Concurrent vs. Terminal Augmented Feedback in the Learning of a Discrete Bimanual Coordination Task.

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CONCURRENT VS. TERMINAL AUGMENTED FEEDBACK IN THE LEARNING OF A DISCRETE BIMANUAL COORDINATION TASK

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the final exam for the degree of Doctor of Philosophy

in

The Department of Kinesiology

by

Cynthia Marie Hadden
B.S., Louisiana State University, 1981
M.S., Louisiana State University, 1985
August 1998
DEDICATION

In loving memory of George Phillip Hadden
ACKNOWLEDGEMENTS

I would like to express heartfelt thanks to Dr. Richard Magill for his guidance and encouragement throughout my program of study. Dr. Magill has served as my major professor and as the chair of my dissertation committee. I am very fortunate to be counted among his students. I would also like to thank Drs. Bob Mathews, Ben Sidaway, Brian Maraj and Dennis Landin for serving on my committees and for sharing their knowledge, insight and time with me. Your contributions, guidance and encouragement are much appreciated.

Thanks to Dr. Don Franks, Dr. Amelia Lee, to the staff in the Department of Kinesiology and to the staff in the Graduate School who have helped me during my course of study. Thanks also to the many graduate students who have studied with me, helped me and encouraged me. Particular thanks to Dr. Kellie G. Hall and Dr. David Anderson.

Special thanks to Ron Hay for his support and encouragement. Thanks also to the AIS management team - Barbara Evans, Robin Montgomery and Joel Donnelly - and to the AIS staff for their understanding and encouragement.

Thanks to special friends - Connie Moody, Patricia Horvilleur, and John Borne - for their unwavering support.

Last, but not by any means least, heartfelt thanks to my family - mama, Rachel, Tee, Lynn and Emily. Special thanks to my father who inspired me to work toward a doctorate and to whose memory I dedicate this dissertation.
PREFACE

This dissertation documents a series of experiments conducted at the Motor Behavior Laboratory in the Department of Kinesiology at Louisiana State University, Baton Rouge. Chapter 1 outlines the problem under study and presents a brief rationale for the experiments presented in subsequent chapters. Chapter 2 outlines an experiment conducted in 1995 and presented at the NASPSPA conference in Asilomar, California. Chapter 3 outlines an experiment which extends the findings presented in chapter 2. Finally, chapter 4 is a general discussion that provides a synthesis of findings from the previous chapters.
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ABSTRACT

Two experiments compared the effects of concurrent and terminal augmented feedback in learning a bimanual coordination task. In the first experiment, twenty-four participants practiced a discrete bimanual task that required a 90° phase offset of the upper limbs under one of two feedback conditions: concurrent or terminal. Participants in the concurrent feedback group received feedback as they performed the task during acquisition. Participants in the terminal feedback group received feedback after they completed each acquisition trial. Results indicated that concurrent group was able to more accurately produce the target figure during acquisition than the terminal group.

Unlike earlier studies which employed single-limb tasks and which showed that terminal participants outperform concurrent participants in retention, there was no significant difference between the two groups on transfer tests with no feedback. In fact, although the difference was not significant, participants in the concurrent group performed better than participants in the terminal group during these retention tests.

In the second experiment, forty-eight participants practiced the same task under one of four conditions: concurrent, terminal, transition, and control. Concurrent and terminal feedback groups received feedback as in Experiment 1. Transition and control groups received concurrent feedback during the first two blocks of acquisition. During the remainder of acquisition, the transition group received terminal feedback and the control group received no feedback. Results indicated that the control group performed less accurately than the other three groups during acquisition. On transfer tests with no feedback, the performance of the concurrent group deteriorated such that
it approached the performance of the control group. The transition and terminal groups were more accurate than the control group. The results of this experiment support previous research which has found that the presentation of concurrent feedback, as opposed to terminal feedback, enhances performance during acquisition but hinders long-term retention. The results of this dissertation demonstrate that there are some conditions under which concurrent augmented feedback can be effective for learning. These findings support the hypothesis by Lee, Swinnen and Serrien (1994) that augmented feedback is most useful when it assists the learner in interpreting intrinsic sources of feedback.
CHAPTER 1

Augmented feedback is feedback about a voluntary movement not normally available in the environment or in the movement itself. It is considered by many researchers to be one of the most critical variables influencing the acquisition and retention of skill (for reviews, see Annett & Kay, 1957; Armstrong, 1970; Newell, 1976; Magill, 1993). Over the past several decades, it has been studied from the perspective of the roles it plays in skill learning. These roles include reinforcement, error correction and motivation.

Much of our understanding of augmented feedback in motor skill learning is based on research that employed simple single-limb tasks. Few studies have directly investigated the relationship between augmented feedback and task characteristics, such as complexity and organization. Task complexity is determined by the number of component parts or dimensions of a task; organization is determined by the interrelationship between the dimensions. In addition, few studies have investigated the influence of augmented feedback on the learning of coordination tasks involving more than one limb. (For a review of augmented feedback research from the perspective of task characteristics, see Appendix A).

The importance of understanding the relationship between task characteristics and augmented feedback was established by research at the University of Illinois. A series of experiments (Newell, Quinn, Sparrow, & Walter, 1983; Newell, Sparrow & Quinn, 1985; Newell & Carlton, 1987; Newell, Quinn & Carlton, 1987; Newell, Carlton & Antoniou, 1990), employing horizontal flexion tasks, isometric force
production tasks and two-dimensional drawing tasks, demonstrated that the appropriate feedback for skill learning is feedback that matches the constraints imposed on a task by the task criterion. Kinematic feedback, typical of the movement feedback provided in many real-world settings (Schmidt & Young, 1991), was provided in these studies. In the real world, with the exception of gymnastics, ice skating, diving and similar skills, the goal of the task is often distinct from the kinematic pattern required to attain it. In the Newell et al. studies, the movement pattern was the movement goal. As such, Schmidt and Young suggested that the kinematic feedback employed in the Newell et al. studies was reduced to outcome information and that these studies had limited generalizability. The Newell et al. studies were important, however, in that they provided systematic, empirical evidence that task constraints specify the appropriate feedback for skill learning.

The influence of tasks characteristics on the effectiveness of augmented feedback is also apparent when existing research is examined from the positive, negative and neutral effects augmented feedback has on learning. Magill (1993) cited empirical evidence which indicated that augmented feedback influences skill acquisition in one of four ways. Augmented feedback can be essential for skill acquisition, beneficial to skill acquisition, not necessary for skill acquisition, or a deterrent to skill acquisition. In the studies reviewed, augmented feedback was necessary for skill acquisition when critical sensory information was not available in the environment or in the task itself, such as when drawing a line of a certain length (Trowbridge & Cason, 1932) or positioning a lever to a criterion location (Bilodeau,
Bilodeau, & Schumsky, 1959; Bennett & Simmons, 1984) without vision. It was also necessary for skill acquisition when critical sensory information available in the environment could not be used to evaluate the response due to inexperience or novelty. Augmented feedback was found to enhance skill acquisition in situations where the learner was able to evaluate to a limited degree the outcome of the movement response in relation to the movement goal, such as when learning a complex arm movement (Stelmach, 1970) or a one-hand set-shot in basketball with the nondominant hand (Wallace & Hagler, 1979). Augmented feedback was shown to be redundant and, thus, not necessary for skill acquisition when task intrinsic feedback was sufficient for the evaluation of movement outcome, such as when learning an anticipation timing task (Magill, Chamberlin & Hall, 1981) or the Pedestal Sight Manipulation Test (Goldstein & Rittenhouse, 1954). Finally, augmented feedback was shown to deter skill acquisition when the learner developed a dependency on the feedback, such as when learning a constant force task under conditions of concurrent augmented feedback (Annett, 1959). Although the degree to which sensory information feedback could be detected was proposed as one possible explanation for these positive, negative and neutral effects of augmented feedback on learning, Magill (1993) suggested that other skill characteristics which may also account for these effects should be considered.

