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Title: The Relative Effectiveness of Three Forms of Visual Knowledge of Results on Maximal Strength Output in an Isokinetic Extension / Flexion of the Knee.

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This experiment was conducted to study the effects of three different forms of visual knowledge of results (KR) on maximal strength output in isokinetic exercise. The task used was an isokinetic extension of the knee, followed by a corresponding flexion. Four, six-subject experimental groups completed four testing sessions conducted over a five-day period. Group one represented a no-KR control condition. Group two was provided with visual KR in the form of a continuous torque-output display during treatment sessions. Groups three and four were provided with concurrent and summary torque-time graphs as visual KR, respectively. A pre-test was completed during the first experimental session. Two consecutive testing sessions followed the pre-testing session. After a one-day retention interval, a post-test and a retention test comprised the final session.

The dependent measure of maximum peak torque (MPT) was collected at each of two exercise speeds. Pre- and post-test MPT scores were analyzed using a 2 X 4 (pre-/post- X group) analysis of variance (ANOVA) for each exercise speed and movement direction. Day-to-day effects were evaluated using 3 X 4 (day 1 / day 2 / retention day X group) ANOVAs. Group means for factors yielding significant F-scores were compared using Tukey's WSD post-hoc comparisons procedure.

The experimental findings indicated that post-test scores increased for all groups, in both movement directions, when compared to pre-test scores. Results also revealed that although the no-KR control group exerted significantly higher mean MPT output during treatment and retention sessions, visual KR presented concurrent with performance led to significant increases in mean MPT output when compared to visual KR presented according to a summary schedule.

Four major conclusions resulted from the experimental findings. First, maximal strength output may be achieved in the absence of visual KR. Second, more precise information (such as provided by a concurrent torque-time graph) becomes more effective at low exercise speeds when sufficient time for information processing is available subsequent to the presentation of visual KR. Third, visual KR presented concurrent with performance is a more effective performance and learning variable in isokinetic exercise when compared to visual KR presented according to a summary schedule. Last, visual KR may provide a reference of performance which serves as a limiting criterion in a maximal-effort task.

# The Relative Effectiveness of Three Forms of Visual Knowledge of Results On Maximal Strength Output in an Isokinetic Extension / Flexion of the Knee

by

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# Chapter One

## Introduction

In 1938, Elwell and Grindley identified knowledge of results (KR) as one of the important variables in the learning of a motor skill. Their ideas on the values of KR have since been elaborated by Bilodeau and Bilodeau (1961), who declared that KR was not only important to learning but was "the strongest and most powerful variable controlling performance and learning" (p. 250). Knowledge of results (KR) has recently been defined as information provided from an external source, after a performance, that "tells of the learner's success in meeting the environmental goal" (Salmoni, Schmidt, and Walter, 1984, p. 355). In 1972, Gentile proposed that it was knowledge of performance (KP), rather than KR that was vital to learning. Most researchers have since accepted general definitions of KR that encompass both external information related to execution and outcome of the skill. Knowledge of results, as used in this investigation, will extend the definition of Salmoni et al. (1984) to also include information provided during the execution of the performance. The effects of KR in motor skill performance and learning have been widely investigated in laboratory environments, using a variety of novel and simple motor tasks. These studies have, in turn, yielded many findings relative to the value and utilization of KR in practical settings. One of the practical settings in which these findings are currently being applied is rehabilitation.

Previously, KR given to patients in rehabilitation programs consisted of verbal encouragement by the therapist. The primary intent of this KR , or feedback, as it has often been called, was to maintain and/or elevate the motivation of the performer, while also reinforcing good performances during rehabilitation sessions. These two functions of KR are among three defined by Annett (1969). The third, and perhaps most important, learning-related function KR is believed to serve is to provide error-correction information. This is the function which has generally been overlooked in traditional physical therapy practice (Coplin, 1971; Hald & Bottjen, 1987). This may be a critical oversight, given Annett's hypothesis that the motivational effects of KR may be due to its informational content. The error-correction function of KR would thus appear to be the most important of the three.

Using KR as error-correction information is a practice that is bound by considerations of its own. A recent review of the KR literature by Salmoni, Schmidt, and Walter (1984) presents several factors which must be considered prior to the use of KR as a means of correcting errors in performance. These include the form in which KR is given, the frequency with which it is provided, the precision of the information given, and the processing time provided the subject following presentation of KR. The method of presentation of KR considered to be the most effective in facilitating learning is in a form that is meaningful to the subject. KR effectiveness increases when given frequently in the early stages of learning and less frequently later, at a level of precision compatible with the level of the learner. With sufficient time between presentation of KR and the next trial, the subject can optimally use the information to improve performance and enhance learning. Salmoni et al. (1984) stress the possibility that KR given too frequently becomes a 'crutch' for the performer and hinders learning, although benefitting performance.

Lavery (1962, 1964b) investigated the effects of presenting KR in summary form, presented after a block of trials. The information provided was not specific to any one trial performance but, rather provided the learner with a more general evaluation of his/her performance. In his experiment, subjects were provided with verbal KR after each 20-trial block (one testing session). He found that although initial performance was depressed, the summary KR group performed significantly better in retention conditions when compared to groups receiving KR which was more frequently presented and specific to the performance on the trial which it followed. These results seem to indicate that one could manipulate the KR presentation conditions to considerably change the effect of KR on performance and learning.

Current trends in physical therapy have created a situation in which therapists are treating more patients in less time and are no longer available to personally direct each patient through the rehabilitation program. Coincidentally with this change in practice, many manufacturers have incorporated visual displays with rehabilitation equipment. For example, visual displays in the form of graphs of peak torque output are now provided as a part of the Biodex, Cybex II and 360, and Orthotron systems. These displays provide the means for subjects to monitor their own performance throughout each exercise bout.

In addition to offsetting demands for the therapist's attention, a series of experiments by Newell and colleagues (Newell & Carlton, 1987; Newell, Sparrow, & Quinn, 1985; Newell & Walter, 1981) suggests that graphical displays have the potential to serve a much more important purpose in rehabilitation programs. This series of experiments compared the performance effects of terminally presented force-time graphs to those of terminally presented discrete KR, such as reports of distance-from-criterion. The experimental findings indicated that concurrently-presented graphical displays of the task's kinematic parameters (e.g., velocity, displacement, acceleration) resulted in significantly better subject performance when compared to the more traditional types of discrete KR provided (e.g. error scores). Newell, Quinn, Sparrow, and Walter (1983) also found that presentation of kinematic parameters in the form of a terminally-presented force-time graph proved more effective as a performance tool than the terminal presentation of a single, numeric force value. These conclusions provide support for Salmoni et al.'s proposition that more precise KR provides more effective error-correction information.

Figoni and Morris (1984) conducted an investigation into the effects of graphical KR on strength output in isokinetics. In this study, the authors evaluated the effects of graphical KR on the Maximum Peak Torque (MPT) output of subjects performing a flexion/extension of the knee. The results showed a significant increase in the MPT output in a low-speed exercise condition, but no significant increase in strength output in a high-speed condition. The finding of no significance in the high-speed condition was attributed to the degraded quality of the graph presented. They also suggested that the subjects in the high-speed condition may not have had sufficient time to process the information contained in the graph during the high-frequency repetitions. Finding a significant increase in the low-speed condition, however, lends support to the idea that KR presented in a graphical form can serve a significant role in the therapeutic setting.

A more recent study investigating the use of graphical KR in a therapeutic setting was conducted by Hald and Bottjen (1987). The authors sought not only to reaffirm the value of KR in eliciting a maximal strength output, as indicated by increases in MPT, but to evaluate whether the information provided could be used to establish a reproducible, correct reference of a criterion submaximal performance in memory. Unlike the earlier results of Figoni & Morris (1984), the results of the more recent study showed a significant increase in MPT output for both the high and low-speed conditions, however there was no evidence of formation of a reference mechanism.

While these two studies reflect an effort by therapists to better understand the role of KR in the clinical setting, several questions remain to be answered. Neither of these studies draw extensively from the KR research that has been conducted, and both do not address the influences of other critical KR variables such as precision, frequency of presentation, and time for information processing. Knowledge of results which provides error-related information may help the subject create a correct model of performance that can be called upon during self-guided rehabilitation efforts outside of the clinic.

## Statement of the Problem

The purpose of the present study was to investigate the relative effectiveness of three forms of visual KR: (a) continuous torque output display, (b) concurrent torque-time graph and, (c) summary torque-time graph, on maximal strength output in an isokinetic flexion/extension of the knee. The effectiveness of each form of information was explored relative to its influence on performance of the criterion task, and on retention of the qualities of the task. The relative effectiveness of the visual displays as a function of the speed at which the task was performed was also investigated.

## Hypotheses

1. Subjects provided with a continuous torque-output display, a concurrent torque-time graph, or a summary torque-time graph during treatment sessions will achieve higher maximal peak torque output in treatment sessions, a retention session, and a maximal-effort post-test at both low and high exercise speeds when compared to subjects who were provided with no KR during treatment sessions.

2. Subjects provided with torque-time graphs, either concurrent with, or subsequent to performance, will achieve higher maximal peak torque output in a maximal-effort post-test at both low and high speeds when compared to subjects provided with a continuous torque-output display.

3. Subjects provided with a continuous torque-output display or a concurrent torque-time graph during performance of the criterion task will achieve higher maximal peak torque output during treatment sessions at low exercise speed when compared to subjects provided with a summary torque-time graph.

4. Subjects provided with a concurrent torque-time graph will achieve higher maximal peak torque output in both movement directions during treatment sessions at high exercise speed when compared to subjects provided with a continuous torque-output display or a summary torque-time graph.

5. Subjects provided with either a concurrent torque-time graph or a summary torque-time graph during treatment sessions will achieve higher maximal peak torque output in retention tests at both low and high exercise speeds when compared to subjects provided with a continuous torque-output display.

6. Subjects provided with a summary torque-time graph during treatment sessions will achieve higher maximal peak torque output in a retention test at high exercise speed when compared to subjects provided with a continuous torque-output display or a concurrent torque-time graph during treatment sessions.

## Statistical Hypotheses

$\mu_1$ = Mean MPT Group 1; no-KR control group

$\mu_2$ = Mean MPT Group 2; continuous torque output display

$\mu_3$ = Mean MPT Group 3; concurrent torque-time graph

$\mu_4$ = Mean MPT Group 4; summary torque time graph

1. $H_{o1} : \mu_1 = \mu_2$ $\quad H_{a1} : \mu_1 < \mu_2$

   $H_{o2} : \mu_1 = \mu_3$ $\quad H_{a2} : \mu_1 < \mu_3$

   $H_{o3} : \mu_1 = \mu_4$ $\quad H_{a3} : \mu_1 < \mu_4$

2. $H_{o1}: \mu_3 = \mu_2$ $H_{a1}: \mu_3 > \mu_2$

   $H_{o2}: \mu_4 = \mu_2$ $H_{a2}: \mu_4 > \mu_2$

3. $H_{o1}: \mu_2 = \mu_4$ $H_{a1}: \mu_2 > \mu_4$

   $H_{o2}: \mu_3 = \mu_4$ $H_{a2}: \mu_3 > \mu_4$

4. $H_{o1}: \mu_3 = \mu_2$ $H_{a1}: \mu_3 > \mu_2$

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5. $H_{o1}: \mu_4 = \mu_2$ $H_{a1}: \mu_4 > \mu_2$

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6. $H_{o1}: \mu_3 = \mu_2$ $H_{a1}: \mu_3 > \mu_2$

   $H_{o2}: \mu_4 = \mu_2$ $H_{a2}: \mu_4 > \mu_2$

## Delimitations

This experiment was delimited to four groups of six, uninjured male subjects. The subjects ranged in age from 19 to 28 years, and were volunteers from Oregon State University. The task to be performed was a maximal isokinetic flexion/extension of the knee, in either one of three KR conditions, or one no-KR control condition. Each subject was required to perform the criterion task at two exercise speeds: (a) low speed at 120 degrees/second, (b) high speed at 240 degrees/second. Each subject was randomly assigned to perform high-speed trials with one leg and low-speed trials with the other. The subjects were also randomly assigned to one of the four treatment conditions. A four-stage protocol involved each group performing a two-trial, maximum-effort pre-test with each leg on day one, 30 high-speed trials with one leg and 15 pre-test with each leg on day one, 30 high-speed trials with one leg and 15 low-speed trials with the other leg on days two and three, one day of rest on day four, and a two-trial, maximum-effort post-test followed by a no-KR retention block of trials on day five.

