derived from the retention data was a near significant finding ($p = .06$) found in the interaction between frequency of KR and schedule of KR for the dependent variable AE. Although the probability level was achieved .06, given the eta squared (.06) and observed power (.468) ranked as medium to large, the schedule of KR shows a tendency to interact with the effects of reduced frequency of KR. The individual comparisons (for AE) indicated that participants who practiced tasks in the 30% evenly distributed KR condition ($M = 40 \pm 13$ ms) were more accurate in retention than those who practiced tasks with the 30% fading KR ($M = 56 \pm 22$ ms). These results demonstrated that the schedule of KR might be a factor in addition to the effect of reduced frequency of KR for RA participants in these timing tasks.

An early study by Winstein and Schmidt (1990) used a 50% fading KR group on participants in both Experiment 2 and Experiment 3, and demonstrated a significantly lower error in retention compared to a 100% KR group. They argued that a fading schedule might prevent dependence on extrinsic feedback in later practice and may be an effective way to manipulate reduced frequency of KR for motor learning. However, in the Winstein and Schmidt's study the effects of a fading KR schedule were confounded with reduced frequency of KR. Thus, the better performance of the fading KR schedule compared to 100% KR in retention was not independent of reduced frequency of KR and may have been due to less KR, not the specific fading schedule. Also, Nicholson and

Schmidt (1991) explored the issue of schedule of KR further by comparing a fading KR group with two other 50% KR groups in a constant practice order (one task for all practice trials). Their results demonstrated that there were no significant differences in retention among the three 50% groups, hinting that the schedule of KR (i.e., when KR is presented) might not be a factor in affecting the effects of reduced frequency of KR compared to the actual amount of reduced KR administered. Given the methodological problems with these previous studies, the issue of schedule of KR as a factor remained unsolved. The current study was designed to remove the confounding of frequency from schedule of KR.

Although participants who practiced tasks with the 30% evenly distributed KR received the same amount of KR as those who practice tasks with the 30% fading KR, the differential performance in retention for AE indicated that not only how much KR is important, but also when KR presented might be crucial for retention for our participants. For the 30% evenly distributed KR, participants received evenly distributed KR across practice trials. Reduced frequency of KR enables RA participants to focus on processing their intrinsic feedback and thus enhance their elaborative processing. This view is particularly relevant for practicing tasks in RA because on each trial a new task is presented. Thus, too much KR can be distracting.

In the 30% evenly distributed KR condition, participants benefited from both extrinsic and intrinsic feedback to develop internal error detection, which is so necessary in retention when KR is withdrawn. The argument that both extrinsic and intrinsic KR is necessary is consistent with the point of view in a recent publication by Shewokis, Kennedy, and Marsh (2000). They used the bandwidth KR (a type of reduced frequency of KR) compared to 100% KR for learning a shoulder internal rotation isokinetic strength task. Their results in retention revealed that participants in the 10% bandwidth performed more accurate and consistent than the 100% KR condition. They argued that reduced frequency of KR will allow participants to become independent learner and process both intrinsic and extrinsic feedback to facilitate their performance compared to those who received extrinsic KR on all practice trials. These findings agree with other literature that suggest that processing both intrinsic and extrinsic feedback is beneficial in developing internal error detection and this superior error detection ability will be advantageous in retention.

In contrast to the 30% evenly distributed KR, participants who practiced tasks in the 30% fading KR condition received too much KR during initial practice which distracted them from processing their own intrinsic feedback and no KR at the end of practice (60% frequency of KR presented in the beginning of trials and gradually decreased until 0 at the end of trials). Given the order of presentation for RA, i.e., on each trial a new task is presented, frequent extrinsic feedback was a distraction to RA performers during practice because KR about the previous trial could not be used to modify the current response. Frequent extrinsic feedback not only distracts RA performers in preparation of the next response, but also interrupts performers from elaborative and distinctive processing.

According to Schmidt (1975), both intrinsic and extrinsic feedback are important in motor learning. Participants who practiced tasks in the 30% fading KR condition received no KR in the later practice. They thus lacked a standard of goal attainment to evaluate their intrinsic KR and did not have opportunities to process both intrinsic and extrinsic feedback to develop internal error detection. Such internal error detection is most critical for performance in retention because no KR will be provided during this phase and participants have to correct errors on their own.