Both empirical evidence and reviews of augmented feedback research support the hypothesis that task constraints specify the appropriate feedback for learning. As such, there exists a need to systematically determine the nature of this relationship (Magill, 1993) and to re-examine the principles which have been found to govern the
effectiveness of augmented feedback in light of this relationship. The principles which account for the influence of augmented feedback on the acquisition of simple single-limb tasks may not account for the influence of augmented feedback on the acquisition of coordinated movements involving more than one limb.

One area of research that can provide insight into the relationship between task characteristics and augmented feedback is the comparison of concurrent and terminal augmented feedback on skill learning (Vander Linden, Cauraugh, & Greene, 1993; Patrick & Mutlusoy, 1982; Smyth, 1978; Annett, 1970; Fox & Levy, 1969). Concurrent augmented feedback is augmented feedback presented during a movement response. Terminal augmented feedback is feedback presented upon completion of the movement. Tasks employed in research comparing concurrent and terminal presentations of feedback have included constant pressure tasks (Annett, 1959), linear slide tasks (Patrick & Mutlusoy, 1982), isometric force production tasks (Vander Linden, Cauraugh & Greene, 1993), and arc drawing tasks (Fox & Levy, 1969). Studies employing these tasks have typically shown that the presentation of concurrent augmented feedback enhances performance during acquisition more than does the presentation of terminal augmented feedback but leads to poorer performance on transfer tests with no feedback. However, the nature of the tasks used in these experiments was such that the augmented feedback provided (e.g. movement extent) could readily be interpreted by the learner as a prescription for movement correction. It is possible that the presentation of concurrent vs. terminal augmented feedback would
have different effects on tasks of high complexity or high organization for which augmented feedback does not prescribe how to correct a movement response.

One set of complex, organized tasks currently being used in motor learning research is asymmetric bimanual coordination tasks. These tasks require the two arms or hands to simultaneously perform movements that are spatially and/or temporally different. Studies investigating the acquisition of simple asymmetric bimanual aiming movements (e.g. Kelso, Southard, Goodman, 1979; Kelson, Putnam & Goodman, 1983) and those investigating the acquisition of more organized asymmetric bimanual movements (Swinnen, Walter & Shapiro, 1988) have shown that the limbs initially tend to move together, temporally and spatially, as a coordinated unit and that the behavior of one limb influences the behavior of the other limb. Because the initial tendency in highly organized bimanual coordination tasks is for the limbs to act as a unit and because the feedback typically provided in these tasks does not set forth a plan for movement correction, it is possible that the effects of concurrent and terminal augmented feedback found for single-limb tasks may not apply to the learning of these tasks. Swinnen, Lee & Serrien (1994) and Swinnen, Lee, Verschueren, Serrien, & Bogaers (1997) found that concurrent augmented feedback led to more accurate and consistent acquisition and retention performance than deprived feedback for tasks of this type. These recent studies support the hypothesis that tasks characteristics play an important role in determining the effectiveness of various augmented feedback manipulations and highlight the need to extend earlier work comparing the effects of concurrent and terminal feedback on learning to more complex tasks. The purpose of
this dissertation is to examine how the concurrent and terminal presentations of augmented feedback influence the acquisition and retention of a discrete asymmetric bimanual coordination task.

References to Chapter 1


CHAPTER 2

Introduction

Much of our understanding of the influence of concurrent and terminal presentations of augmented feedback on motor skill learning is based on research that relied heavily on the learning of simple single-limb tasks. Tasks employed in these studies include constant pressure tasks (Annett, 1959), linear slide tasks (Patrick & Mutlusoy, 1982), isometric force production tasks (Vander Linden, Cauraugh & Greene, 1993), and arc drawing tasks (Fox & Levy, 1969). These studies showed that the presentation of concurrent feedback, as compared to terminal feedback, enhances performance during acquisition, but leads to poorer performance in retention. However, the feedback provided for the one-dimensional tasks employed in these studies (e.g. movement extent) could be used as a prescription for how to correct movement errors. Thus, it is possible that concurrent and terminal augmented feedback might operate differently for the learning of tasks in which the augmented feedback provided does not or cannot dictate a movement correction strategy, such as tasks of high organization.

One highly organized task employed in recent motor learning research, with feedback that cannot be easily interpreted as a prescription for action, is an asymmetric bimanual coordination task requiring a 90° phase offset in the movement of the upper limbs. Evidence from experiments employing various asymmetric bimanual coordination tasks supports the notion that the principles which account for the learning of single-limb movements may not fully account for the
learning of coordinated movements involving more than one limb (Kelso, Putnam, &
Goodman, 1983; Kelso, Southard, & Goodman, 1979; Swinnen, Walter, & Shapiro,
1988). These studies have shown that during practice the limbs initially tend to act
together, spatially and temporally, as a coordinated unit; the behavior of one limb
influences the behavior of the other. Because the tendency is toward synchronization
in these tasks and because the feedback provided does not prescribe how to overcome
this synchrony, the presentation of concurrent and terminal augmented feedback may
not influence the learning of these tasks in the same way that these presentations
influence the learning of simple single-limb tasks. In recent studies requiring
participants to learn the asymmetric 90° relative phase task, Swinnen, Lee, and
Serrien (1994) and Swinnen, Lee, Verschueren, Serrien, & Bogaers (1997) showed
that participants receiving concurrent augmented feedback performed more accurately
and consistently in both acquisition and retention than participants receiving deprived
feedback. The results of these studies support the notion that the influence of
concurrent and terminal feedback on the acquisition and retention of motor skills may
interact with task organization and needs to be further studied. The present study
extends previous research by comparing concurrent and terminal presentations of
augmented feedback in the acquisition and retention of a discrete asymmetric
bimanual coordination task.
Method

Participants

Twenty-four students from kinesiology lecture and activity classes completed the experiment in exchange for course credit. All provided informed consent. Participants were randomly assigned to one of two experimental conditions: concurrent or terminal.

Apparatus

The apparatus employed in this study, which operated much like a large Etch-A-Sketch, is shown in Figure 2.1. This apparatus is similar to that employed by Swinnen, Walter, Lee and Serrien (1993). The apparatus consisted of two horizontal manipulanda attached to two vertical axles. Potentiometers located at the base of the axles allowed for the collection of displacement data which was displayed, when appropriate, to participants via a computer monitor.

The manipulandum to the subject’s right controlled the movement of the cursor on the computer monitor in the horizontal direction. The manipulandum to the subject’s left controlled the movement of the cursor in the vertical direction. By coordinating the movement of the manipulanda, participants could “draw” various diagrams on the computer monitor. These diagrams served as feedback to the participants about their bimanual movement.

Data were collected at the rate of approximately 500 cycles per second via a Keithley Metrabyte uCDAS-16G data acquisition board installed in an IBM Model 70 personal computer. The entire experiment, including the collection of data, was
Figure 2.1 Illustration of apparatus
controlled by a computer program written in Quick Basic. (A copy of the program is found in Appendix C.)