## Limitations

1. The types of visual KR displays available were determined by the type of equipment used, and may not be generalizable to other rehabilitation apparatus.

2. The subjects had no leg injuries, limiting generalizations to non-injured populations.

## Assumptions

1. All subjects performed the task to the best of their capabiltites.

2. Maximum peak torque output is higher for low-speed than for high-speed repetitions.

3. Maximum peak torque is a reliable indicator of maximum strength output.

## Terminology

bout - all exercise sets performed in a series at one speed.

continuous skill - a skill with arbitrary beginning and ending points.

discrete skill - a skill marked by distinct beginning and ending points.

isokinetics - exercise performed with constant velocity of movement and variable torque production.

kinematic - relating to the aspects of movement apart from mass and force; e.g., velocity, displacement, acceleration.

kinetic - relating to the energy and forces associated with motion; e.g., impulse, force, torque.

knowledge of performance (KP) - information provided from an external source, relative to the execution of the skill. (Gentile, 1972)

knowledge of results (KR) - information (concerning outcome or execution) provided from an external source, during and/or after a performance, relating the subject's success in meeting the environmental goal.

learning - a relatively permanent change in behavior, inferred from performance after a retention period.

maximum peak torque - the maximum rotational force exerted in a set, used as a measure of strength output.

performance - temporary observable behavior subject to transient variables such as motivation and fatigue.

qualitative - imprecise information refering to the qualities of a skill without giving numerical quantification.

repetition - one cycle of knee extension (to 0 degrees) and flexion ending when leg returns to starting position (90 degrees of flexion).

retention session - an experimental session during which two full exercise bouts are performed without visual KR.

set - a block of repetitions separated from others by a rest period; a subunit of a bout.

treatment session - an experimental session during which performance is supplemented with the appropriate form of visual KR.

# Chapter Two

## Review of Literature

Knowledge of results (KR) is undisputedly an important variable in the performance and learning of many motor skills (e.g., Annett, 1969; Bilodeau & Bilodeau, 1961; Elwell & Grindley, 1938). In a 1984 KR review paper, Salmoni, Schmidt and Walter discuss many of the factors which influence the effectiveness of KR in improving motor performance. One factor that must be considered prior to presenting KR is the form to be used. The forms of KR most often investigated include visual, verbal, and auditory (e.g., Doody, Bird & Ross, 1985; Newell & Walter, 1981). Once the form has been determined, one must select an appropriate level of KR precision for the level of the learner(s). Studies investigating the differences between various levels of precision have compared qualitative and quantitative KR, or levels of each (e.g., Magill & Wood, 1983; Newell & Carlton, 1980). After the form of KR and the level of precision have been identified, one must determine the most effective schedule of KR presentation. The schedules most often referred to are absolute frequency (KR presented after every trial), relative frequency (KR after every few trials), or summary KR (KR for a block of trials, presented after completion of the entire block) (Lavery, 1962; Schmidt, Young, Swinnen & Shapiro, 1989). Although the research exploring the influence of each of these factors has provided valuable information to motor learning theorists, relatively little research has been done to investigate the effects of manipulating these same variables when presenting KR in applied settings. This review of literature will be divided into the following sections: Introduction to Theoretical Research in Knowledge of Results, Knowledge of Results Research in Rehabilitative Settings, Isokinetic Exercise in Rehabilitation.

## Introduction to Theoretical Research in Knowledge of Results

Salmoni, Schmidt and Walter (1984) defined KR as information from an external source, provided after a performance, that "tells of the learner's success in meeting the environmental goal" (p. 355). Others ( e.g., Gentile, 1972) have used the term knowledge of performance (KP) to refer to information provided to a learner, during or after a performance, that relates to specific aspects of the movement that led to the outcome. Neither term has been exclusively adopted in the literature, and they are often used interchangeably although there are differences between the definitions. Magill (1989) suggests that, since the differences between the terms are a source of confusion, the term KR represents a consolidation of both types of information. While this investigator is in agreement with the need for such a consolidation, the definiition forwarded by Salmoni et al. will be extended to include information also provided concurrent with performance.

Early work investigating the effects of KR presentation on performance was conducted by Thorndike (1914, 1927) and continued by many behavioral psychologists (e.g., Arps, 1917; Elwell & Grindley, 1938; Johanson, 1922). One critical difference between early KR experiments and those conducted more recently is that the early studies considered only the temporary effects of KR on performance. The conclusions forwarded were based on observations in a single testing session. As such, no inferences could be made concerning the learning effects of KR. In order to make such inferences contemporary researchers have included retention periods of various lengths, as well as retention testing sessions which are conducted in the absence of KR. Only when the KR effects observed during performance are still evident in the retention phase can learning be inferred.

The value of KR was established through these early studies, and reiterated in review papers by Bilodeau and Bilodeau (1959, 1961). The work of Bilodeau and Bilodeau and their colleagues repeatedly showed that the initial performance and learning of motor skills improved significantly when KR was provided to the subjects. The repeated occurrence of such significant results led Bilodeau and Bilodeau (1961) to conclude that KR was "the strongest and most powerful variable controlling both performance and learning" (p. 250).

A later focus of KR research was to identify the characteristics of KR that impact its effectiveness. Annett (1969) was one of the first to propose specific functions for KR. He wrote that KR served the following functions: motivation, reinforcement, and/or error correction information. Arps (1920) and Elwell and Grindley (1938) were among those providing supporting evidence that KR served to motivate subjects by showing that enthusiasm, willingness to cooperate, and positive regard towards participation increased when verbal KR was provided. Annett (1969) however, proposed that the motivational and reinforcing effects were a product of the error-correction function, thereby delimiting the latter KR function as the most important of the three. Reinspection of early KR research, and consideration of more recently completed work provided support for Annett's (1969) contention that giving non-specific verbal encouragement, such as "...good job," was not sufficient to effect improvements in performance and learning when compared to KR which was more precise in nature and provided specific error-correction information (e.g., Newell, 1977).

Salmoni, Schmidt and Walter (1984) further identified variables affecting KR presentation, such as the form of KR, frequency of presentation, temporal locus of KR presentation, and the processing time allowed following its presentation. Each of these variables has been subsequently shown to influence the effectiveness of KR in both the performance and learning of motor skills.

While KR may be provided in many forms, it is most often presented as visual, verbal, or auditory information. Visual KR can be provided through modeling and demonstrations, videotape, or, less frequently, through graphical representations of kinetic (i.e. impulse, peak force, mass) and kinematic (i.e. displacement, velocity, acceleration) characteristics of performance. The benefits of visual KR are determined by the number of elements of a skill that can be portrayed in a single demonstration, and the instructor's ability to use visual media to prompt imitation. In most skill-teaching situations, visual KR is supplemented by verbal KR, which may be qualitative in nature and/or address quantitative aspects of the performance. Qualitative KR may be an instructor saying "...nice shot," or "...you missed," whereas quantitative KR includes numeric information such as "...your shot was six inches to the left of the target." Although verbal KR is frequently used, the difficulty in giving precise verbal KR, and the potential for misunderstanding are concerns when using it in this form. The third and least used form of KR is auditory, although recent experiments have shown that auditory KR can effect improvements in the performance and learning of timing-related movement patterns (e.g., Doody, Bird & Ross, 1985).

Graphical visual KR can take a simple form, such as a plot of performance error, or it can be presented in more complex forms, such as graphs of the kinetic and kinematic parameters of a movement. A series of studies conducted by Newell and his colleagues (Newell & Carlton, 1987; Newell, Quinn, Sparrow & Walter, 1983; Newell, Sparrow & Quinn, 1983; Newell & Walter, 1981) explored the effects of graphical KR on the initial performance and learning of simple motor tasks, such as isometric finger pressing and barrier-blocking tasks. In each of these studies the investigators provided subjects with graphs of certain kinetic and kinematic parameters of the movement being performed. The results provided evidence that presentation of graphs containing information relative to the kinetic and kinematic parameters after each performance can be helpful in improving both initial performance and eventual learning of a task. It was suggested by Newell and Walter (1981) that some of the important characteristics of a movement, such as acceleration and velocity, could not be conveyed to a learner through any other type of KR, nor could these characteristics be provided soon enough after the actual performance using more traditional and less precise forms of KR such as videotape. The results of further studies indicated that subjects provided with a visual force-time record after each trial produced a significantly more accurate criterion peak force output in both isometric (Newell, Sparrow & Quinn, 1985) and isotonic (Newell, Quinn, Sparrow & Walter, 1983) contractions of the arm when compared to subjects receiving verbal reports of force output. These significant differences were evident in both the performance and retention phases of the experiments. A later study by Newell and Carlton (1987) also investigated the role of graphical displays as KR, providing subjects with not only a record of their own performances, but showing each trial relative to a template of the criterion performance. The results of this study showed non-significant decreases in absolute error across performance and retention trials for the group receiving the template in addition to the force-time record when compared to the group receiving only the force-time record. The authors accounted for the lack of statistical significance by stating that once the task constraints are familiar to the performer the criterion information is no longer important to successful performance. However, provision of the subject's own force-time record remained important to maintaining accurate task performance.

Another variable that has been investigated is that relating to KR precision. The effects of varying degrees of KR precision have been explored using the verbal medium as the primary form of KR. The level of KR precision is related to the amount of information contained in the KR. For example, qualitative information is usually relatively low in precision, whereas quantitative information is often more precise. Hunt (1961), Magill and Wood (1983), and Newell and Carlton (1980) are among those who have shown the number of performance errors to decrease significantly as a function of increasing the precision of verbal KR presented. These studies showed the effectiveness with which precise KR can lead to decreased error across trials using discrete skills. Hunt (1961) also showed the beneficial effects of KR presentation using a continuous skill (tracking task). In Hunt's (1961) study, the primary factor determining tracking accuracy was the precision of the information provided to the performer. The optimal level of KR precision is ultimately dependent on the level of the learner, with novices requiring less precise information to improve performance and elite performers requiring more detailed information to effect improvements in performance (Magill, 1985).

A theoretical hypothesis to account for the various KR effects on performance and learning has been forwarded by Salmoni et al. (1984). The major assumption of the guidance hypothesis is that KR provides a subject with information about how to correct movement-related errors. Given this strong problem-solving function, the presence of KR during skill acquisition leads to more efficient motor performance. However, Salmoni et al. (1984) extend the guidance role of KR beyond initial performance of the skill. The role of KR in later stages of learning changes, they suggest, to one in which a performer becomes dependent on the presence of KR to guide performance (the 'crutch' effect). Such a dependence on KR is presumed to prevent the performer from processing other relevant movement-related information, such as response-produced feedback or task-relevant environmental information. Subsequent performances in the absence of KR will then be marked by the performer's inability to use intrinsic error detection/correction strategies and consequent decreases in performance. Salmoni et al. (1984) suggest that optimal learning of a skill will only be achieved if a subject is afforded the opportunity to independently select and process information relevant to performance of the skill, and subsequently attempt to solve the movement problem independently of externally provided information. The authors recognize that this independence cannot be achieved during the initial acquisition of the skill, but are careful to point out the importance of allowing such independent exploration as early in the learning process as possible.