The empirical evidence has shown that a certain minimum amount of KR is necessary in acquisition in order to evaluate the standard of goal attainment. Due to the above two deficiencies in processing information feedback for participants who practiced tasks with the 30% fading KR, they did not develop internal error detection as well as those who practiced tasks with the 30% evenly distributed KR and resulted in less accurate performance in retention compared to those who practiced task with the 30% evenly distributed KR.

The present data indicated that the more accurate retention performance of participants in the 30% evenly distributed KR compared to 30% fading KR group may due to the interactive effect of reduced frequency of KR and schedule of KR, and that schedule of KR may be a factor, in addition to the effect of reduced frequency of KR. The present study provides empirical evidence for using reduced frequency of KR when learning a timing task, suggesting that how much KR should be considered in acquisition, as well as when KR is of concern. Further studies are needed to confirm this argument.

Other important findings in the current study ($p < .05$) were that participants who practiced tasks in the 30% evenly distributed KR condition were more accurate in retention than those who practiced tasks in the 70% evenly distributed KR and the 0% KR conditions. Two hypotheses about retention performance were strongly supported by these results. The data for AE in retention showed that participants who practiced tasks in the 30% evenly distributed KR condition were more accurate than those who practiced tasks in both 0% KR and 70% evenly distributed KR conditions. Thus, the 30% evenly distributed KR as hypothesized was more effective in developing internal error detection for RA participants compared to the 0% KR and the 70% evenly distributed KR, supporting the hypothesis that there is an optimal range of frequency of KR and it is the 30% evenly distributed KR for our timing tasks. Our findings indicate that the 70% relative frequency of KR (evenly distributed KR) was too high for RA participants. Due to the order of presentation for a high contextual interference condition, on each trial a new task is presented, frequent extrinsic feedback (e.g., 70%) was a distraction to RA performers during practice because KR about the previous trial could not be used to modify the current response. Elaborative processing (Shea and Zimny, 1983) is a result of comparisons made across tasks (intertask processing) during RA practice. Frequent extrinsic feedback not only distracts RA performers in preparation of the next response, but also interrupts performers from elaborative and distinctive processing (Del Rey & Shewokis, 1993; Sherwood, 1996). Thus, elaborative processing is degraded for RA participants in a frequent extrinsic feedback condition. However, the 30% evenly distributed KR did not present the magnitude of distraction that irrelevant feedback produced compared to the 70% evenly distributed KR, thus freeing participants to focus on their own intrinsic feedback. In fact, the 30% evenly distributed KR enhances intertask processing and results in more distinctive and elaborative processing by removing irrelevant extrinsic feedback. Moreover, relying on intrinsic feedback is what is essential for performance in retention and transfer because no extrinsic KR is provided. Thus, benefits did accrue to participants who practiced tasks in the 30% evenly distributed KR condition in retention and transfer because these participants were able to take advantage of both intrinsic and extrinsic feedback and therefore, develop internal error detection. The results in Figure 5 for CE indicated that the difference between 30% frequency of KR and 70% frequency of KR in retention tended to disappear over retention trials, however, the main effects for AE and VE in retention in contrast demonstrated that participants in the 30% frequency of KR overall were more accurate and consistent than those who practiced tasks with the 70% frequency of KR. However, the Figure 7 illustrated that participants in the 70% frequency of KR, in contrast to retention data, tended to make more errors in transfer at Trial Block three compared to those in the 30% frequency of KR. These findings support that for CE too much KR in acquisition (70%) does not negatively affect retention performance but does affect transfer. Participants who received 70% KR did not worse than 30% KR in transfer at Trial Block three. Also, for AE and VE practicing with 70% KR negatively affected retention.

In contrast to the 70% evenly distributed KR condition, participants who practiced tasks in the 0% KR condition received too little KR, such that they did not have a standard to evaluate their goal attainment. Although participants who practiced tasks with the 0% KR can totally depend on their intrinsic feedback, they lack sufficient extrinsic information to evaluate a standard of goal attainment. Thus, they did not develop internal error detection as well as those participants who practiced tasks with the 30% evenly distributed KR. However, participants who practiced tasks in the 0% KR were more accurate in acquisition in Trial Block two and three for AE compared to Trial Block one, indicating that improvement without KR does indeed occur with practice.