**Task**

Participants were asked to use the apparatus to inscribe a circle in a square. To inscribe a circle in a square is to draw a circle inside the square so as to touch as many points on the square as possible. The square, oriented as a diamond, represented a pure 90° relative offset of the movement of the participant’s left arm as a function of the movement of the participant’s right arm. The circle approximates this 90° offset given the constraints of deceleration in movement reversal. Participants were not informed of the relationship between the offset of their arm movements and the shape of the diagram being drawn on the computer screen.

The task employed in this experiment was highly organized because the two-dimensions of this task were interdependent. The movement goal could only be achieved by coordinating limb movement so as to maintain a 90° relative phasing. For most individuals, the coordination of bimanual movement is most stable at the more symmetric phase offsets of 0° (in-phase) and 180° (anti-phase). As such, for most participants, learning the 90° relative phasing required overcoming the attraction to these dominant coordination patterns.

**Procedure**

The experiment was conducted over four consecutive days. Acquisition sessions were held on each of the first two days; retention sessions were conducted on the third and fourth day. Each acquisition session consisted of one block of scanning...
(probe) trials, followed by eight blocks of 20 acquisition trials with feedback according to group assignment, and followed finally by another block of scanning trials. Each retention session consisted of 3 blocks of 10 test trials followed by a block of scanning trials. No feedback was presented to participants in either group during retention.

Scanning Trials

The purpose of the scanning (probe) trials was to assess changes in preexisting coordination patterns as a function of the acquisition of the new coordination pattern needed to draw a circle. Lee, Swinnen & Verschueren (1995, p. 263) refer to these scanning trials as "periodic transfer tests." Zanone and Kelso (1992) introduced this technique as a means of assessing changes in overall coordination dynamics as a function of learning. The objective of each set of scanning trials was to probe changes in a participant’s ability to generate various relative phasing movements at that point in time. The initial probe served as a pretest of the participant’s ability to generate relative phasing movements before any intervention had taken place.

Each set of scanning trials comprised seven contiguous blocks of 10 continuous trials in which subjects were instructed to draw an elliptical figure that best fit one of seven rectangular figures. The seven rectangular figures represented relative phases of 0, 30, 60, 90, 120, 150, and 180 degrees respectively. The target rectangular figures are shown in Figure 2.2. The figures were always presented in the same order
Figure 2.2 Scanning Target Rectangles
in step fashion from 0 to 180. Continuous concurrent feedback was presented to the participants in both groups during each scanning trial.

**Acquisition Trials**

Each block of acquisition trials comprised 20 discrete iterations of the to-be-learned movement with feedback as determined by group assignment.

Participants assigned to the concurrent feedback group received feedback as the movement was being performed during acquisition; participants assigned to the terminal feedback group received feedback after the movement was completed during acquisition.

Participants began each trial in acquisition and each trial in retention with the left arm set at a 90° relative offset to the right arm. At the start of each trial, the diamond to be inscribed was displayed to the participants on the computer monitor. After a few seconds, the diamond was withdrawn, the screen was cleared and a signal tone was sounded. Participants were instructed to draw the circle which inscribed the diamond at the sound of the tone. A second tone sounded to indicate that the movement should be complete. The participants were instructed to draw exactly one circle in the duration defined by the beginning and ending tones. The duration of each trial was approximately 1 second.

The requirement to draw only one circle per trial makes the task discrete and distinguishes it from the 90° relative phase task employed in other recent experiments. In other bimanual coordination experiments, participants practiced continuous versions of this task. For example, Zanone and Kelso (1992) had participants practice the 90°
relative phase task for 20 s at 1.75 Hz. Lee, Swinnen, and Verschueren (1995) had participants practice the same task for 15 s at 1 Hz. The time required to complete one circle in this experiment was approximately the time required to complete one circle in the Lee et al. study.

Familiarization Trials

Prior to acquisition, seven blocks of 10 continuous familiarization trials were administered. The number of blocks of familiarization trials was the same as the number of blocks in each set of scanning (probe) trials. The first few blocks of these trials were structured so that participants would become comfortable with the operation of the apparatus. Concurrent feedback was provided to participants in both groups during each of these seven blocks.

Data Analysis

The apparatus did not allow for a single direct measure of the participant’s ability to generate the target figure. Each trial comprised 1200 data samples; each sample included the sample number, the displacement of the right arm, and the displacement of the left arm.

Because there was no direct measure of the accuracy of the participant’s performance, six different aspects of the movement were assessed: relative phase, trial-to-trial consistency of relative phase, movement duration, trial-to-trial consistency of movement duration, range of motion of the left arm and range of motion of the right arm. Eight dependent measures corresponding to these six different aspects of the movement were calculated: absolute delta of relative phase, mean root mean squared
(RMS) error, standard deviation of relative phase, standard deviation of RMS error, duration, standard deviation of duration, range of motion of arm 1 and range of motion of arm 2 respectively.

Mean absolute delta of relative phase and mean RMS error measured the performance in terms of the required relative phasing. Before either of these measures could be calculated, it was necessary to normalize each displacement value for each arm in each trial to a value ranging from 0 to 1. The data were normalized using the range of motion of the corresponding arm on the corresponding trial. On the normalized scale of 0 to 1, a 90° relative phase is 0.25. Thus, the goal relative phase in this experiment was 0.25.

Mean absolute delta of relative phase was defined as the mean difference between the observed relative phase and the required relative phase. Observed relative phase was calculated by subtracting the normalized displacement of the left arm from the normalized displacement of the right arm on a sample by sample basis. If, for example, the normalized displacement of the right arm was 0.30 and the normalized displacement of the left arm was 0.20, then the observed relative phase was 0.10. Absolute delta of relative phase was calculated by taking the absolute value of the difference between the observed relative phase and goal relative phase. In the example above, absolute delta of relative phase would be 0.15. RMS error was calculated by taking the square root of the sum of the squared deltas for each trial.

Standard deviation of relative phase and standard deviation of RMS error measured each participant’s ability to consistently draw a circle from trial to trial.
Mean duration indicated whether or not participants in both groups were drawing the circle in approximately the same amount of time; the standard deviation of duration indicated whether or not participants were consistent in their timing from trial to trial. Duration was calculated as the total number of samples taken to complete the movement.

The range of movement of the right arm and the range of movement of the left arm indicated whether participants were drawing circles of the same size. Range of motion was calculated by subtracting the minimum sample value of each arm from the maximum sample value of that same arm.

Results

Individual Data

To provide a general view of performance on the to-be-learned task from the perspective of each individual, selected acquisition and retention trials are plotted for one participant representative of the concurrent group (CAW) and one participant representative of the terminal group (TRH) in figures 2.3 and 2.4 respectively. (Selected acquisition and retention trials are plotted for all participants in both groups in Appendix E.) Visual inspection of these figures indicates that by the second block of acquisition (trial 50), all participants in the concurrent group were drawing figures that appear circle-like. In contrast, three of the participants in the terminal group, JWW, NMK, and TRH, were drawing figures that resembled neither the circle expected given a 90° relative phasing of the arms nor the
Figure 2.3 Selected Trials for Experiment 1 Concurrent Participant CAW
Figure 2.4 Selected Trials for Experiment 1 Terminal Participant TRH
Figure 2.5 Selected Scan Trials for Experiment 1 Concurrent Participant CAW

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Figure 2.6 Selected Scan Trials for Experiment 1 Terminal Participant TRH
diagonal lines expected given 0° or 180° relative phasing movements. It is also interesting to note that when participants in the concurrent group regressed from the 90° relative phasing toward one of the relative phases found to be dominant for most individuals, these participants tended toward a 0° phasing pattern. Examples include trial 150 for participant BAJ, trial 170 for participant DSS, 24-hr retention trial 15 for participant ACC, and 24-hr retention trial 15 for participant MKH. Participants in the terminal group tended to regress toward the 180° relative phasing. Examples include trials 150 and 170 for participant SJN and trial 150 for participant BLN.