Adams (1971) characterized the learning of a motor skill as a problem-solving situation, with one of the requirements for finding the solution to a problem being familiarity with what is essential for the success of that solution. Within this framework he outlined the role of KR in learning a motor skill. Each learner must have some representation of the process and the goals of a skill in order to be able to perform that skill. Subsequent to executing the skill, the learner must decide whether or not the movement that was executed sufficiently satisfied the goal(s) of the skill. However, a novice performer is often not familiar enough with the skill to determine the quality or success of the completed performance. To accurately identify the errors made, the learner needs KR. Based on the task-relevant information presented, the learner can compare his/her internal representation of correct performance to actual performance and thereby modify the next attempt. The goal, according to Adams, is to know exactly what is needed for optimal performance of the skill. Once such a representation of correct performance has been formed, the learner can independently identify the discrepancies between actual and optimal performance and no longer depend on KR for successful skill performance. Although the development of an internal model of correct performance increases one's ability to use more internally based sources of feedback, a great deal of practice supplemented with KR in the most appropriate forms is necessary to develop such a model.

One important factor in optimizing the effectiveness of KR is the schedule by which KR is presented. Knowledge of results can be provided at either an absolute or relative frequency, or on a summary schedule. Absolute frequency KR is that which is provided for each trial until the prescribed amount of KR has been given. This frequency of KR presentation is very helpful in guiding a learner through the initial performances of a skill. However, Salmoni et al. (1984) warn against using absolute frequency KR beyond the initial performances because of the learner's tendency to rely exclusively on the externally-presented KR, i.e. the 'crutch' effect. Conversely, relative frequency KR involves presenting KR after some interval of trials has been performed. An example of relative frequency KR is providing information to a learner for every third performance, allowing him/her to execute two trials without KR before each presentation of KR. The advantage of relative KR is that some number of trials must be performed without KR being provided for them, thereby forcing the learner to independently problem-solve. Unfortunately, most of the empirical work investigating relative effectiveness of the two frequencies of KR presentation did not include a retention test. Investigations conducted by Ho and Shea (1978) and Lee and Magill (1987) provide further support for the idea that relative frequency KR is a more effective KR schedule when compared to absolute frequency KR because it discourages over-reliance on externally-presented KR and encourages the subject to solve the movement problem using internal sources of feedback as well as other task-relevant information. Additional work has been done to explore the crutch effect by providing subjects with summary KR. Summary KR is presented after a number of trials have been completed, and is intended to provide the learner with an overview of their collective performance. The summary schedule presents KR for every trial performed, as opposed to relative frequency, which only presents KR for the last trial of the prescribed interval. The first studies of summary KR were performed by Lavery (1962, 1964). While summary KR did not produce significant improvements in performance during the acquisition phase, it resulted in superior performance during the no-KR retention phase. Lavery's interpretation of these results was that learning of appropriate error detection and correction strategies was facilitated by allowing the subjects to problem-solve before giving KR. This conclusion was recently supported in a study conducted by Schmidt, Young, Swinnen and Shapiro (1989). Subject groups that received summary KR after five, ten or fifteen trials in the acquisition phase showed improved performance in a no-KR retention test when compared to a group that received absolute frequency KR during acquisition. Schmidt et al. (1989) were not, however, able to identify an optimal number of trials after which to provide summary KR.

Recent studies completed by Lee and Magill (1987) and Magill and Wood (1986) have addressed yet another variable which may influence the effectiveness of KR, that being the temporal locus of KR presentation. Prior to discussion of this work one must be familiar with the time intervals separating a trial, presentation of KR for that trial, and the execution of the next attempt. The first time period identified is the KR delay interval and is the time elapsed from the completion of one performance to presentation of KR specific to that performance. The next interval, that of post-KR delay, refers to the time between presentation of KR and execution of the next performance. Finally, the intertrial interval is the time elapsed from the beginning of one response to the beginning of the next and therefore encompasses both the KR delay and post-KR delay intervals. Research investigating the effect of varying each of the KR time intervals has attempted to identify those intervals which appear to be most critical to the effectiveness of KR. For example, Bourne and Bunderson (1963) and Timmons and Wiegand (1982), conducted studies to determine the effect of manipulating the KR delay interval. The major finding of both experiments was that increasing the length of the KR delay interval (within reasonable limits) had no significant effect on performance or learning. The duration of the intertrial interval was also found to have little influence on performance or learning in these experiments, when covaried with KR delay. Covarying intertrial interval with post-KR delay was shown to effect significant changes in the effectiveness of KR. However, the significance of these results was attributed to the extended post-KR delay, not the lengthened intertrial interval. The remaining conclusion forwarded was that the critical period of time was the post-KR delay. This has been the finding of Magill and colleagues (1983, 1985), Swinnen, Schmidt, and Shapiro (1984) and Timmons and Wiegand (1982). Each group of authors forward the same explanation for the increase in performance accuracy and learning as a function of increasing the length of the post-KR delay interval. The stated reason for the improvement is the increased time allowed for information processing and, more importantly, the increased time for independent problem-solving.

Optimal use of KR requires one to integrate the findings of the many studies that have been reviewed. The critical factors affecting the use of KR appear to be the form, level of precision, and schedule of KR presentation (Salmoni et al., 1984). The most appropriate form and level of precision of KR may change as the level of the learner improves (Magill & Wood, 1983) and should therefore be reassessed throughout the learning process. The schedule of KR presentation also influences the effectiveness of the information, and evidence exists supporting the use of relative frequency KR (e.g., Ho & Shea, 1978; Lee & Magill, 1987) or KR on a summary schedule (e.g., Schmidt, Young, Swinnen & Shapiro, 1989). The explanation proposed to account for the effectiveness of these two schedules of presentation over absolute frequency KR is related to the time allowed subsequent to KR presentation for the subject to problem solve and process other task-relevant information (e.g., Salmoni et al., 1984). Ultimately, the guidance of the KR in conjunction with the other information gained by the subject, helps the subject form an internal reference of performance that can be utilized to evaluate and modify his/her own performance(s) (Adams, 1971).

## Knowledge of Results Research In Rehabilitative Settings

One of the most prominent criticisms of KR research is that it is based in laboratory settings and performed with simple tasks that are not easily generalizable (Lee, 1980). However, there are applied settings within which hypotheses of KR presentation can be explored. One such setting is a rehabilitation facility. Modern day rehabilitation equipment, such as the Cybex II & 360, and the Biodex 2000 isokinetic machines, often incorporates an auditory indicator of whether a performance criterion has been met, or video and/or graphical displays that provide performance-related information to a practitioner or directly to the subject. Currently, these sources of information are being regarded only as sources of motivation and reinforcement. However, such displays seem to have the potential to provide the performer with error-correction information to aid in the development of an internal model of a criterion performance, which would subsequently facilitate reproduction of that criterion when rehabilitation continues outside of the clinical setting. In addition to the KR-providing apparatus, the rehabilitative environment is a relatively controlled applied setting, increasing its conduciveness to KR research.

Investigators that have conducted KR research in the rehabilitative setting have obtained significant results. Figoni and Morris (1984) conducted an experiment designed to investigate the effectiveness of KR in a rehabilitative setting. Specifically, the study explored the influence of concurrent graphical KR on strength output in an isokinetic flexion/extension of the knee. The graphical information presented was a scrolling plot of torque output over time, produced by a chart recorder as the subjects performed the movement. Two exercise speeds were tested; the slow speed used was 60 degrees/second and the high speed was 120 degrees/second. The authors found that strength output significantly increased as a function of the graphical KR at the low exercise speed, but significant effects were not found at the high exercise speed. The non-significant results of the high-speed exercise were attributed to the lack of precision and clarity of the graph and decreased processing time afforded the subjects in this high-speed condition. The significant effects of visual KR presented during low-speed exercise were encouraging, however, and suggested that graphical KR may provide relevant error-correction information .

A second KR study conducted in a rehabilitative setting investigated not only the role of KR in performance, but also in learning a criterion sub-maximal performance. Hald & Bottjen (1987) repeated the study by Figoni and Morris (1984) and included a submaximal performance criterion at both exercise speeds. The purpose of this inclusion was to determine whether subjects provided with graphical KR during a performance session could extract enough information to develop an internal reference of a submaximal performance, and subsequently use that reference as a guide to reproduce the criterion. Hald and Bottjen (1987) also changed the display by projecting the chart recording onto a video screen. This modification was intended to remedy the lack of clarity of the graph which Figoni and Morris (1984) identified as a problem in their high-speed condition. The results showed that strength output significantly increased as a function of graphical KR at both exercise speeds, but provided no evidence for the formation of a reference of performance for the submaximal task. The authors suggested that to form a reference of a criterion performance, instruction would have to supplement KR presentation to facilitate extraction of the necessary information.

Both of these studies indicate a trend toward the incorporation of visual KR in applied settings, and show that visual KR can have significant effects on performance and learning outside of the laboratory. The significant findings also suggest that the value of graphical, visual KR as error correction information may still be largely untapped.

## Isokinetic Exercise in Rehabilitation

Isokinetic exercise has become the primary modality of rehabilitation, particularly during its later stages, since Moffroid and Whipple (1969) profiled its effectiveness. The major advantage of isokinetic exercise is that it reduces the risk of injury. Isokinetic means 'constant speed' that is achieved through variable resistance. Therefore, if a subject reduces force against the lever of an isokinetic dynamometer, the resistance of the dynamometer decreases compensatorily to maintain the set speed of movement.

One of the important considerations in isokinetic programs is the speed at which exercise is to be performed. Moffroid and Whipple (1970) were the first to explore the specificity of speed in isokinetic exercise. They found that the rate at which the exercise was performed was a more critical variable than the amount of work that was done. The authors concluded that high power (high speed, low load) exercise increases muscular strength at all speeds of contraction while low power (low speed, high load) exercise produces increases in strength only at low speeds. These findings were supported by Lesmes, Costill, Coyle, and Fink (1979). Later, Sherman, Plyley, Vogelgesang, Costill, and Habansky (1981) conducted a more specific investigation into the rehabilitative value of isokinetic speeds from 60 deg/s to 300 deg/s (at each 60 degree increment). These authors found that the principle of specificity of speed held, and improvements were limited to performance at each individual isokinetic speed. Sherman et al. (1981) investigated the recruitment patterns for each speed also, and determined that although each speed produced specific results, both speeds were valuable in the rehabilitation process. This suggests that a full program should include isokinetic exercise to restore contractile integrity through the full range of movement speeds.

In specifying exercise speeds one must also consider the forces resulting from the exercise. Early isokinetic rehabilitation was performed at very low speeds (60 degree/second and less) and has since been shown to have produced destructive forces at the joints (Pearson, Sherman, Plyley, Costil, Habansky & Vogelgesang, 1982). Relative to the knee, speeds of less than 90 degrees/second have been identified as producing extreme compressive forces (Nisell & Ekholm, 1985). For this reason, the trend in isokinetic rehabilitation has been toward higher speed exercise, with low-power training being left for post-rehabilitative programs.

Another concern raised with intensive isokinetic rehabilitation is the effect of fatigue on performance and long-term rehabilitative effects. Criticism has been levied that the fatigue induced by rigorous isokinetic exercise reduces its effectiveness (Rube & Secher, 1981). This issue was addressed by Barnes (1981), who determined that although there was a significant decrease in torque output over a series of isokinetic knee extensions, fatigue was equal at all isokinetic speeds and did not reduce performance levels on subsequent days of rehabilitation. This conclusion is consistent with earlier conclusions that fatigue exerts temporary effects on performance but does not exert a permanent influence on the learning of a skill.

## Summary

Early work by Elwell and Grindley (1938) and Bilodeau and Bilodeau (1961) helped to establish the value of knowledge of results as a performance variable. Later studies extended the previous findings to include learning effects, and it became widely accepted that KR was a necessary element in skill acquisition and performance improvements. The performance and learning functions of KR were outlined by Annett (1969), who suggested that KR served three functions: motivation, reinforcement, and/or error correction information. The third function was determined by Annett (1969) to be the most important, and he was later supported by many authors, including Salmoni et al. (1984).