The findings in the present study identify both intrinsic and extrinsic feedback as important in developing error detection and facilitating performance in retention and transfer. In a study conducted by Magill, Chamberlin, and Hall (1991), their acquisition tasks were similar to the timing tasks in the current study. They found that KR and no KR groups did not show significant differences during retention and transfer tests. They argued that verbal KR (similar to what we used) was redundant in their timing tasks in which visual feedback gave sufficient information to correct their errors in acquisition. Therefore, based on Magill et al.'s viewpoint, we would predict no difference between our 0% KR group and the 30% evenly distributed KR group because enough visual feedback (intrinsic KR) is available. However, Del Rey and Liu (1990) used similar timing tasks and did not support this. Findings from Del Rey and Liu indicated that extrinsic KR was not redundant and was necessary with the same timing tasks. The results from Del Rey and Liu, along with the findings of the present study, suggest that verbal KR is not redundant for RA participants during acquisition with these timing tasks. Thus, the empirical evidence (e.g., Ho & Shea, 1978; Del Rey & Liu, 1990) together with the current results support the notion that practicing tasks for RA participants with a minimum amount of extrinsic KR during acquisition is necessary for memory and transfer.

It has been well known in motor learning that participants will perform more accurately, but also with more consistency in retention and transfer as skill develops. In the field of motor learning, the most commonly used dependent measures of performance for accuracy and consistency are constant error (CE), absolute error (AE) and variable error (VE). CE provides information about the direction of error, and AE provides information about the magnitude of error. However, VE provides information regarding the degree of consistency of performance. It is often the most sensitive indicator regarding the changes across practice trials. Investigations on the effects of KR have shown that participants perform with less error over practice trials, but VE improves much more slowly. The previous studies in reduced frequency of KR (e.g., Winstein & Schmidt, 1990; Del Rey & Shewokis, 1993) indicated that participants in reduced frequency of KR performed more consistent in retention and transfer compared to those practicing with a high frequency of KR. These findings also show that participants tend to change their behavior more often when frequent KR is presented. In these studies, high VE in acquisition with frequent KR during practice did not yield benefits in retention and transfer.

The retention data in the present study revealed that participants who practiced tasks in the 30% evenly distributed KR not only tended to be more accurate than those who practiced tasks in the 0% KR and the 70% evenly distributed KR, but tended to be more consistent as well. In retention, the 30% evenly distributed KR group ($\underline{M}$ = 51 ± 18 ms) had significantly smaller VE compared to the 0% KR ($\underline{M}$ = 78 ± 24 ms) and the 70% evenly distributed KR group ($\underline{M}$ = 78 ± 30 ms). This finding suggests that the 30% evenly distributed KR is more effective to enhance response consistency in retention than both the 0% KR and the 70% evenly distributed KR. Similarly, in a reduced frequency of KR study conducted by Winstein and Schmidt (1990), in their Experiment 2, they found that their 50% group had smaller VE in retention than the group with 100% KR. Also, in a recent study by Shewokis et al. (2000), a group using a bandwidth KR in which KR is administered only when errors in performance exceed predetermined boundaries of correctness was compared to 100% KR groups. Their results indicated that the bandwidth

KR group (reduced KR) performed more consistent (lower VE) than 100% KR groups in retention.

The present results suggest that low frequencies of KR yield reduced variability of performance in acquisition and also benefits in retention. This is in line with previous findings that frequent KR encourages participants to frequently change their response in practice (e.g., Wulf, 1992; Del Rey & Shewokis, 1993). This high frequency KR-induced variability has at least two detrimental effects to motor learning. First, intrinsic feedback provides rich information about the outcome of the movement and process of the movement itself. However, frequent KR distracts participants from processing intrinsic feedback which cannot be replaced by extrinsic KR and has negative effects in developing an internal error detection mechanism. Such internal error detection is so critical in retention and transfer when there is no KR presented. Second, given the order of RA, the tasks change from trial to trial, frequent KR is not useful in modifying the current response because the current trial is different from the previous trial to which the KR referred. Frequent KR will induce maladaptive short-term corrections (Schmidt, 1991). Frequent KR prompts participants to correct even small response errors that may result from random error in the neuromuscular system and results in unproductive response variability.

It may seem reasonable to assume that removing all extrinsic KR during practice would facilitate retention. Unfortunately, retention findings in the present study did not support this assumption. The 30% evenly distributed KR group ($\underline{M}$ = 51 ± 18 ms) demonstrated more consistent performance in retention than the 0% KR group ($\underline{M}$ = 78 ± 24 ms). This finding has important implication for motor learning. It is known that intrinsic feedback is crucial in motor learning. But the findings in the present study indicated that intrinsic feedback could not totally substitute for extrinsic feedback. Thus, both intrinsic feedback and extrinsic feedback are important to motor learning, especially when measuring retention and transfer. Different sources of information provide different information about movement to participants so that they take advantage of both sources of information to make appropriate response. To maximize the effect of information feedback, keeping a balance between intrinsic feedback and extrinsic feedback is critical to motor learning.