To provide a general view of changes in the overall coordination patterns of each individual as a function of learning the 90° relative phasing task, selected scanning (probe) trials are plotted for one participant in the concurrent group and one participant in the terminal group in figures 2.5 and 2.6 respectively. (Selected scanning trials are plotted for all participants in both groups in Appendix F.) These figures highlight the differences and similarities between individual participants. Two participants in the concurrent group, BAJ and LAO, for example, were not able to generate the goal figures for any of the trials assessed during the first block of scanning trials. Other participants including CAW, MKH, BLN and MNW were able to execute the 90° and 180° phasings but had difficulty on the 0° phasing in this first block. Participant MDW drew circle-like figures in response to the request for 0°, 90°, and 180° phasings in the same block. Visual inspection of the selected scanning trials indicates that most participants were able to generate the 90° relative phasing...
movement in the first set of scanning trials and that the two groups did not differ dramatically in their ability to generate the target figures. Previous research (Zanone and Kelso, 1992) has shown that the 90° phase offset is not very stable for most individuals. As such, it is somewhat surprising that such a large number of participants were able to perform the 90° relative phase with little to no practice. Some individuals including EGA, BLN, MDW and MNW appeared to achieve the 90° relative phasing by ignoring the time constraints of the audible metronome.

**Group Data**

Additional insights were gained from the statistical analysis of the group data. Acquisition trials were blocked into groups of 40 for analysis. Retention trials were blocked into groups of 10. Scanning (probe) trials were not analyzed statistically. An alpha level of $p < 0.05$ was selected to protect against Type I errors. The probability level for all analyses was computed using the Greenhouse-Geisser degrees of freedom adjustment.

**Acquisition**

Acquisition data were analyzed with a $2 \times 8$ (Feedback by Trial block) analysis of variance with repeated measures on the Trial block factor. The analysis of variance was performed once for each of the eight dependent measures.

**Relative Phase**

Mean absolute delta of relative phase and mean RMS error are plotted as a function of feedback and block in Figures 2.7 and 2.8 respectively. Significant effects
were found in the analysis of relative phase for Feedback, $F(1,22) = 10.14$, $p=0.0043$ and Block, $F(7,154) = 10.75$, $p=0.0001$. The Block x Feedback interaction, $F(7,154) = 0.46$, $p=0.7314$, was not significant. Similarly, significant effects were found in the analysis of mean RMS error for Feedback, $F(1,22) = 10.21$, $p=0.0042$ and Block, $F(7,154) = 10.72$, $p=0.0001$. The Block x Feedback interaction, $F(7,154) = 0.45$, $p=0.7120$, was not significant. Visual inspection of the means of absolute delta of relative phase and RMS error as well as the statistical analysis of these data indicated that these two dependent measures were redundant and that neither dependent measure was more sensitive in detecting differences between the groups than the other. The Feedback effect found for both dependent measures resulted from the concurrent group performing with significantly less error than did the terminal group throughout acquisition. The Block effect suggests that all participants improved with practice.

**Trial-to-Trial Consistency of Relative Phase**

Standard deviation of relative phase and standard deviation of RMS error as a function of feedback and blocks are plotted in Figures 2.9 and 2.10. The analysis of standard deviation of relative phase identified significant effects for Feedback, $F(1,22) = 5.40$, $p=0.0298$ and for Block, $F(7,154) = 13.51$, $p=0.0001$. There was no Block x Feedback interaction, $F(7,154) = 0.61$, $p=0.6241$. The analysis of standard deviation of RMS error also showed significant effects for Feedback, $F(1,22) = 7.21$, $p=0.0135$. 

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Figure 2.7 Absolute Delta of Relative Phase by feedback and block
Figure 2.8 RMSE by feedback and block

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Figure 2.9 Standard Deviation of Relative Phase by feedback and block
Figure 2.10 Standard Deviation of RMSE by feedback and block
and for Block, $F(7,154) = 17.68$, $p=0.0001$. Again, there was no Block x Feedback interaction, $F(7,154) = 0.97$, $p=0.4221$. Participants in the terminal feedback group were more variable from trial to trial than participants in the concurrent feedback group throughout practice. Participants in both groups became more consistent from trial to trial as a function of practice.

**Duration**

Block effects were found to be significant for both mean duration, $F(7,154)=11.77$, $p=0.0001$, and standard deviation of duration, $F(7,154)=17.21$, $p=0.0001$. Participants used more of the allotted time and became more consistent in their timing as a function of practice. Mean duration and mean standard deviation of duration are plotted in Figures 2.11 and 2.12 respectively.

**Range of Motion**

Range of motion as a function of right and left arms is plotted in figures 2.13 and 2.14. Feedback effects were found to be significant for the range of motion of the right arm, $F(1,22) = 4.65$, $p=0.0422$ and approached significance for the range of motion of the left arm $F(1,22) = 4.01$, $p=0.0577$. The Block x Feedback interaction was found to be significant for the range of motion of the right arm, $F(7,154) = 4.34$, $p=0.0031$.

Tests for simple effects examined the influence of trial block on range of motion of the right arm for each feedback group considered independently of the other group. The terminal group drew smaller circles as a function of practice $F(7,77)=3.27$, $p=0.0410$. A Tukey’s post-hoc analysis indicated that, on the second
Figure 2.11 Mean duration by feedback and block
Figure 2.12 Standard deviation of duration by feedback and block
Figure 2.13 Range of Motion in Arm 1 by feedback and block
Figure 2.14 Range of Motion in Arm 2 by feedback and block
day of acquisition, participants assigned to the terminal group drew circles that were significantly smaller than the circles drawn by the concurrent group.

Retention

Retention data were analyzed with a 2 x 6 (Feedback x Trial blocks) analysis of variance with repeated measures on the Trial block factor. The ANOVA was performed once for each of the variables under study.

Significant effects were found only for range of motion. Feedback effects were significant for the range of motion in both the right $F(1,22)=11.93, p=0.0023$ and left arm, $F(1,22)=9.45, p=0.0056$. As on the second day of acquisition, participants in the terminal group generated circles that were significantly smaller than those drawn by the terminal group.

Discussion

The results of the present study are not consistent with the findings of previous research investigating the influence of concurrent vs. terminal augmented feedback in the acquisition and retention of motor skills. Previous studies, employing unimual skills, indicated that terminal augmented feedback depresses performance during acquisition but enhances performance in retention when compared to concurrent augmented feedback (Vander Linden, Cauraugh, & Greene, 1993; Patrick & Mutlusoy, 1982; Smyth, 1978; Annett, 1970; Fox & Levy, 1969). Further, these studies have shown that when the performance of the concurrent and terminal groups on transfer tests with no augmented feedback is examined relative to the performance of these groups at the end of acquisition, the performance of the concurrent group deteriorates...
substantially whereas the performance of the terminal group remains consistent. In this study, participants in the concurrent group outperformed participants in the terminal group during acquisition as expected. However, no significant difference was found between the groups in retention. In fact, although the difference was not significant, the concurrent group performed more accurately than the terminal group during retention. The discrepancy between these results and previous results is due to the inability of the terminal group to achieve and retain the to-be-learned movement rather than to the ability of the concurrent group to retain the level of performance achieved at the end of acquisition. The concurrent group did demonstrate the characteristic performance degradation on transfer tests with no augmented feedback.