Recently, manipulations of different forms, levels of precision, and schedules of KR presentation have dominated this research area. Some authors (e.g., Doody, Bird & Ross, 1985; Newell & Walter, 1981) have provided evidence that different forms of KR are effective in different situations. Other studies have suggested that as skill level improves higher levels of KR precision are necessary to provide the learner with enough information to improve performance (Hunt, 1961; Magill & Wood, 1983). Different schedules of KR presentation have also been shown to influence the effectiveness of KR by increasing the amount of time allowed for information processing and problem solving and, therefore, improving the efficiency of initial performances and rate of learning (Bourne & Bunderson, 1963; Magill & Wood, 1986; Schmidt, Young, Swinnen & Shapiro, 1989; Timmons & Wiegand, 1982).

The guidance hypothesis was forwarded by Salmoni et el. (1984) to account for the effects of KR presentation in motor skill performance and learning. During skill acquisition, Salmoni et al. suggest that KR serves as error-correction information to help the learner identify and correct movement-related errors. In the later stages of learning, however, the role of KR changes. At this stage, the authors propose that the learner becomes dependent upon the externally-provided information, preventing processing of other response-produced internal or task-relevant environmental information, i.e. the crutch effect. Based on this hypothesis, the authors suggest that KR be provided frequently during the initial performances, but then less frequently, on a relative frequency or summary schedule, to allow the learner to develop a reference of performance that incorporates their internal, response-produced feedback and other task-relevant environmental information.

In an effort to test the principles of KR presentation in applied settings, some investigators have conducted research in rehabilitative settings. Figoni and Morris (1984) and Hald and Bottjen (1987) each performed studies related to the form of KR presentation in isokinetic rehabilitation. Both studies found that graphical KR can lead to increases in strength output in isokinetic exercise. Figoni and Morris (1984) found increases only at slow exercise speeds, while

Hald and Bottjen (1987) found significant increases at both a high and low exercise speed. Differences in the findings of these two studies can be attributed to differences in the quality of the graph presented as KR.

Finally, variables in isokinetic exercise protocols were considered. Moffroid and Whipple (1969) established isokinetics as a valuable rehabilitative tool, and in 1970, established protocols based on the specificity of speed principle. Specificity of speed was also later shown by Lesmes, Costill, Coyle, and Fink (1979) and Sherman, Plyley, Vogelgesang, Costill, and Habansky (1981). Rehabilitation protocols have since been influenced by studies of joint forces at various exercise speeds, resulting in a trend toward safer, higher-speed exercise. Although fatigue was intially thought to be a factor in the effectiveness of isokinetics, Barnes (1981) provided evidence suggesting that fatigue is only a temporary influence.

By combining the principles of isokinetic exercise with the factors governing the effectiveness of KR presentation, one is provided with a multitude of conditions in which to explore the role of KR within a rehabilitative setting. Research exploring the manipulation of KR presentation variables suggests that there may be different optimal KR conditions for different exercise speeds and criterion force output levels. By moving laboratory protocols to an applied setting such as rehabilitation, where many forms of KR are readily available, one may be able to determine the most effective form, precision, and schedule of KR presentation, and thereby optimize performance and learning of movement patterns through maximization of KR.

# Chapter Three

# Methods and Procedures

## Introduction

The purpose of this study was to investigate the relative effectiveness of three forms of visual knowledge of results (KR): (a) continuous torque output display, (b) concurrent torque-time graph and, (c) summary torque-time graph, on maximum strength output achieved in an isokinetic flexion/extension of the knee. The strength output was measured at a low (120 degrees/second) and a high (240 degrees/second) speed for each of the KR conditions. In addition to comparing the pre- and post-test scores for increases in Maximum Peak Torque (MPT) output, performance in the treatment sessions was compared to performance in a retention session. The relative effectiveness of the three forms of visual KR as learning variables was investigated as a result of this latter experimental manipulation.

## Subjects

Twenty-four male volunteers served as subjects for this experiment. All volunteers were students at Oregon State University, and ranged in age from 19 to 28 years, with an average age of 22 years. The average height and weight of the subjects was 70.2 inches and 174 pounds, respectively. None of the subjects reported a record of previous knee injuries, nor were they familiar with the rehabilitation equipment to be used. After being apprised of the requirements of participation, all subjects signed letters of informed consent.

## Apparatus

The rehabilitation machine used in this study was the Biodex B-2000 system. Although the Biodex has many operational modes, this study used the system strictly as an isokinetic dynamometer. The components of the system are illustrated in Figure 1. The patient restraint chair was adjusted for each subject so seat-back angle and seat length were comfortable. After adjusting the seat, the subjects were secured by two, over-shoulder velcro straps, and one pelvic strap, to prevent forward lean during testing. The thigh of the treatment leg was also restrained with a velcro strap that was adjusted as tightly as was comfortable for the subject. This strap was necessary to prevent changes in lever length resulting from raising the thigh from the seat. Finally, the height of the powerhead was adjusted so the center of rotation coincided with the subject's joint center. Once positioning of the subject was complete the lever arm of the knee attachment was adjusted so the upper edge of the ankle cuff contacted the leg just below the calf muscles. This cuff was also fastened firmly with a velcro strap to minimize rotation of the leg during exercise.

The specifications for each exercise session were entered through the control module. The isokinetic mode, sensitivity setting of 'c', and 'hard' cushion setting prescribed for this exercise in the Biodex manual remained constant throughout the study. The high-speed bouts were performed at 240 degrees per second and the low-speed bouts at 120 degrees per second, with both the flexion and extension phases being performed at the same speed. The maximum peak torque (MPT) values were collected and stored by a NEC APC IV PowerMate 2 computer, through the Bioware software package provided by Biodex Corp. Visual KR displays, specified by the experimenter prior to each session, were projected on a NEC Multisync Color Monitor positioned on a table four feet in front of the patient chair at a height of four and one half feet above the ground (approximately eye level for the seated subject). The monitor was mounted on a rotating base so it was only turned toward the subject for the

1. DYNAMOMETER CONTROLLER
2. DYNAMOMETER POWERHEAD
3. POWERHEAD MOUNT / PATIENT RESTRAINT CHAIR (Double Chair)
4. ACQUISITION CONTROL MODULE (ACM)
5. IBM®-XT WITH MONITOR (Optional-supplied by user)
6. BIOWARE SOFTWARE (optional-purchased from BIODEX at additional cost)
7. ATTACHMENTS FOR EACH JOINT/PATTERN*
8. ACCESSORY CHAIR FOR TESTING JOINTS OTHER THAN KNEE
9. INSTRUMENT TABLE
10. PRINTER

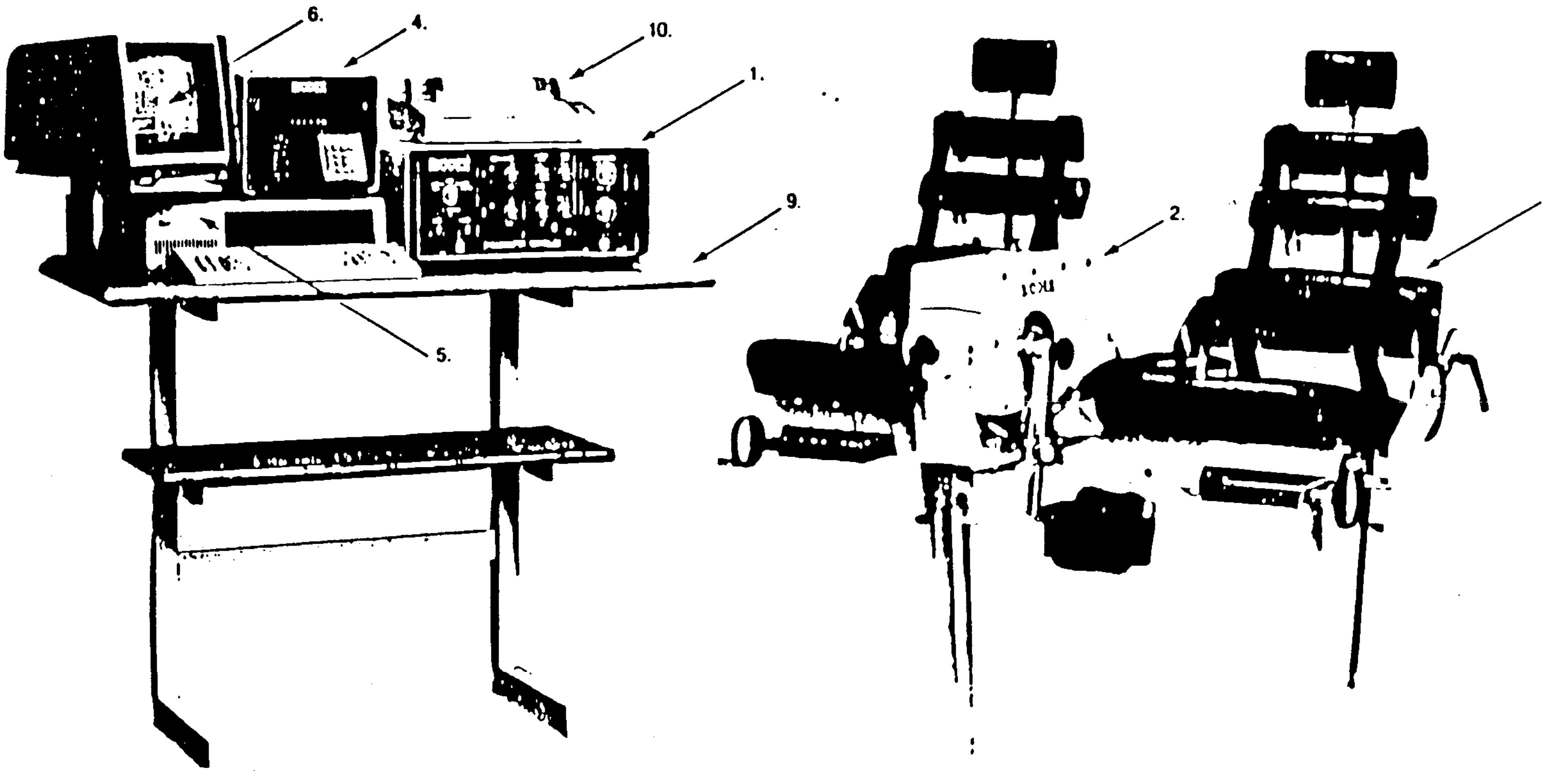


Figure 1 Biodex System

appropriate display of KR. All other components of the apparatus were turned away from the subject to eliminate possible distraction due to the array of indicator lights on the control station.

## Procedure

The experiment was completed with four, six-subject groups. All subjects in each group performed high-speed bouts with one leg, and low-speed bouts with the other. The twenty-four volunteers were randomly assigned to one of the four treatment conditions, representing either the no-KR control condition, or one of the three forms of visual KR. The leg used to perform the criterion task at each speed was also randomly assigned to each subject. The four groups differed only with respect to the type of visual KR presented. Group 1 served as the no-KR, control group. Group 2 received KR concurrent with performance, in the form of the 'bouncing cursor' display illustrated in Figure 2. This screen displayed the absolute torque output independently for the flexion and extension phases of the movement, as each was performed. KR in the form of a continuous torque-over-time graph was presented to Group 3 (Figure 3a). This display graphed each trial independently, although the flexion and extension phases were displayed together. Each trial was graphed concurrent with performance, and subsequent trials in the set were graphed over the preceding trials. Group 4 received a summary graph of torque output over time at the conclusion of each set (Figure 3b). This graph collectively displayed the torque/time records of each trial (five in the slow speed and ten in the high speed) in the order performed. The instructions given to each of the groups differed only with respect to directions specific to the KR condition. The standardized instructions that were read to each subject are presented in Appendix A, with the three group-specific amendments.