Furthermore, the 30% evenly distributed KR group demonstrated not only a more accurate and consistent performance in the memory test (i.e., retention) compared to the 0% KR group, but had more accurate performance ($\underline{M}$ = 40 ± 14 ms) and more stable responses ($\underline{M}$ = 45 ± 19 ms) with novel tasks (i.e., transfer) compared to the 0% KR group ($\underline{M}$ = 68 ± 31 ms and $\underline{M}$ = 74 ± 36 ms, respectively). These findings support the hypothesis that the 30% evenly distributed KR is more effective in facilitating transfer performance compared to the 0% KR and the 70% evenly distributed KR. This result further confirms the importance of maintaining the balance between intrinsic feedback and extrinsic feedback. However, the parallel results have not been found for the fading KR schedules. The hypotheses in retention and transfer for the fading KR schedules were not supported by the current study. No differences were found in acquisition, retention and transfer between the 30% fading KR and the 70% fading KR conditions. Having the same relative frequencies of KR for both evenly distributed KR and fading KR conditions but different schedules led to different results in retention and transfer. These results indicate that schedule of KR may interact with reduced of frequency of KR. These findings in retention and transfer support the view that an optimal relative frequency of KR for RA participants in practicing timing tasks combined with schedule of KR are factors affecting memory and generalization of knowledge to novel tasks.

Figure 3 for AE in acquisition shows that participants who practiced tasks in the 0% KR are more accurate in Trial Block three (M = 61 ± 17 ms) compared to Trial Block one (M = 94 ± 34 ms), suggesting learning effects occurred for the 0% KR group. Although the 0% KR group improved their performance during practice, they were still less accurate (M = 94 ± 34 ms) than the 30% evenly distributed KR group (M = 61 ± 22 ms) in Trial Block one and their improvement over practice did not benefit retention performance. This result indicates that sufficient visual information was available for the 0% KR group helping them to improve acquisition performance, but it cannot replace the advantage of some verbal KR. Thus, a certain amount of verbal KR is necessary for retention benefits.

According to the guidance hypothesis (Salmoni, Schmidt, & Walter, 1984), frequent KR will be beneficial in acquisition and guide performers to the correct response. Thus, the 70% evenly distributed KR group was predicted to be better in acquisition compared to the 0% KR and the 30% evenly distributed KR groups. But the results from acquisition data in the present study did not support this predication. Participants who practiced tasks with the 0% KR and the 30% evenly distributed KR were not different from those who practiced tasks with the 70% evenly distributed KR. The detrimental effects for reduced KR did not occur during acquisition as the guidance hypothesis predicted. As result of reduced frequency of KR, it did not show any negative effective to acquisition performance, but also did not enhance acquisition performance compared to high frequency of KR. The similar results in acquisition were replicated in a number of studies (e.g., Winstein & Schmidt, 1990; Wrisberg & Wulf, 1997; Lai & Shea, 1999). These results, together with the current data, suggest that providing less frequent KR may not degrade acquisition performance as previously assumed and will benefit retention and transfer.

Conclusions

Based on the above findings, the following conclusions were drawn. First, schedule of KR may interact with the effect of reduced frequency of KR. It was found in the present study that participants who practiced tasks with the 30% evenly distributed KR were more accurate in retention than those who practiced task with 30% fading KR. Therefore, it was concluded that schedule of KR might be a factor, in addition to reduced frequency of KR. Hence, when providing KR in motor learning, schedule of KR should be taken into account. Second, there is an optimal relative frequency of KR for RA in our timing tasks. Results from the present study confirm this conclusion. Participants who practiced tasks with the 30% evenly distributed KR were not only more accurate and consistent in retention than those who practiced tasks with the 0% KR, but more accurate and consistent than those who practiced tasks with the 70% evenly distributed KR. Hence, when using a reduced frequency of KR in motor learning, an appropriate relative frequency of KR should be selected to maximize the effects of reduced frequency of KR. Third, low frequency of KR is more effective in retention than high frequency of KR. Participants who practiced tasks with the 30% KR were more accurate overall than those who practiced with the 70% KR without regard to schedule. Last, providing less frequent KR does not degrade acquisition performance compared to a higher frequency of KR.