The results of this experiment suggest that augmented feedback may operate differently under various levels of task complexity and organization. A highly organized task, such as the task employed in this experiment, which requires interlimb decoupling may be more difficult than a less organized task and may benefit from the guidance of concurrent feedback. It is interesting to note that, for cognitive skills, highly organized tasks are considered less difficult than tasks of low organization. It was hypothesized that a high level of interdependency between task parts facilitates skill acquisition. Evidence from previous bimanual studies (Kelso, Putnam, & Goodman, 1983; Kelso, Southard, & Goodman, 1979; Swinnen, Walter, Lee, & Serrien, 1993; Swinnen, Walter, Pauwels, Meugens, & Beirinckx, 1991; Swinnen, Walter, & Shapiro, 1988) suggests that this might not be the case for motor skills. These studies showed that the limbs tend to act initially as a coordinated unit and that
the acquisition of a new bimanual coordination pattern requires the decoupling of existing patterns.

One explanation for these results may be that much of the existing research examining augmented feedback in motor learning did not consider the stage of learning of the individual. Gentile (1972, 1987) suggested the practice environment should be structured to consider the stage of learning of the performer. Early in practice, augmented feedback which aids the performer in "getting the idea of the movement" and in detecting regulatory stimuli may be appropriate. Later, feedback which facilitates movement consistency or movement diversification would be appropriate. The interaction between the stage of learning of the performer and the effectiveness of augmented feedback would be more pronounced in highly organized tasks, such as the task employed in this experiment, which require the establishment of new movement patterns and the decoupling of existing ones. Participants in the terminal group may not have gotten "the idea of the movement".

Finally, experimental procedures may have accounted for the failure of participants in the terminal group to learn the movement. Concurrent feedback was administered to subjects in both the terminal and concurrent feedback groups during the pre-acquisition practice trials and during each of the six scanning trial blocks. Presentation of this concurrent feedback may have worked to the benefit of participants in concurrent group and to the detriment of participants in the terminal group. The failure to find an interaction between block and feedback in acquisition
suggests that the groups were different from the initial trial block through the end of acquisition.

References to Chapter 2


CHAPTER 3

Introduction

Results from several bimanual coordination experiments (Kelso, Putnam, & Goodman, 1983; Kelso, Southard, & Goodman, 1979; Swinnen, Walter, & Shapiro, 1988) support the hypothesis that the principles which account for the acquisition and retention of single-limb movements may not fully account for the acquisition and retention of coordinated movements involving more than one limb. Experiment 1 of this dissertation lends support to this growing body of evidence. One explanation for these results may be that the stage of learning of the individual (Gentile, 1987) must be taken into account for tasks of high organization and for tasks that require the development of a new pattern of coordination. Because much of the research investigating augmented feedback has employed familiar single-limb tasks, the stage of learning of the individual has not been considered.

The purpose of this experiment was to replicate and extend the findings of Experiment 1 by testing the hypothesis that participants in the concurrent group outperformed participants in the terminal group because concurrent augmented feedback facilitates "getting the idea of the movement" whereas terminal augmented feedback does not. Four feedback groups were employed: concurrent, terminal, transition, and control. Concurrent and terminal feedback groups received feedback as in Experiment 1. Transition and control groups received concurrent feedback during the first two blocks of acquisition trials only. During the remaining acquisition trials,
the transition group received terminal feedback and the control group received no augmented feedback. The transition group was included to test the hypothesis that initial presentation of concurrent feedback allows participants to “get the idea of the movement” early in practice and then benefit from terminal feedback later in practice. The control group was included to control for the amount of practice. If the results of Experiment 1 can be explained by a stages of learning scenario, then it was expected the transition group would perform more accurately than the other experimental groups during retention.

A second hypothesis tested in this experiment is that the "periodic transfer tests" incorporated in Experiment 1 biased the learning of the bimanual task in favor of the concurrent augmented feedback group. If the results of Experiment 1 can be explained by the influence of these scanning (probe) trials, then it was expected than the elimination of these trials would eliminate their effects on learning.

Method

Participants

Forty-eight students from kinesiology lecture classes completed the experiment in exchange for course credit. None of the participants completing this second experiment participated in Experiment 1. All participants gave informed consent.

Participants were randomly assigned to one of four feedback groups: concurrent, terminal, transition, and control. Participants in the concurrent feedback group received feedback as the to-be-learned movement was practiced during each trial of acquisition. Participants in the terminal feedback group received feedback after
the to-be-learned movement was completed. Participants in the transition group received concurrent augmented feedback during the first two trial blocks of acquisition then terminal feedback for the remainder of acquisition. Participants in the control group received concurrent feedback during the first two trial blocks of acquisition followed by no feedback for the remainder of practice.

**Apparatus**

The apparatus used in this experiment was the same apparatus that was used in Experiment 1 of this dissertation. It consisted of two horizontal manipulanda attached to two vertical axles. Potentiometers located at the base of the axles allowed for the collection of displacement data which was displayed, when appropriate, to participants via a computer monitor.

Data were collected at the rate of approximately 500 cycles per second via a Keithley Metrabyte uCDAS-16G data acquisition board installed in an IBM Model 70 personal computer. The computer used in this experiment was different than the computer used in Experiment 1. The data acquisition board had been set up in this new computer so that the polarity of the sample points was exactly opposite of that in Experiment 1. In the first experiment, all data were positive values; in this experiment, all data were negative values.

The entire experiment, including the collection of data, was controlled by a computer program written in Quick Basic. The program used in Experiment 1 was modified to include two new experimental groups, to account for the change in
polarity of the data acquisition board and to eliminate the collection of scan trial data. (A copy of the modified program is found in Appendix G.)

**Task**

Participants were asked to use the apparatus to inscribe a circle in a square.

**Procedure**

The procedure followed in this experiment was similar to that followed in Experiment 1. However, no scan trial blocks were administered during this experiment and the number of practice trials was reduced to one block of 10 trials.

Feedback administered during the practice trials was consistent with the feedback to be administered on the first block of acquisition trials. If the participant was to receive concurrent feedback on the first block of acquisition, concurrent feedback was administered during practice. If the participant was to receive terminal feedback on the first block of acquisition, terminal feedback was administered during practice.

The experiment comprised five experimental sessions on four consecutive days. The first two sessions were acquisition sessions; the remaining three sessions were retention sessions. On the second day of the experiment, participants completed an acquisition session followed five minutes later by a retention session.

Each acquisition session consisted of eight blocks of learning trials. A block of learning trials comprised 20 iterations of the to-be-learned movement with feedback as determined by group assignment. Each retention session consisted of three blocks of
retention trials. A block of retention trials consisted of 10 iterations of the to-be-learned movement without feedback.

**Data Analysis**

Four different aspects of the movement were considered: relative phase, trial-to-trial consistency of relative phase, range of motion of the left arm and range of motion of the right arm. Six dependent measures corresponding to these four different aspects of the movement were calculated from the collected data. These measures include absolute delta of relative phase, RMS error, standard deviation of relative phase, standard deviation of RMS error, range of motion of the right arm and range of motion of the left arm. Because duration and standard deviation of duration revealed no differences between experimental conditions in Experiment 1, these measures were not considered in this experiment.