Each group performed identical four-stage protocols over the course of a five-day period (Table 1). Every session was preceded by a five-minute

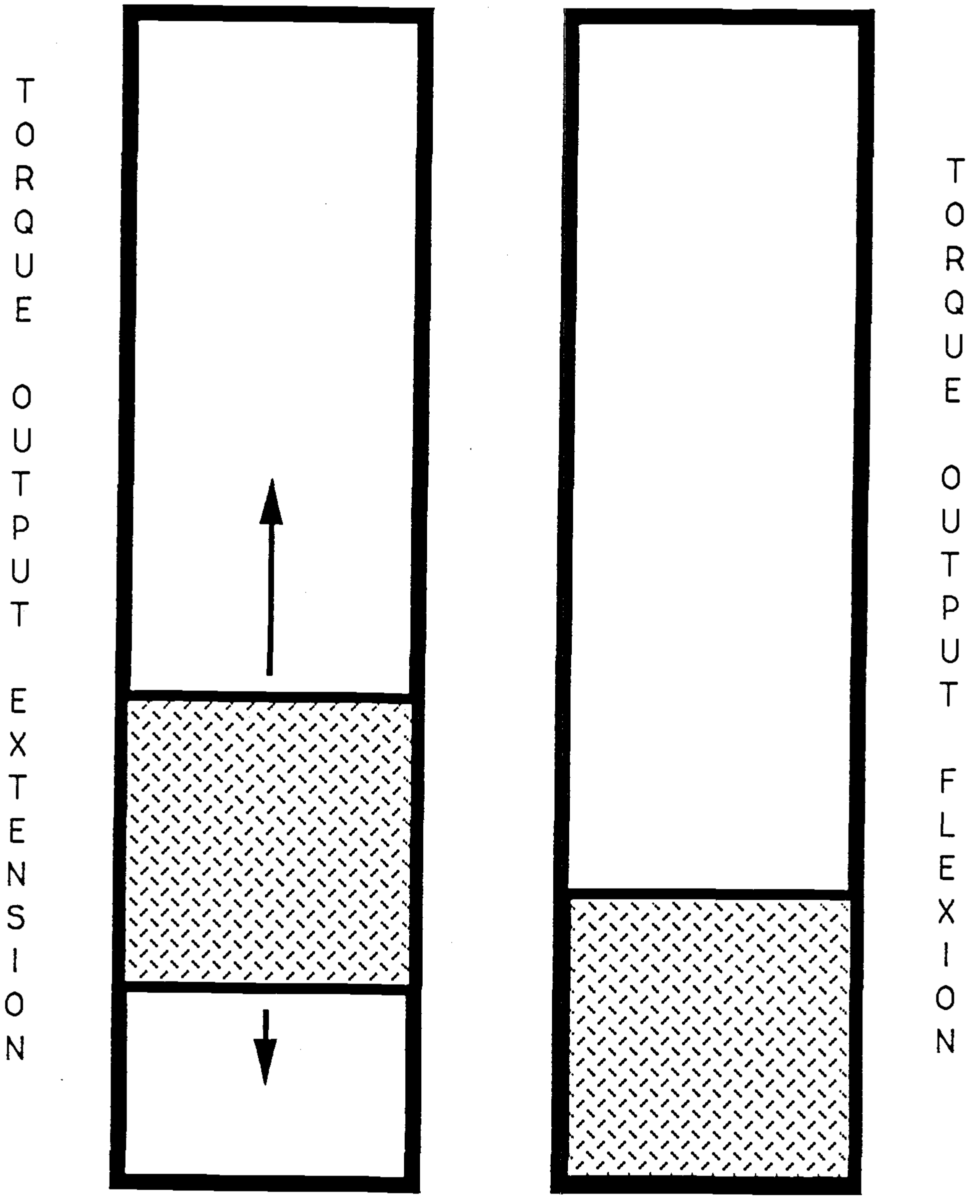


FIGURE 2: Continuous Torque-output Display

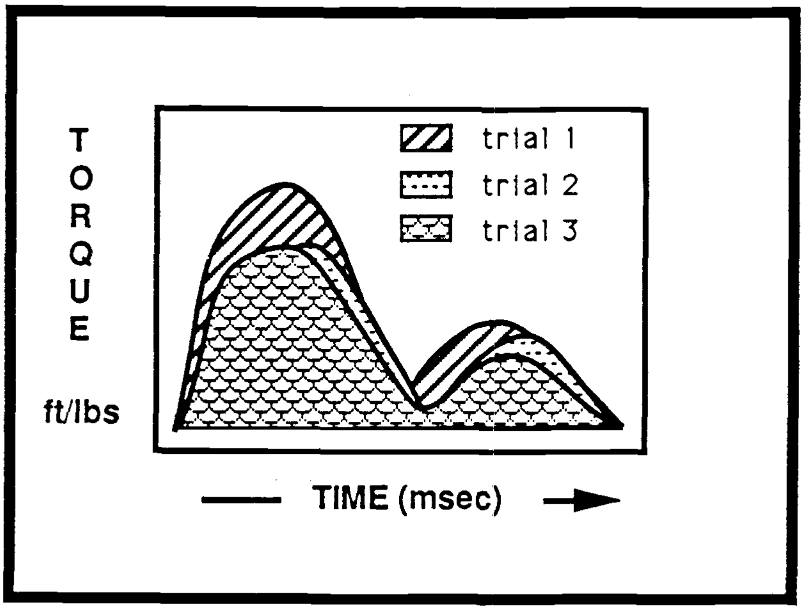


FIGURE 3A: Concurrent Torque-time Graph

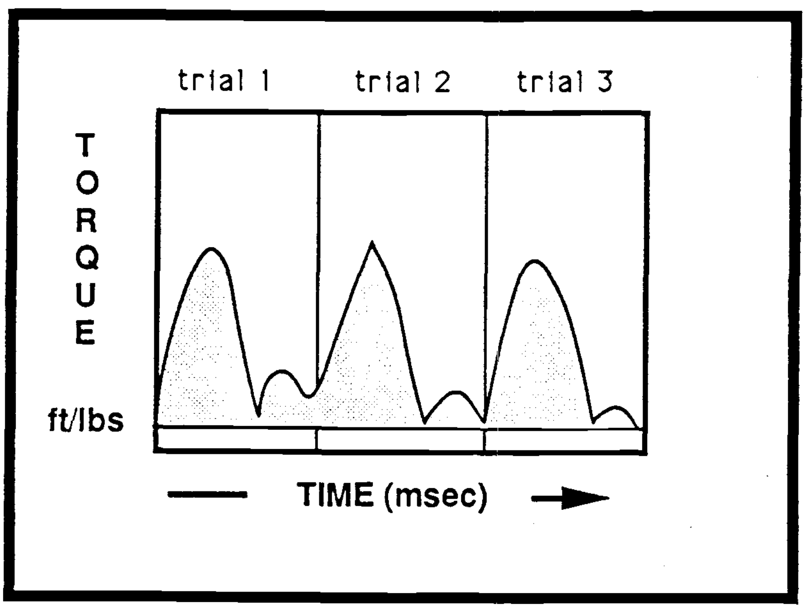


FIGURE 3B: Summary Torque-time Graph

warm-up on a bicycle ergometer. Stage one (day one) included assignment of subjects to a KR group and which leg each exercise speed would be performed with, collection of height, weight, age, and pertinent injury history for each subject, signing of consent forms (see Appendix B), and pre-testing. The pre-test consisted of a two-repetition, maximal-effort flexion/extension at each speed, with the designated leg. This test was administered in the absence of KR. The maximum peak torque (MPT) exerted in this test was recorded as the pre-test score. Stages two and three (days two and three) constituted the treatment sessions, in which the experimental groups' performance was supplemented with the prescribed form of visual KR. Subjects were required to perform three sets of five repetitions at low-speed, and three sets of ten repetitions at high-speed on each of the two treatment days. The order in which different speeds were performed was counterbalanced so each subject performed the low-speed bout first once and the high-speed bout first once. Sets were separated by a one-minute rest period, with a three minute rest interval inserted between bouts. This three-minute period was necessary to make adjustments to the subjects' positioning on the other side of the powerhead. On day two, the first exercise set was preceded by the presentation of instructions related to the intensity of performance and also to the information to be gained from the visual display. Day four served as the retention period. Stage four (day five) served as the final retention session. After the five-minute warm-up, each subject performed a two-repetition, maximal-effort flexion/extension at each speed. The MPT output recorded from this test constituted the post-test score. The subject was then given a five-minute rest prior to performing a no-KR retention bout at each speed. The procedures used for these bouts were identical to those implemented during the treatment bouts, with one important difference, the removal of KR for all groups. The instructions were to equal or exceed the torque output exerted during the treatment sessions, without the aid of KR. As in the treatment sessions, sets were separated by one-minute and bouts by three-minute rest intervals.

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 |
|---|---|---|---|---|
| DAY 1 | Background information; 2 Rep-Max Pre-test at 120 & 240 deg/s. | Background information; 2 Rep-Max Pre-test at 120 & 240 deg/s. | Background information; 2 Rep-Max Pre-test at 120 & 240 deg/s. | Background information; 2 Rep-Max Pre-test at 120 & 240 deg/s. |
| DAY 2 | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with bouncing cursor display. | 5 minute warm-up;3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with concurrent torque-time graph. | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with summary torque-time graph. |
| DAY 3 | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with bouncing cursor display. | 5 minute warm-up;3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with concurrent torque-time graph. | 5 minute warm-up; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s with summary torque-time graph. |
| DAY 4 | RETENTION DAY | | | |
| DAY 5 | 5 minute warm-up; 2 Rep-Max post-test without KR; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. | 5 minute warm-up; 2 Rep-Max post-test without KR; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. | 5 minute warm-up; 2 Rep-Max post-test without KR; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. | 5 minute warm-up; 2 Rep-Max post-test without KR; 3 sets of 5 at 120 deg/s; 3 sets of 10 at 240 deg/s without KR. |

**TABLE 1: Experimental Protocol**

## Treatment of the Data

The dependent measure, MPT, were analyzed using analysis of variance (ANOVA) procedures. Data from each of the two exercise speeds was analyzed independently since the low-speed condition provides greater resistance and yields higher torque values than the high-speed condition. Similarly, movement directions were also analyzed separately because of the significant differences in mean MPT output between extension and flexion. Four 1 X 4 (pre-test X KR condition) ANOVAs were calculated to determine the pre-test homogeneity between the four groups for each exercise speed and movement direction. Pre- and post-test MPT values, as a function of the type of visual KR presented in each of the four KR conditions, were analyzed using 2 X 4 (pre-/post-test X KR condition) ANOVAs. Day-to-day comparisons of the treatment sessions, and a comparison to MPT output in the retention session were made by computing 3 X 4 (day 1 / day 2 / retention day X KR condition) ANOVAs. For factors yielding significant F-scores, post-hoc comparisons of group means were made using the Tukey Wholly Significant Difference (WSD) technique at a significance level of 0.05.

# Chapter Four

## Results and Discussion

The purpose of this experiment was to investigate the effects of three forms of visual KR on maximum strength output in isokinetic exercise. The effects of visual KR presentation were explored through comparisons of mean maximum peak torque (MPT) output in pre- and post-tests, two treatment sessions and one retention session. Strength output was also considered as a function of the speed of exercise and the direction of movement. By comparing strength output across these conditions it was proposed that an optimal KR presentation condition could be identified. This chapter presents and discusses the experimental findings and is divided into the following sections: pre- and post-tests, treatment sessions, retention session, and general discussion.