Recommendations

The findings of the current study had the following implications for future research. First, since the 30% evenly distributed KR was more effective for RA in facilitating retention performance compared to the 30% fading KR with a timing task, future research may investigate other tasks such as multi-segments movements to determine whether this is a robust finding or a task-specific phenomenon.

Second, since RA participants who practiced tasks with the 30% evenly distributed KR condition were more accurate and consistent in retention compared to whose who practiced tasks with the 0% KR and the 70% evenly distributed KR conditions, future research may explore different relative frequencies of KR (e.g., 20%, 30%, 40%, 50% and 60%) to determine the optimal range of frequency of KR for RA in anticipation-timing tasks.

Third, the previous literature suggested that verbal KR was redundant for anticipation-timing tasks like these where visual KR is available. However, the findings from the present study did not support this. Given inconsistent findings of these experiments, further research is needed to clarify this issue.

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APPENDIX A
ACTIVITY QUESTIONNAIRE

The following questionnaire is to gather information about your experience participating in sports and other physical activities, your driving experience and health. Your responses to this questionnaire will be kept confidential. (After reviewing the answers regarding health conditions with you, the health condition page will be coded with a no. and removed from the activity questionnaire)

Name _________________________________ CODE __________

Address ____

____

Home Phone #: (_____)_______________ Work Phone #:(_____)________________

E-mail __________________________

Best time to contact you: __Morn. __After. __Evening __weekend

Gender: ____ Male ____ Female Age _______

Do you have at least 30/30 vision with/without glasses in both eyes? _____Yes _____ No

Current Participation (Past 1 year, from November 1999 to present)

1. Please list the sports and physical activities you are or have regularly participated in during the past 1 year, such as aerobic exercises (running, walking, swimming, etc.), weight training, and sports (tennis, basketball, volleyball, etc.). Indicate the average duration of a single session (e.g., length of 1 workout) and frequency (days per week). Also, using three levels (**Beg**inner, **Int**ermediate, or **Adv**anced), please evaluate your ability in each activity that you listed.

List Sports/Physical Activity	Duration per session (minutes/session)	Frequency (days/week)	Skill level
______________________	___________	__________	Beg / Int / Adv
______________________	___________	__________	Beg / Int / Adv
______________________	___________	__________	Beg / Int / Adv
______________________	___________	__________	Beg / Int / Adv
______________________	___________	__________	Beg / Int / Adv

Prior Experience in Past 3 Years from Nov. 1997 – Nov. 1999

2. For your physical activity, please indicate length of time of involvement in the past 3 years and how frequently you participated in the sports and activities you identified above. Also, using three levels (**Beg**inner, **Int**ermediate, or **Adv**anced) evaluates your ability level in each activity that you listed. If there are other activities not listed in #1, please list those below.

Sports/Physical Activity	For how many years?	When? (19 ___- 19___)	Approx. Average Frequency (days/week)	Skill level (mark one)
____________	__________	__________	__________	Beg / Int / Adv
____________	__________	__________	__________	Beg / Int / Adv
____________	__________	__________	__________	Beg / Int / Adv
____________	__________	__________	__________	Beg / Int / Adv
____________	__________	__________	__________	Beg / Int / Adv

Driving Experience

If you don’t drive, place a check here:_______

3. How long have you had a driver’s license? ______ years, ______months

4. How many days do you use your car each week? (circle number)

   1. 1 - 2 days　　3. 5 - 6 days

   2. 3 - 4 days　　4. 7 days

Health Condition **CODE_______**

6. Please identify how you would rate your current overall health. (circle number)

   1. Excellent　2. Good　3. Fair　4. Bad　5. Poor

7. Have you had any injuries or medical problems during the past year that I asked for more than two weeks or required medical attention? If yes, please explain the problem(s):

____

____

____

8. Medication:

a) What medications are you currently taking? (If none, write "N/A")

____

____

b) What side effects are you current experiencing? (If none, write "N/A")

____

____

8. Do you have any uncorrected vision problems, and if so, please describe?

____

____

Thank you very much for your time.

APPENDIX B
CONSENT FORM

I agree to participate in the research entitled "*Effects of high contextual interference and reduced frequency of knowledge of results on retention and transfer*", which is being conducted by Zhangyun Chen (706-542-4183), Motor Learning Lab, Department of Exercise Science at the University of Georgia, under the direction of Dr. Patricia Del Rey. I understand that this participation is entirely voluntary; I can withdraw my consent at any time without penalty and have the results of the participation, to the extent that it can be identified as mine, returned to me, removed from the research records, or destroyed.