**Results**

**Individual Data**

Selected acquisition and retention trials are plotted for one participant representative of each group in figures 3.1 through 3.4. (Selected acquisition and retention trials are plotted for all participants in this experiment in Appendix I.) In the first experiment, by the second block of acquisition, all participants in the concurrent group were drawing circle-like figures. In this experiment, less than half the participants in the concurrent group were drawing circle-like figures at the same point.
Figure 3.1 Selected Trials for Experiment 2 Concurrent Participant JLD
Figure 3.2 Selected Trials for Experiment 2 Control Participant EEC

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Figure 3.3 Selected Trials for Experiment 2 Terminal Participant SAV
Figure 3.4 Selected Trials for Experiment 2 Transition Participant CJB
in time. A summary of the number of participants approximating a circle based on a relative phase criterion value for each of the selected trials in both Experiments 1 and 2 is shown in Figure 3.5. Participants approximated a circle if they drew a figure with an average relative phase between 0.20 and 0.30 on the normalized scale ranging from 0 to 1. A 90° relative phase is 0.25 on this scale.

**Group Data**

Acquisition trials were blocked into groups of 40 for analysis. Retention trials were blocked into groups of 10. An alpha level of $p < 0.05$ was used to protect against Type I errors. The probability level for all statistical analyses was computed using the Greenhouse-Geisser degrees of freedom adjustment.

**Acquisition**

Acquisition data were analyzed with a $4 \times 8$ (Feedback by Trial block) analysis of variance with repeated measures on the Trial block factor. The analysis of variance was performed once for each of the six dependent measures.

**Relative Phase**

Mean absolute delta of relative phase and mean RMS error are plotted as a function of feedback and block in Figures 3.6 and 3.7 respectively. Statistical analysis of mean absolute delta of relative phase indicated that the Block x Feedback interaction was significant, $F(21,308) = 5.44$, $p=0.0001$. Statistical analysis of mean RMS error also indicated that the Block x Feedback interaction was significant,
Figure 3.5 Number of subjects approximating a circle on selected trials.
Figure 3.6 Absolute Delta of Relative Phase by feedback and block
Figure 3.7 RMSE by feedback and block

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\[ F(21,308) = 5.58, p=0.0001. \] Because the analysis of mean RMS error proved to be redundant with the analysis of mean absolute delta of relative phase, tests for simple effects and post hoc analyses were performed on the absolute delta of relative phase only.

Tests for simple effects examined the influence of trial block on the mean absolute delta of relative phase for each feedback group considered independently of other feedback groups. These tests showed that the means of the absolute delta of relative phase for the control group displayed no significant differences across time, \[ F(7,77) = 1.00, p = 0.3814. \] All other experimental groups including the concurrent group \[ F(7,77) = 19.49, p=0.0001, \] the terminal group \[ F(7,77) = 14.73, p = 0.0001, \] and the transition group \[ F(7,77) = 8.60, p=0.0001, \] showed significant improvement in mean absolute delta of relative phase as a function of practice.

Post-hoc analyses examined the differences between the feedback groups at each trial block. These tests were conducted via the Tukey's multiple comparison procedure. The Tukey's test indicated that there was no significant difference between the feedback groups during the first three blocks of acquisition. During block 4, the last trial block of the first acquisition session, participants in the control feedback group were significantly less accurate than participants in the other three feedback groups. Participants in the concurrent feedback group were significantly more accurate in producing the required relative phase than were participants in the other three feedback groups. Throughout the entire second practice session, participants in the control feedback group were significantly less accurate than participants in the
remaining three feedback groups. Participants in the concurrent group were consistently more accurate in generating the goal figure than participants in the terminal and transition groups although this difference did not reach significance. The Tukey's post hoc procedure indicated that the minimum difference between the means of any two experimental groups required to reach significance was approximately 15. The difference between the means of the concurrent and terminal groups was approximately 5.5 throughout the second acquisition session. The difference between the means of the terminal and transition groups was approximately 2.5, roughly half the difference between the terminal and concurrent groups.

These analyses indicate that the concurrent, terminal and transition groups improved in their ability to generate the required relative phase over the course of acquisition. The control group did not improve as a function of practice; this group performed more poorly throughout acquisition than the other three experimental groups. The concurrent group acquired the task more quickly than either the terminal or transition groups. The concurrent group also performed consistently better than the terminal or transition groups throughout practice. However, this difference was only significant on block 4 of acquisition.

**Trial-to-Trial Consistency of Relative Phase**

Standard deviation of relative phase and standard deviation of RMS error as a function of feedback and blocks are plotted in Figures 3.8 and 3.9. Statistical analysis revealed a significant block effect $F(7,308)=40.39$, $p=0.0001$. All participants became more consistent from trial to trial as a function of practice.
Figure 3.8 Standard Deviation Relative Phase by feedback and block
Figure 3.9 Standard Deviation of RMSE by feedback and block

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Range of Motion

Range of motion of the right and left arms are plotted in Figures 3.10 and 3.11 respectively. Block effects were found to be significant for both the range of motion of the right arm, $F(7,308)=9.10$, $p=0.0001$, and the left arm, $F(7,308)=4.30$, $p=0.0084$. However, a significant block x feedback interaction $F(21,308)=2.36$ was also found for range of motion in the right arm. Tests for simple effects show that the mean range of motion of the right arm for the control group increased significantly as a function of practice, $F(7,77)=6.10$, $p=0.0050$ as did the range of motion of the right arm for the transition group, $F(7,77)=9.41$, $p=0.0001$.

Retention

Retention data were analyzed with a 4 x 9 (Feedback by Trial block) analysis of variance with repeated measures on the Trial block factor. The analysis of variance was performed once for each of the four dependent measures.

Relative Phase

Significant effects were found in the analysis of absolute relative delta for Feedback, $F(3,44)=3.34$, $p=0.0277$, and Block, $F(8,352)=3.51$, $p=0.0091$. A Tukey's post-hoc analysis of the Feedback effect indicated no significant differences between the control and concurrent groups. This analysis also indicated no significant difference between the concurrent, terminal and transition groups. Figure 3.1 shows that the performance of participants in the concurrent group deteriorated over the nine blocks of retention such that it approached the level of the performance of participants
Figure 3.10 Range of Motion in Arm 1 by feedback and block
Figure 3.11 Range of Motion in Arm 2 by feedback and block
in the control group. Although this difference did not effect a significant interaction, it explains the finding that there was no significant difference between concurrent and control groups and no significant difference among concurrent, transition and terminal groups. Post-hoc analysis of the Block effect indicated that the second block of the 24-hr retention test and all blocks of the 48-hr retention test were significantly less accurate that the first block of retention.

**Trial-to-Trial Consistency of Relative Phase**

Statistical analysis revealed a significant block effect, $F(8,352) = 2.72$, $p=0.0362$, for standard deviation of relative phase. Participants in all groups became more consistent from trial-to-trial as a function of time.

**Range of Motion**

Block effects were found to be significant for the range of motion in both the right, $F(8,352) = 4.30$, $p=0.0084$ and left arm $F(8,.352) = 5.31$, $p=0.0003$. The range of motion of both arms tended to increase over retention.

**Discussion**

According to Gentile (1972, 1987), skill learning comprises at least two stages: "getting the idea of the movement" and "fixation/diversification". The goal in the first stage is to determine a means-end relationship with respect to the task goal. In the second stage of learning, the individual attempts to refine the ability to attain the goal of the task. For the purposes of this experiment, it was hypothesized that giving participants concurrent feedback on the first two trial blocks of acquisition would allow these participants to "get the idea of the movement" and to then benefit from
terminal augmented feedback later in practice. The results of this experiment did not support this hypothesis. Participants in the transition group did not perform more accurately than participants in the terminal group either at the end of practice or during retention. In fact, the performance of participants in the transition group declined in the block following the transition from concurrent to terminal feedback.