### Pre- and Post Tests

Prior to comparison of the mean MPT output for the pre- and post-tests, four 1 X 4 (pre-test X group) ANOVAs were computed to determine pre-test homogeneity between the four groups. The four analyses compared pre-test mean MPT output of the four experimental groups for extension at high and low speeds, and for flexion at high and low speeds. The two levels of the exercise-speed and direction-of-movement factors were analyzed separately because of the significant differences in mean MPT output observed across the levels of each respective factor. It was evident that mean MPT output at the low exercise speed was higher than at high speed, and likewise, that mean MPT output in the extension phase was higher when compared to the flexion phase. A summary of the ANOVAs is presented in Table 2. None of the four analyses revealed significant differences between the pre-test mean MPT output for the four groups, thereby justifying the use of mean MPT values rather than difference scores in subsequent analyses. Table 3 presents the mean MPT

Table 2: **Summary of 1 X 4 Analyses of Variance for Pre-test Mean MPT as a Function of Exercise Speed and Movement Direction**

| Exercise Speed | Movement Direction | Source | df | MS | F |
|---|---|---|---|---|---|
| High | Extension | Group | 3 | 184.11 | 0.463 |
| | | Error | 20 | 397.98 | |
| High | Flexion | Group | 3 | 111.67 | 0.468 |
| | | Error | 20 | 238.72 | |
| Low | Extension | Group | 3 | 1111.38 | 1.654 |
| | | Error | 20 | 671.88 | |
| Low | Flexion | Group | 3 | 100.28 | 0.263 |
| | | Error | 20 | 381.05 | |

Table 3: Mean MPT Scores for 1 X 4 Analyses of Variance

| Exercise Speed | Movement Direction | Group | Mean MPT |
|---|---|---|---|
| High | Extension | 1 | 118.00 |
| | | 2 | 113.50 |
| | | 3 | 115.33 |
| | | 4 | 105.17 |
| High | Flexion | 1 | 77.17 |
| | | 2 | 76.17 |
| | | 3 | 67.67 |
| | | 4 | 72.33 |
| Low | Extension | 1 | 176.17 |
| | | 2 | 167.67 |
| | | 3 | 162.67 |
| | | 4 | 144.00 |

scores for each group used in these analyses.

The treatment sessions during which the prescribed forms of visual KR were provided were preceded by a two-repetition, no-KR, maximal-effort pre-test. An identical post-test was conducted prior to the retention session. The effects of the type of visual KR presented on the mean MPT output achieved in the post-test were evaluated by calculating 2 X 4 (pre-/post-test X group) ANOVAs for each exercise speed and direction of movement. The results of these ANOVAs are summarized in Table 4.

Post-hoc Tukey's WSD comparisons were calculated to compare means between-groups for differences between post-test scores (Table 5), and within-groups for pre- to post-test effects (Table 6). The between-groups comparisons revealed that the mean MPT output achieved in the high-speed flexion post-test by group one was significantly higher when compared to the three remaining groups. This result is contrary to the first prediction of hypothesis one that states that mean post-test MPT output by the treatment groups would be significantly higher when compared to the no-KR control group. One possible explanation for this finding is that subjects provided with visual KR developed a reliance upon the information as a performance guide, consequently ignoring internal sensory feedback. It would follow that mean MPT output produced in the flexion phase at high speed was adversely affected as a result of this reliance upon external information sources. In high-speed extension, mean MPT output by group two was higher than that achieved by group one, however, the difference was not statistically significant. In both movement directions of the low-speed condition, mean MPT output for groups two and three was significantly higher when compared to group one, although group four demonstrated a lower mean MPT output when compared to group one. The decrement between groups one and four was only statistically significant for the extension phase of the movement. The differences in mean MPT output observed between exercise speeds suggests that visual KR provided concurrent with exercise, whether in the form of a torque-output display or a torque-time graph, may be a more effective performance aid at low exercise speeds as opposed to high exercise speeds. At high exercise speeds sufficient time is not available for subjects to adequately process the visual information. The provision of summary visual KR did not produce higher mean MPT output at either exercise speed.

The within-group comparisons of pre-and post-test mean MPT output also revealed significant increases in mean MPT output. In the extension phase at both exercise speeds, significant improvements in mean MPT output between pre- and post-tests were evident for groups two and three. The mean MPT output achieved by group four also increased for the extension phase at both exercise speeds, although a statistically significant difference was only observed for the low exercise speed. Significant increases in mean MPT output at both speeds were demonstrated by all groups in the flexion phase of the movement. The fact that more groups achieved significant improvements in the flexion than in the extension phase of movement may reflect the novelty of performing a concentric contraction with the flexor muscles in the flexion phase of isokinetic exercise. This movement is opposite to the eccentric contraction of the extensor muscles that occurs during flexion in the more common isotonic exercise mode.

The second hypothesis predicted that group three (concurrent torque-time graph) and group four (summary torque-time graph) would demonstrate higher post-test mean MPT output when compared to group two (continuous torque-output display). In the low-speed condition, group three produced significantly higher mean MPT output in both movement directions when compared to the other three groups, providing partial support for hypothesis two. Conversely, at high speed, mean MPT output achieved by group two was significantly higher than for groups three and four in both movement directions. This result did not support the hypothesis.

**Table 4: Summary of 2 X 4 Analyses of Variance for Mean MPT as a Function of Exercise Speed and Movement Direction**

| Exercise Speed | Movement Direction | Source | df | MS | F |
|---|---|---|---|---|---|
| High | Extension | Pre-/Post- (A) | 1 | 1656.75 | 1.44 |
| | | Group (B) | 3 | 1248.72 | 1.08 |
| | | A X B | 3 | 324.14 | 0.28 |
| | | Error | 40 | 1154.53 | |
| High | Flexion | Pre-/Post- (A) | 1 | 1813.02 | 6.15* |
| | | Group (B) | 3 | 897.91 | 3.05* |
| | | A X B | 3 | 109.58 | 0.37 |
| | | Error | 40 | 294.90 | |
| Low | Extension | Pre-/Post- (A) | 1 | 1240.33 | 1.27 |
| | | Group (B) | 3 | 3193.22 | 3.26* |
| | | A X B | 3 | 220.78 | 0.37 |
| | | Error | 40 | 978.87 | |
| Low | Flexion | Pre-/Post- (A) | 1 | 2945.33 | 8.70* |
| | | Group (B) | 3 | 625.17 | 1.85 |
| | | A X B | 3 | 197.17 | 0.58 |
| | | Error | 40 | 338.38 | |

Table 5: **Between-Groups Comparisons of Means for Post-test MPT.**

| Exercise Speed | Movement Direction | Group | M | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|---|---|
| High | Extension | One | 148.33 | (3.73) | 6.79* | 10.41* |
| | | Two | 154.00 | | 10.52* | 14.14* |
| | | Three | 138.00 | | | 3.62† |
| | | Four | 132.50 | | | |
| High | Flexion | One | 99.00 | 7.86* | 19.27* | 17.42* |
| | | Two | 90.50 | | 11.41* | 9.56* |
| | | Three | 78.17 | | | (1.85) |
| | | Four | 80.17 | | | |
| Low | Extension | One | 146.33 | (8.46) | (19.19) | 5.71† |
| | | Two | 158.67 | | (10.73) | 14.17* |
| | | Three | 174.33 | | | 24.90* |
| | | Four | 138.00 | | | |
| Low | Flexion | One | 97.33 | (0.14) | (18.18) | 0.74 |
| | | Two | 97.49 | | (18.04) | 0.88 |
| | | Three | 117.67 | | | 18.92* |
| | | Four | 96.50 | | | |

Values in parentheses ( ) reflect negative mean difference scores.

† represents an F-value significant to $p < 0.05$.

* represents an F-value significant to $p < 0.01$.

**Table 6: Within-Group Comparisons of Means for Pre- and Post-test MPT.**

| Exercise Speed | Movement Direction | Group | $M_{pre}$ | $M_{post}$ | F |
|---|---|---|---|---|---|
| High | Extension | One | 145.83 | 148.33 | 1.64 |
| | | Two | 135.83 | 154.00 | 11.95† |
| | | Three | 115.00 | 138.00 | 15.13† |
| | | Four | 129.17 | 132.50 | 2.19 |
| High | Flexion | One | 82.83 | 99.00 | 14.96* |
| | | Two | 76.50 | 90.50 | 12.95* |
| | | Three | 62.50 | 78.17 | 14.50* |
| | | Four | 76.83 | 80.17 | 3.09 |
| Low | Extension | One | 148.33 | 146.33 | (1.37) |
| | | Two | 145.33 | 158.67 | 9.14* |
| | | Three | 163.00 | 174.33 | 7.77* |
| | | Four | 120.00 | 138.00 | 12.34* |
| Low | Flexion | One | 87.00 | 97.33 | 9.23* |
| | | Two | 93.33 | 97.49 | 3.72† |
| | | Three | 91.50 | 117.67 | 23.39* |
| | | Four | 78.67 | 96.50 | 15.94* |

Values in parentheses ( ) reflect negative mean difference scores.

† represents an F-value significant to $p < 0.05$.

* represents an F-value significant to $p < 0.01$.

## Treatment Sessions

Treatment sessions were conducted on two consecutive days, with both sessions following the same protocol. Each session was preceded by a short warm-up period, and was comprised of six exercise sets. Three sets of ten repetitions were performed at the high exercise speed, and three sets of five repetitions were performed at low speed. MPT output was averaged across trials for each set as a function of exercise speed and movement direction. The mean MPT values were subsequently used in the analyses of the treatment sessions.

Day-to-day comparisons were made using 3 X 4 (day 1 / day 2 / retention day X group) ANOVAs. A summary of the ANOVA results is presented in Table 7. There were no significant differences in mean MPT observed between days, therefore between-groups comparisons mean treatment MPT output were made using the values averaged across both treatment days. The results of these post-hoc comparisons are summarized in Table 8. Between-groups comparisons indicated a significantly higher mean MPT output during treatment sessions for group one when compared to groups two, three and four in both movement directions and at both exercise speeds. These results do not support the second and third predictions of the first hypothesis which stated that groups provided with visual KR (two, three and four) would achieve higher mean MPT output both during treatment sessions and during the retention session when compared to group one.

The third hypothesis predicted that groups two and three would achieve higher mean MPT output at low-speed during treatment sessions when compared to group four. The results provide support for this hypothesis in the case of group three, but not for group two. Mean MPT output produced by group three was significantly higher in the treatment sessions than that observed for group four in both movement directions. No significant differences were observed in mean MPT output between groups two and four. Comparison of groups two and three revealed that mean MPT output was significantly higher for group three when compared to group two. The difference in precision between the two forms of concurrent KR may be reflected in these results. The information contained in the continuous torque-output display provided to group two may not have provided sufficient information to improve mean MPT output, while the concurrent torque-time graph provided to group three provided more information which may have been used to improve performance.

In the case of the high-speed exercise condition, hypothesis four predicted that mean MPT output achieved by group three would be significantly higher than that achieved by groups two and four. This hypothesis was supported for the extension phase of the movement only. With respect to this direction, group three achieved significantly higher mean MPT output when compared to groups two and four. However, in the flexion phase of the movement statistically significant differences were only observed between groups two and three. Group three did achieve a higher mean MPT output in the flexion phase when compared to group four, but this difference was not statistically significant. These findings indicated that the higher level of KR precision associated with torque-time graphs was more effective in improving mean MPT output, particularly when presented concurrent with performance, than the other forms of visual KR provided during treatment sessions at low exercise speed.

## Retention Session

The retention session was conducted after a one-day rest period, and consisted of six exercise sets identical to those administered in each treatment session. The only difference in protocol between the treatment and retention phases was that the retention testing was performed in the absence of visual KR. This session was included to evaluate whether the effects of visual KR observed in the treatment sessions would still be evident after a retention interval.