The following points have been explained to me.

1. The purpose of this study is to explore the relationship between reduced frequency of feedback and random practice and to examine whether participants will benefit from practicing in reduced frequency of feedback condition.
2. The benefit that I may expect from it is a better understanding of my eye-foot coordination and my anticipation timing ability.

3. The Procedures are as follows:
   I will respond to 3 trials without feedback and 90 trials with 0%, 30% or 70% feedback and 36 trials without feedback. The tasks will be presented on a Bassin Anticipation Timer. The task is to push a response pedal to coincide with the illumination of the last lamp. Testing will last about 50 minutes. I will receive an orientation to the laboratory in which all procedures will be explained. The research will occur in the Motor Learning Lab, 106, Ramsey Center.

4. No discomforts or stresses are expected.

5. No risks are expected.

6. The results of this participation will be confidential, and will not be released in any individually identifiable form without my prior consent, unless otherwise required by law.

7. The investigator will answer any further questions about the research, either now or during the course of the project, and can be reached by phone at 706-542-4183.

____________________________________ ____________________________________

Signature of PARTICIPANT Date Signature of RESEARCHER Date

Please sign both copies of this form. Keep one and return the other to the researcher.

Research at the University of Georgia which involves human participants is overseen by the Institutional Review Board. Questions or problems regarding your rights as a participant should be addressed to Ms. Julia Alexander, M.A., Institutional Review Board; Office of Vice President for Research; University of Georgia; 606A Graduate Studies Research Center; Athens, Georgia 30602-7411; Telephone (706) 542-6514; E-mail Address IRB@uga.edu.

APPENDIX C

INSTRUCTIONS FOR PARTICIPANTS

(KR group)

1. Please take a seat in the chair and adjust the chair so that you are close enough to the pedals and feel comfortable pushing the left response pedal with your right foot. Please try to push the left pedal several times now. You will begin by resting your right foot on the right pedal when you are ready to respond you will take your foot off the right pedal and press the left pedal down like a breaking action in a car. Be sure to press the pedal all the way down.
2. Now I am going to describe to you how to respond. At the beginning of each trial, I will say "Ready." "Ready" is your signal to watch the yellow warning light, put your hands on the steering wheel and rest your right foot on the response pedal. Please respond by saying “yes” or “no” after I say "Ready."
3. After you respond, the yellow light will illuminate for a short period of time. Immediately after, the red light will move down the trackway. You will need to watch the lights so that you can push the response pedal all the way down to coincide with the illumination of the last lamp. You should try to be as accurate as possible.
4. After you respond,:
   - On some trials I will tell you how accurate you were in terms of "early" or "late" in hundredths of a second. For example, if you push the response pedal before the illumination of the last lamp, I may say "early .02." .02 means .02 seconds (i.e., 20 milliseconds). If you push the brake pedal after the illumination of the last lamp, I may say "late .40."
5. Your goal is that the illumination of last light and your pushing the response pedal occur at the same time. You want your best score to be “perfect.” or "on time" just as the last light illuminates. I may say “perfect” when this happens. Do you understand? Any questions?

INSTRUCTIONS FOR PARTICIPANTS

(0% KR)

1. Please take a seat in the chair and adjust the chair so that you are close enough to the pedals and feel comfortable pushing the left response pedal with your right foot. Please try to push the left pedal several times now. You will begin by resting your right foot on the right pedal when you are ready to respond you will take your foot off

the right pedal and press the left pedal down like a breaking action in a car. Be sure to press the pedal all the way down.

2. Now I am going to describe to you how to respond. At the beginning of each trial, I will say "Ready." "Ready" is your signal to watch the yellow warning light, put your hands on the steering wheel and rest your right foot on the response pedal. Please respond by saying “yes” or “no” after I say "Ready."
3. After you respond, the yellow light will illuminate for a short period of time. Immediately after, the red light will move down the trackway. You will need to watch the lights so that you can move your foot to the left pedal and push the left pedal all the way down to coincide with the illumination of the last lamp. You should try to be as accurate as possible to match your response to the illumination of the last lamp.
4. Your goal is that the illumination of last light and your pushing the response pedal occur at the same time. You want your best score to be “perfect.” or "on time" just as the last light illuminates. Do you understand? Any questions?