The most likely cause of the discrepancy in findings between Experiment 1 and Experiment 2 is that the "periodic transfer tests" employed in Experiment 1 biased learning in the favor of the concurrent augmented feedback group. One possible explanation for this discrepancy is that the concurrent feedback employed in the scanning (probe) trials enhanced the efficacy of this feedback in the acquisition trials. That is, the variability of practice encountered in the scanning trials allowed participants to better interpret concurrent augmented feedback in acquisition.

References to Chapter 3


CHAPTER 4

Previous studies employing simple, single-limb tasks have shown that the presentation of concurrent augmented feedback, as compared to terminal feedback, promotes performance during acquisition, but leads to poorer performance in retention. The purpose of this dissertation was to determine if these findings for simple, single-limb tasks would be found for a highly organized, discrete, asymmetric bimanual coordination task. The results of Experiment 1 indicated that, different from its influence on learning simple, single-limb tasks, concurrent augmented feedback can be effective for learning a discrete bimanual coordination task. However, Experiment 2 suggested that concurrent augmented feedback can influence the acquisition of both types of tasks in the same way. Thus, the hypothesized characteristic, task organization, does not account for these apparent discrepant results.

Anderson (1994) suggested several explanations for previous experiments that demonstrated that terminal feedback is more effective than concurrent augmented feedback in motor skill learning. These explanations can now be considered in light of the seemingly disparate findings reported in this dissertation. One explanation was that the visual system discourages participants from attending to the task intrinsic feedback (see Posner, Nissen, & Klein, 1976). However, the dominance of the visual system can not completely account for the findings reported in this dissertation and in recent experiments by Swinnen, Lee and Serrien (1994) and Swinnen, Lee Verschelen, Serrien and Bogaers (1997). Results from these studies demonstrated
that there are instances in which concurrent augmented feedback can be effective for skill acquisition even when vision is the mode of presentation.

The second explanation was that the degree to which participants become dependent on concurrent augmented feedback is determined by the degree to which information in the task intrinsic feedback can easily be detected (Magill, 1993). For example, Anderson (1994) cited several studies that indicated that learners substitute augmented feedback for task intrinsic feedback when the task intrinsic feedback is difficult to perceive and interpret. However, in both experiments reported in this dissertation, participants were not informed that the goal figure they were instructed to draw actually represented a 90° relative phase offset of two limbs. Because there was no apparent need in either experiment for participants to pay attention to proprioceptive information, results of the first experiment indicate that there are instances in which concurrent augmented feedback can be effective for skill learning even when the intrinsic feedback available in the task is not easy to detect.

The third explanation proposed by Anderson (1994) was that concurrent augmented feedback interferes with the development of subjective error detection and correction capabilities. Vander Linden, Cauraugh, and Green (1993) suggested that participants acquiring a skill under conditions of concurrent augmented feedback do not develop an internal reference for correctness. Evidence from Smyth (1978) supported this explanation in that it demonstrated that participants trained under concurrent augmented feedback were much less accurate in estimating error that were participants trained under terminal augmented feedback or under constrained
movement to a physical stop. Again, results of the experiments reported in this
dissertation indicated that the ability of concurrent feedback to detract from subjective
error detection and correction capabilities can not be explained solely in terms of the
time of presentation of augmented feedback.

The most likely explanation for the findings of the experiments reported in
this dissertation lies in a methodological difference between the two experiments. The
first experiment incorporated a series of “periodic transfer tests” (referred to as
“scanning trials” in Experiment 1). These tests were designed to assess changes in
preexisting coordination patterns as a function of the acquisition of the new
coordination pattern. However, each transfer test also provided the opportunity to
receive and employ concurrent augmented feedback on several different relative
phasings movements. It is notable that these transfer tests differentiate this experiment
from other experiments investigating the influence of concurrent and terminal
presentations of augmented feedback. It can be argued that the introduction of these
transfer tests is similar to the introduction of variable practice trials in a the variability
of practice study conducted by Shea and Kohl (1990) in which more variable practice
led to better learning of a skill than non-variable practice. When this difference
between Experiments is considered, the results of the experiments taken together
suggest that it is not the organization of the task that led to concurrent feedback being
at least as effective as terminal augmented feedback in Experiment 1, but the
supplemental practice on various relative phasings.

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Thus, the results of both experiments taken together support the view that the effectiveness of augmented feedback is related to the degree to which that feedback, in combination with practice variables (e.g., variability of practice), increases the efficacy of task intrinsic feedback. If the augmented feedback presented in a learning situation increases the effectiveness of task intrinsic feedback, then it is effective for learning. If augmented feedback does not increase the effectiveness of task intrinsic feedback or if augmented feedback suppresses the effectiveness of task intrinsic feedback, then it is not effective for learning. In most studies comparing the roles of concurrent and terminal augmented feedback, concurrent feedback has detracted from the effectiveness of task intrinsic feedback for reasons cited by Anderson (1994) and has not been effective for learning. However, in Experiment 1 of this dissertation, concurrent augmented feedback presented in combination with variable practice on the scanning trials, increased the efficacy of task intrinsic feedback and was at least as effective as terminal augmented feedback. Thus, the findings of this dissertation support the hypothesis by Lee, Swinnen and Serrien (1994) that augmented feedback is most useful when it assists the learner in interpreting intrinsic sources of feedback that are always available.

Implications for Training and Therapeutic Intervention

Because concurrent augmented feedback can be difficult to provide, it does not tend to be used to the degree that terminal augmented feedback is used in everyday applications. The general exception is that concurrent augmented feedback in the form of kinematic and kinetic feedback is used in many sports training and therapeutic
situations. The results of the studies reported in this dissertation as well as the results of other studies investigating the effectiveness of augmented feedback suggest that providing concurrent augmented feedback in these situations may lead to dramatic improvements in the lab or clinic which may not be replicated when the learner or patient returns to an environment where such feedback is not available, unless action is taken to enable this feedback to increase the meaningfulness of the task intrinsic feedback.

References to Chapter 4


APPENDIX A. REVIEW OF RELATED LITERATURE

Introduction

Augmented feedback has been considered by many researchers to be the single most critical variable influencing the acquisition and retention of skill (Annett & Kay, 1957; Armstrong, 1970; Newell, 1976; Schmidt, 1988; Magill, 1993). Defined as feedback about a movement response not normally available in the environment or in the movement response itself, augmented feedback is one of few motor learning variables under the direct control of the practitioner. Much of the verbal feedback given to learners of motor skills is augmented feedback. Historically, considerations of augmented feedback have revolved around the potential roles it plays in skill learning: reinforcement, information and motivation.

The earliest consideration of augmented feedback was from the perspective of reinforcement. This consideration was heavily influenced by stimulus-response (S-R) psychology. The Law of Effect, proposed by Thorndike (1927), posits that responses followed by rewards are strengthened whereas responses followed by punishments are avoided or weakened. According to Thorndike, augmented feedback serves as a reward, increasing the probability of reoccurrence of a motor response. Evidence from the line-drawing study reported by Thorndike suggested that the Law of Effect accounts for the role of feedback in skill acquisition. However, subsequent contributions by Elwell and Grindley (1938) and Seashore and Bavelas (1941) indicated that the Law of Effect does not provide a sufficient account of the role of feedback in motor learning. The Elwell and Grindley study suggested that augmented
feedback also has directive (informational) and conducive (motivational) effects on skill learning. The S-R approach to understanding human learning which gave rise to the Law of Effect began to decline in the early 1960s; subsequently, it fell out of favor. Its major legacy to the understanding of augmented feedback in skill acquisition was a number of empirical studies investigating the effects of delaying the presentation of feedback on learning.