Table 7: **Summary of 3 X 4 Analyses of Variance for Mean MPT as a Function of Exercise Speed and Movement Direction**

| Exercise Speed | Movement Direction | Source | df | MS | F |
|---|---|---|---|---|---|
| High | Extension | Day (A) | 2 | 694.06 | 2.80 |
| | | Group (B) | 3 | 1871.99 | 7.54* |
| | | A X B | 6 | 97.28 | 0.39 |
| | | Error | 204 | 248.26 | |
| High | Flexion | Day (A) | 2 | 212.25 | 1.07 |
| | | Group (B) | 3 | 1802.39 | 9.07* |
| | | A X B | 6 | 342.30 | 1.72 |
| | | Error | 204 | 198.73 | |
| Low | Extension | Day (A) | 2 | 64.10 | 0.15 |
| | | Group (B) | 3 | 5704.99 | 13.25* |
| | | A X B | 6 | 139.59 | 0.32 |
| | | Error | 204 | 430.67 | |
| Low | Flexion | Day (A) | 2 | 110.02 | 0.21 |
| | | Group (B) | 3 | 3452.16 | 6.55* |
| | | A X B | 6 | 31.42 | 0.06 |
| | | Error | 204 | 527.40 | |

Table 8: **Between-Groups Comparisons of Means for Treatment Session MPT.**

| Exercise Speed | Movement Direction | Group | M | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|---|---|
| High | Extension | One | 117.69 | 16.19* | 8.05* | 16.80* |
| | | Two | 104.95 | | (8.14) | 0.61 |
| | | Three | 111.36 | | | 8.76* |
| | | Four | 104.47 | | | |
| High | Flexion | One | 83.82 | 23.62* | 9.85* | 8.59* |
| | | Two | 66.24 | | (13.77) | (12.08) |
| | | Three | 76.49 | | | 8.76* |
| | | Four | 75.23 | | | |
| Low | Extension | One | 178.85 | 24.91* | 15.34* | 25.05* |
| | | Two | 156.36 | | (10.80*) | 0.14 |
| | | Three | 165.00 | | | 9.71* |
| | | Four | 156.23 | | | |
| Low | Flexion | One | 111.08 | 18.96* | 8.74* | 17.35* |
| | | Two | 93.07 | | (10.22*) | (1.61) |
| | | Three | 102.78 | | | 8.61* |
| | | Four | 94.60 | | | |

Values in parentheses ( ) reflect negative mean difference scores.

† represents an F-value significant to $p < 0.05$.

* represents an F-value significant to $p < 0.01$.

Significant differences in mean MPT output between treatment and no-KR retention sessions were identified using Tukey's WSD procedure (Table 9). The results of these comparisons varied across exercise speeds and movement directions. Statistically significant increases in mean MPT output between treatment and retention sessions were achieved by all groups in the high-speed extension phase, but significant increases in mean MPT output for the high-speed flexion phase were only achieved by group two. In the low-speed condition groups one, two and three achieved significantly higher mean MPT output in the extension phase during the retention session, with none of the groups showing significant increases in mean MPT output for the flexion phase. These findings suggest that the provision of visual KR during the treatment sessions facilitated improvements in the mean MPT output during the extension phase of this movement only. The between-groups comparisons of mean MPT output for the retention session are summarized in Table 10.

As in the pre-/post-test and treatment session comparisons, the analysis of mean MPT output in the retention session did not provide support for hypothesis one. Relative to the retention session, hypothesis one predicted that all three groups provided with visual KR during the treatment sessions would achieve significantly higher mean MPT output when compared to the no-KR control group. Rather, the between-groups comparisons showed that group one achieved significantly higher mean MPT output in all four conditions when compared to the remaining three groups.

The fifth hypothesis predicted that groups three and four would achieve higher mean MPT output at both exercise speeds in the retention session when compared to group two. This hypothesis was not supported in the high-speed exercise condition for either movement direction. Conversely, during the flexion phase of the movement group two demonstrated significantly higher mean MPT output when compared to groups three and four. Support for the hypothesis was partially provided for low exercise speeds given that group three produced significantly higher mean MPT output in both movement directions when compared to group two. No significant differences in mean

Table 9: **Within-Group Comparisons of Means for Treatment and Retention Session MPT.**

| Exercise Speed | Movement Direction | Group | $M_t$ | $M_r$ | F |
|---|---|---|---|---|---|
| High | Extension | One | 117.69 | 121.33 | 4.63† |
| | | Two | 104.95 | 113.69 | 11.10* |
| | | Three | 111.36 | 115.48 | 5.25† |
| | | Four | 104.47 | 107.90 | 4.36† |
| High | Flexion | One | 83.82 | 85.50 | 2.26 |
| | | Two | 66.24 | 79.76 | 18.17* |
| | | Three | 76.49 | 76.03 | (0.62) |
| | | Four | 75.23 | 72.38 | (3.83) |
| Low | Extension | One | 178.85 | 177.21 | 1.82 |
| | | Two | 156.36 | 161.17 | 5.32* |
| | | Three | 165.00 | 166.16 | 1.29 |
| | | Four | 156.23 | 153.69 | (2.81) |
| Low | Flexion | One | 111.08 | 108.16 | (3.07) |
| | | Two | 93.07 | 94.08 | 1.06 |
| | | Three | 102.78 | 100.58 | (2.32) |
| | | Four | 94.60 | 91.32 | (3.45) |

Values in parentheses ( ) reflect negative mean difference scores.

† represents an F-value significant to $p < 0.05$.

* represents an F-value significant to $p < 0.01$.

MPT output were observed between groups two and four. Comparisons between groups three and four revealed significantly higher mean MPT output by group three in all conditions except high-speed flexion. These results parallel the significant increases in mean MPT output demonstrated by group three in the treatment sessions.

The final hypothesis predicted that mean MPT output achieved in the high-speed condition of the retention test would be higher for group four when compared to groups two and three. There was no support for this hypothesis in the case of either movement direction or exercise speed. The results show, rather, a significantly higher mean MPT output for groups two and three in the extension phase when compared to group four. Group three also achieved a significantly higher mean MPT output when compared to group four in the flexion phase of the movement. These results were observed in both high- and low-speed exercise. This indicates that summary KR is not an effective performance or learning variable in this type of exercise setting.

## General Discussion

The effects of visual KR on maximal strength output in isokinetic exercise were investigated through the presentation of three different visual KR displays. While two groups received visual KR concurrent with performance, the torque output display of group two, and the torque-time graph of group three, each represented a different level of information precision. The torque-output display provided the subject with a scaling of the torque output level only during exercise, while the torque-time graph combined the factors of torque-output and time in a graphical display. The addition of time to a visual display has been shown to positively affect performance when compared to provision of a single, numeric force value (Newell & Carlton, 1983). The third type of visual KR, a summary torque-time graph, contained the same form of information as the concurrently-presented torque-time graph, but was presented at the conclusion of each exercise set. Summary presentation of KR

Table 10: Between-Groups Comparisons of Means for Retention Session MPT.

| Exercise Speed | Movement Direction | Group | M | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|---|---|
| High | Extension | One | 121.33 | 9.71* | 7.43* | 17.07* |
| | | Two | 113.69 | | (2.28) | 7.36* |
| | | Three | 115.48 | | | 9.64* |
| | | Four | 107.90 | | | |
| High | Flexion | One | 85.50 | 7.71* | 9.85* | 11.54* |
| | | Two | 79.76 | | 5.01 | 9.92* |
| | | Three | 76.03 | | | 4.91* |
| | | Four | 72.38 | | | |
| Low | Extension | One | 177.21 | 17.76* | 12.24* | 26.06* |
| | | Two | 161.17 | | (5.53) | 8.28* |
| | | Three | 166.16 | | | 13.81* |
| | | Four | 153.69 | | | |
| Low | Flexion | One | 108.16 | 15.65* | 7.98* | 17.72* |
| | | Two | 94.08 | | (6.84) | 2.91 |
| | | Three | 100.58 | | | 9.75* |
| | | Four | 91.32 | | | |

Values in parentheses ( ) reflect negative mean difference scores.

† represents an F-value significant to $p < 0.05$.

* represents an F-value significant to $p < 0.01$.

has been shown to produce improvements in performance during no-KR retention tests (Schmidt, Young, Swinnen & Shapiro, 1989). The results of the present investigation suggest that summary KR does not affect maximal strength output in isokinetic exercise performed within a rehabilitative setting.

The most surprising result obtained in this experiment was the significantly higher mean MPT output achieved by group one during the treatment sessions and the retention session when compared to the other three groups. The results of the analyses conducted suggest that maximum strength output can be achieved in the absence of visual KR. One possible explanation for such a result is that the visual KR provided information which resulted in subjects altering their initial performance goal from one of producing maximal output to a criterion output as a result of the graph remaining on the visual display screen from the preceding trial. In the case of the summary visual KR group, anticipation of the provision of KR may have served to distract the subjects from attending to internal sensory feedback and other relevant environmental information that would facilitate improvements in performance.

A second possible explanation for the experimental findings appears tenable upon review of the initial 1 X 4 (pre-test X group) ANOVAs. While these analyses did not reveal any significant differences in strength output between the four groups, mean MPT score was always higher for group one (no-KR control) when compared to the remaining three groups (Table 3). While these differences were not statistically significant at the outset, they may have affected the results obtained over the next three testing days.

Results obtained from just the treatment conditions in this experiment suggest that the relative effectiveness of the three forms of visual KR varies across exercise speeds. Analyses comparing pre-test to post-test mean MPT output, post-test mean MPT output, mean MPT achieved in treatment sessions, and mean MPT output in the retention session all revealed that group three, who were provided with visual KR in the form of a concurrent torque-time graph, demonstrated significantly higher mean MPT output at low speed when compared to groups two and four. This increase was not evident, however, in high-speed exercise in pre- to post-test comparisons, or in the retention session. In the case of these latter analyses, significantly higher mean MPT output was demonstrated by group two when compared to groups three and four. These findings parallel those of Figoni and Morris (1984) who found that the effectiveness of high-precision graphical KR decreased as a function of increases in exercise speed. Newell and Walter (1981) accounted for similar findings in their research by suggesting that when kinetic and kinematic information is presented as KR, sufficient time for information processing is required for that information to effect improvements in performance. The authors further explain that when insufficient processing time is available, less-precise forms of KR, which can be processed more quickly, become more effective sources of information.

Differences in results were also seen as a function of the direction of movement. Within-group comparisons of post-test scores and of mean MPT output in the retention session revealed different results between the extension and flexion phases of the movement. Post-test scores were significantly higher than pre-test scores in the extension phase of the movement for groups two, three and four. This suggests that the provision of visual KR during treatment sessions facilitated improvements in performance in the extension phase of the movement. The same conclusion cannot be made in the case of the flexion phase, however, as significant increases in mean MPT output were demonstrated by all four groups. One explanation for such a result may be the novelty of the flexion movement in isokinetic exercise. As was noted earlier, the flexion phase of an isokinetic exercise requires concentric contraction of the flexor muscles. Such a movement is novel to a performer not familiar with isokinetic exercise because the more common, isotonic form of exercise requires eccentric contraction of the extensor muscles during the flexion phase of the movement. Assuming the flexion phase of this exercise is a novel movement for the subjects, the results of the pre- to post-test comparison suggest that all groups learned the flexion as a function of practicing it during the treatment sessions. It is possible that the visual KR provided to groups two, three and four would only produce improvements in performance after initial acquisition of the skill has occurred. Although such a conclusion questions the importance of KR provision during skill acquisition, the fact that the task used in the present experiment required a maximal performance rather than performance to a criterion level may account for the current findings.

The fact that a maximal performance was required in this experiment may also explain the failure to find significant increases in mean MPT output for the group provided with summary KR. The summary KR research conducted by Lavery (1962, 1964) and by Schmidt et al. (1989) used tasks which were to be performed to a predetermined, sub-maximal criterion level. Improvements in the accuracy of performance reported by these respective authors were attributed to the efficiency with which the subjects learned the criterion movement when provided with summary KR as opposed to absolute-frequency KR. Since the criterion performance in the current experiment was maximal effort, subjects may not have benefitted from the additional time provided to problem-solve which is available when a summary KR schedule is used.

Finally, by considering the results of this experiment relative to the guidance hypothesis for KR forwarded by Salmoni et al. (1984) further differences between this study and those presented in the KR literature can be identified. Salmoni et al. (1984) proposed that a learner will become dependent on the provision of KR for accurate performance if KR is provided at an absolute frequency during acquisition of the skill. In this case, groups two and three, who were provided with absolute-frequency visual KR, would be expected to demonstrate lower mean MPT output during the no-KR retention session when compared to the visual KR-supplemented treatment sessions. Contrary to this prediction, the within-group comparisons of mean MPT output during the retention session revealed increased output by group two in all conditions, and by group three in the extension phase, at both exercise speeds. The decrement in mean MPT output for group three in the flexion phase of the movement was small and likely not indicative of a dependence on the presentation of visual KR, as groups one and four also showed decreases in mean MPT output. The fact that no evidence was found to support the KR guidance hypothesis proposed by Salmoni et al. (1984), may again be accounted for by the maximal-effort goal of the movement used in this experiment. Since each subject was to attempt a maximal effort on every trial, the information contained in the KR may not have been as important as it is to subjects attempting to learn a pre-determined criterion performance.

Evidence resulting from this experiment indicates that maximal strength output may be achieved in the absence of visual KR. However, the most significant visual KR effects resulted from presentation of concurrent visual KR in less-precise form at high speed, and with greater precision at lower speeds. Further investigations may provide support for these findings and more information relative to the role of visual KR as a performance and learning variable in maximal-effort tasks such as the one used in this experiment.

# Chapter Five

## Summary and Conclusions

The purpose of this study was to investigate the effects of three different forms of visual KR on maximal strength output in isokinetic exercise. The experiment was comprised of a pre- and post-test, two consecutive treatment sessions, and one retention session, conducted after a one-day retention interval. This chapter will be divided into the following sections: summary of procedures, summary of major findings, conclusions, recommendations for further research.

## Summary of Procedures

The subjects for this experiment were twenty-four male volunteers who were students at Oregon State University during the Spring term of 1989. The subjects ranged in age from 19 to 28 years. None of the subjects reported previous knee injuries, nor were any of them familiar with the rehabilitation equipment used.

The apparatus used in this study was the Biodex B-2000 system, in isokinetic mode. The protocol required each subject to perform a series of maximal-effort extensions and flexions of the knee in each of the following sessions: a two-repetition pre-test, two treatment sessions comprised of six exercise sets, a two-repetition post-test, and a no-KR retention session also comprised of six exercise sets. The treatment sessions were followed by a one-day retention period prior to the post-test and retention session.

Subjects were randomly assigned to one of four experimental conditions. Group one served as the no-KR control group, while groups two, three, and four were provided with visual KR during the treatment sessions of the experiment. Group two was provided with a concurrent torque-output display, group three with a concurrent torque-time graph, and group four with a summary torque-time graph. All groups performed the pre-test, post-test and retention session in the absence of visual KR.

The treatment and retention sessions were each comprised of six exercise sets, three at a low exercise speed (120 degrees/second) and three at a high exercise speed (240 degrees/second). Five repetitions were performed in each low-speed set, while ten repetitions comprised a high-speed set. Sets were separated by a one-minute rest interval while a three-minute rest interval preceded a change in exercise speed. Standardized instructions were presented to each subject prior to each session including pre- and post-tests. The goal of the movement being performed was to exert a maximal peak torque (MPT) output in both movement directions (extension and flexion), at both exercise speeds. The MPT values were measured and stored by a NEC APC IV PowerMate 2 computer and the Bioware software package provided by Biodex Corp.

The dependent variable, MPT, was analyzed using analysis of variance (ANOVA) procedures. The two levels of the exercise-speed and direction-of-movement factors were analyzed separately because of the significant difference in MPT output observed across levels of each factor. Pre-test homogeneity between the four groups was evaluated using a 1 X 4 (pre-test X group) ANOVA calculated for each of the four exercise-speed and movement-direction combinations. A 2 X 4 (pre- / post-test X group) ANOVA for each speed and direction was used to evaluate the effects of the visual KR provided on pre- and post-test mean MPT output. Day-to-day comparisons of mean MPT output , and comparison of the treatment sessions to the retention session were made by calculating 3 X 4 (day 1 / day 2 / retention session X group) ANOVAs. For factors indicating significant F-scores at a 0.05 alpha level, post-hoc comparisons of group means were made using Tukey's WSD technique.

## Summary of Major Findings

Differences in mean MPT output between groups varied as a function of both the exercise speed and movement direction. A within-groups comparison of pre- to post-test scores revealed significant increases in mean MPT output for groups two and three in high-speed extension, and for groups two, three and four in low-speed extension. Groups one, two and three produced significantly higher mean MPT output in high-speed flexion, and all groups improved significantly in the low-speed flexion condition. These findings suggest that the provision of visual KR during treatment sessions facilitated improvements in performance during the post-test.

Between-groups comparisons indicated a significantly higher post-test mean MPT output by group one in the high-speed exercise condition when compared to the other three groups, while groups two and three, who were provided with concurrent visual KR, outperformed groups one and four in the low-speed condition. Comparison of the mean MPT output by groups two, three and four revealed that group two produced significantly higher mean MPT output at high speed when compared to groups three and four. In the low-speed condition, group three produced significantly higher mean MPT output than groups two and four. These results indicate that the more precise torque-time graph is the most effective form of visual KR provided at low speed, while presentation of less-precise information in the form of a torque-output display appears more effective in high-speed exercise.

Group one demonstrated the highest mean MPT output of the four groups during treatment sessions, although group three exerted significantly higher mean MPT output when compared to groups two and four. It may be noted that group one was provided with no external means of evaluating performance, possibly resulting in greater concentration on exerting a maximal effort for each trial. Groups two, three and four may have been basing performance level on previous, but not necessarily maximal, performances. This may have occurred because the visual display provided from the previous trial remained on the screen while the subjects performed the next trial.

A within-groups comparison of mean MPT output between treatment sessions and the retention session revealed increases in performance by all groups in the extension phase at both exercise speeds, although similar increases were not observed during the flexion phase. Failure to find increases for the flexion phase of movement may indicate that this movement skill was still being acquired or that the skill was so new to the subjects that the visual KR provided too much or too complex a level of information. In this case, the level of KR precision may have been limiting the subjects' ability to use the information to improve performance. Increases in mean MPT output evident for the extension phase do, however, indicate that performance of this aspect of the movement was improved across the days of the experiment.

Mean MPT output in the retention session was significantly higher for group one, as in all other conditions, although group three showed significantly higher mean MPT output when compared to groups two and four in all conditions except high-speed flexion. These findings suggest that the concurrent torque-time graph provided to group three was a more effective learning variable than the visual KR displays provided to groups two and four.

## Conclusions

The following conclusions were made from the results of this investigation:

1. Maximal strength output may be achieved in the absence of visual KR.

2. Visual KR, presented in the form of a concurrent torque-output display, is a more effective form of KR in high-speed isokinetic exercise than more precise forms of visual KR, such as a concurrent torque-time graph. The more precise information provided by a concurrent torque-time graph however, becomes more effective

at low exercise speeds, when sufficient time for information processing is available subsequent to its presentation.

3. Visual KR presented concurrent with performance is a more effective performance and learning variable when compared to visual KR presented according to a summary schedule.

4. Visual KR may provide a reference of performance which serves as a criterion and subsequently limits the level of strength output in a maximal-effort task.

## Recommendations for Further Research

The following recommendations for further research are forwarded as a result of the findings of this investigation:

1. Evaluate the relative effectiveness of visual KR in improving maximal strength output in isokinetic exercise by analyzing relative improvements in mean MPT output across treatment and retention sessions. Such an investigation should compare mean MPT output over an extended treatment period to minimize the effects of task novelty.

2. Investigate differences in the effectiveness of various forms of visual KR between performance of an isokinetic exercise at ranges of high and low exercise speeds relative to the specificity-of-speed principle. This principle predicts that the effects of visual KR presentation will only be evident during performance at the same speed at which the effects were established. For example, if

presentation of a concurrent torque-time graph improves performance during treatment sessions performed at 120 degrees/second, the effects of that visual KR will only be evident in a retention test also conducted at 120 degrees/second.

3. Compare the effects of concurrently-presented and summary-scheduled visual KR on criterion-related and maximal-effort isokinetic exercises. The guidance hypothesis for KR (Salmoni et al., 1984) should be tested for each of these four performance conditions, to determine whether the the ineffectiveness of summary KR is due to the maximal-effort goal of the task or the type of visual KR.

4. Conduct analogous experiments in other rehabilitative settings with subjects more representative of the population involved in rehabilitation. These experiments can be conducted using alternate modes of KR presentation, adapted tasks, and/or subjects with impairments unrelated to the exercise of interest. Such investigations would allow generalization of the results to populations that more typically participate in rehabilitative programs.

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## Appendix A: Standardized and Group-specific Instructions

### Pre- and Post-Test Instructions:

This session will consist of two (2) maximal-effort repetitions of a full knee extension followed by flexion back to the starting point. You will perform two repetitions with your 'low-speed' leg, change sides, and perform two repetitions with your 'high-speed' leg. Please kick out and pull back with as much force as possible. It is also very important that you perform each of these two-repetition bouts through the full range of motion that was specified during the set-up stage. If at any point you feel pain or discomfort, immediately stop the exercise and/or push the emergency STOP button on the powerhead.

### Treatment Session Instructions:

This session will consist of three (3) sets of repetitions at each of the two exercise speeds. With your 'low-speed' leg you will perform three sets of five repetitions, separated by a one minute rest. With your 'high-speed' leg you will perform three sets of ten repetitions, also separated by one minute rest intervals. At the conclusion of the first exercise bout you will have a three minute rest during which you will move to the other side of the powerhead and have the machine readjusted.

During each set you are asked to kick out and pull back with as much force as possible, and to complete the movement through the full range of motion. The sets have been designed to produce minimal fatigue, so try to maintain your level of performance throughout each of the bouts.

(INSERT GROUP SPECIFIC INSTRUCTIONS FOR GROUPS 2, 3, & 4)

If at any time you feel pain or discomfort immediately stop the exercise and/or press the emergency STOP button on the powerhead.

## Group-Specific Instructions

<u>Group 2:</u> While you are performing, you will be presented with this type of display (Figure 2). As you kick out the left cursor will 'jump up,' and as you pull back the right cursor will rise. Watch the screen as you perform and try not only to bounce the cursors as high as possible, but also try to maintain your level of performance on every repetition.

<u>Group 3:</u> While you are performing, you will be presented with this type of display (Figure 3a). As you perform each repetition, the computer will graph the force you are exerting over the time of each repetition. The first peak will represent the kick out, and the second peak will represent the pull back. Watch the screen as you perform and try not only to get the peaks as high as possible, but also to make the graph of each repetition similar throughout the entire set.

<u>Group 4:</u> At the conclusion of each set you will be presented with a graph of the force you exerted in each repetition for the entire set. While you are performing, try to kick out and pull back with as much force as possible, and with equal force on each repetition.

**Retention Test Instructions:**

This session will consist of three sets of repetitions at each exercise speed. Just as in the treatment sessions, you will perform three sets of five repetitions with your 'low-speed' leg and three sets of ten repetitions with your 'high-speed' leg. While you are performing, try to recall your performance in the treatment sessions, and make an effort to perform at the same level throughout each of the the exercise bouts. As in the treatment sessions, you are asked to kick out and pull back with as much force as possible, and to complete the movement through the full range of motion. If at any time you feel pain or discomfort immediately stop and/or press the emergency STOP button.

## Appendix B: INFORMED CONSENT FORM

Title: The Relative Effectiveness of Three Forms of Visual Knowledge of Results on Maximal Strength Output in an Isokinetic Extension/Flexion of the Knee.

Investigator: Susan L. Hobbel

I, ______________________ hereby agree to participate as a volunteer in a scientific investigation authorized through Oregon State University, under the supervision of Susan L. Hobbel.

The supervisor has fully defined the investigation and explained my part in the investigation, and I understand her explanation. A copy of the procedures of the investigation and a description of the possible risks and discomforts have been provided for me and fully discussed.

I have been provided the opportunity to ask any questions, and those questions have been answered to my satisfaction.

In the event of physical injury resulting from my participation in this investigation, I understand that neither free medical care nor financial compensation will be provided.

I certify that, to the best of my knowledge, I have no physical or mental illness that will increase the risk associated with my participation.

**I clearly understand that I am free to revoke my consent and terminate my participation in this investigation at any time.**

Date_______________ Signed________________________________
(Subject)

I, the undersigned, certify that the conditions and procedures of this investigation have been defined and explained to the above subject.

Date_______________ Signed________________________________