The advent of the information-processing paradigm around the time of the Second World War led researchers to take a closer look at the information-providing aspects of augmented feedback. The information-processing approach to skill acquisition suggests that performers use the information available in augmented feedback to evaluate the outcome of the current response in an attempt to determine the most effective strategy to use on the next response. The performer uses augmented feedback to form hypotheses about the current response which are then tested in subsequent responses. In the 1950s, the Bilodeau's conducted a series of studies which confirmed the role of augmented feedback as an information provider. The closed-loop theory of motor learning proposed by Adams (1971) and the schema theory of motor learning proposed by Richard Schmidt (1975) draw heavily from research investigating the manner in which feedback is used by the motor system. The information-processing approach has led to empirical questions concerning the optimal precision level of augmented feedback, the frequency of augmented feedback and the post-feedback interval. The investigation of augmented feedback from the standpoint
of information-processing remains popular today (e.g., Guadagnoli, Dornier & Tandy, 1996; Goodwin & Meeuswen, 1995)

The motivational aspects of augmented feedback have often been ignored by researchers who assume, incorrectly, that motivational influences are constant across various feedback conditions (Newell, 1976). It has been shown that augmented feedback can encourage a performer to try harder or persist longer at a task. It can also foster goal setting and attainment (Locke, Cartledge, and Koeppel, 1968). Empirical questions from a motivation perspective consider the goal orientation of the performer in relation to the goal enhancing aspects of the feedback.

Unfortunately, according to Magill (1993), the tremendous efforts that have been made to understand the role of augmented feedback in motor learning from the perspectives of reinforcement, information and motivation have not led to a clearly defined list of principles accounting for its influence. Guidelines for determining the appropriate feedback that can be applied to various motor learning activities remain to be established (e.g., see Magill, 1993; Anderson, 1994). Perhaps, the most obvious principles or conditions to be delineated are those influencing the essential nature of augmented feedback (When is augmented feedback needed?) and its effectiveness with respect to the task being learned (What type of augmented feedback should be administered for which type of task?). The interaction between task characteristics and augmented feedback suggests that one can not be considered independently of the other. In fact, Magill suggested that the essential nature of augmented feedback may be dependent on the skill being acquired.
The primary purpose of the present review is to examine the relationship between augmented feedback and task characteristics. First, evidence suggesting that task characteristics specify the appropriate feedback for learning will be examined. Second, the influence of augmented feedback will be considered from the perspective of the environment, the nature and the goal of the task. Finally, guidelines for the use of augmented feedback in various training situations will be discussed along with potential topics for future research.

**Augmented Feedback**

The term ‘augmented feedback’ has taken on a variety of meanings and has been used synonymously with several other terms (Magill, 1993). It is therefore necessary to define how it, and commonly used related terms, will be used in this paper.

**Definitions**

Feedback is typically defined as all information about a movement response available during or after a response (Schmidt, 1988). Feedback comprises two types: intrinsic and augmented.

**Intrinsic Feedback**

Intrinsic feedback is information inherent in the environment or in the task itself. It is normally available during or after a movement and is often referred to as “task intrinsic feedback”. Sources of task intrinsic feedback can be external or internal. External sources are detected by the visual, auditory or tactile systems. The sound of a bat hitting a ball is an example. Internal task intrinsic feedback relates to
proprioception and is detected by receptors in the skin, joints, muscles and tendons. Dancers are often instructed to find their "center". The feeling of "center", of the body being in balance about the center of gravity, is an example of internal intrinsic feedback.

Augmented Feedback

Augmented feedback is feedback about the movement response not normally available in the environment or in the movement response itself. It is provided by a source external to the person performing the skill. The two primary sources of augmented feedback are knowledge of results (KR) and knowledge of performance (KP). KR is augmented feedback about the outcome of a movement response. KR typically takes the form of a score or error measure. If the goal of a task is to move as fast as possible, KR may reflect the time attained (e.g., 500 msec). If, on the other hand, the goal of a task is to complete a movement in a specified goal time, KR may reflect the discrepancy between the goal and the time realized (e.g., 100 msec slow). KP is augmented feedback about the movement characteristics that led to the response outcome. KP may be descriptive (e.g., you failed to tuck your head) or prescriptive (e.g., keep your chin to your chest). KP is most often presented verbally. However, it can also be provided through videotape replays or graphical presentations of kinematic information.

Augmented feedback can also be classified by time of presentation. Terminal augmented feedback is presented upon completion of a movement response. Concurrent augmented feedback is presented during a movement response. KR and KP
are typically presented as terminal augmented feedback. However, KP can also be presented concurrently.

Anderson (1994) noted that augmented feedback typically involves a supplemental feedback loop against which performance can be compared. He suggested further that it is not always possible to provide a performance standard against which intrinsic feedback can be compared.

**Knowledge of Results**

A great majority of the studies investigating the role of augmented feedback on learning have examined the influence of KR on the acquisition and retention of skill (Newell, 1976; Salmoni, Schmidt, & Walter, 1984; Magill, 1993; Anderson, 1994). The most frequent focus of KR research has been the timing, frequency and scheduling of presentation of KR. Few of these studies have directly investigated the relationship between augmented feedback and task characteristics. However, the interaction of augmented feedback with task characteristics has been suggested as an explanation for the varied, often disparate, findings regarding the effectiveness of KR. The influence of task characteristics on the effectiveness of KR begins to become apparent when one examines KR research from the perspective of the positive, negative and neutral effects KR can have on learning. Magill (1993) cited empirical evidence which demonstrated that augmented feedback influences skill acquisition and retention in one of four ways. Augmented feedback can be essential for skill acquisition, beneficial to skill acquisition, not necessary for skill acquisition, or a deterrent to skill acquisition.
Using a task perspective, Magill (1993) identified two task performance conditions under which augmented feedback is essential for skill acquisition. Augmented feedback is necessary when critical sensory feedback is not available in the environment or in the movement response such as when drawing a line of a certain length without vision (Trowbridge & Cason, 1932) or positioning a lever to a criterion location without vision (Bilodeau, Bilodeau, & Schumsky, 1959; Bennett & Simmons, 1984). Augmented feedback is also necessary when critical sensory information is available but, due perhaps to inexperience or the novelty of the skill, cannot be used to evaluate the response. For example, participants in laboratory experiments do not typically have experience with subsecond goal times. As such, initial feedback regarding time is needed to allow participants to develop an internal referent against which to compare their own performance (Newell, 1974). It follows that augmented feedback enhances skill learning acquisition when participants are able to evaluate to a limited degree the outcome of the movement response in relationship to the movement goal such as when learning a complex arm movement (Stelmach, 1970) or a one-hand set-shot in basketball with the nondominant hand (Wallace & Hagler, 1979).

In contrast, augmented feedback is not needed for skill acquisition when the sensory feedback provided in the environment or through the movement response is inherently sufficient to allow for an evaluation of the movement response against the movement goal (Magill, 1993). Augmented feedback has been shown to be redundant, for example, in the acquisition of an anticipation timing task (Magill, Chamberlin, & Hall, 1981) and of the Pedestal Sight Manipulation Test (Goldstein & Rittenhouse, 1976).
1954). One common characteristic of the skills which can be learned without augmented feedback is that these skills have some external detectable referent that can be used to evaluate movement outcome. The learner may not be consciously aware of this external referent.

Augmented feedback **hinders skill acquisition** when the learner develops a dependency on this feedback such that the withdrawal of the feedback results in degradation or complete deterioration of performance (Magill, 1993; Annett, 1959). A dependency may develop, for example, when the sensory information available is not adequate for skill acquisition and augmented feedback becomes essential. Annett, employing a constant force task, demonstrated that participants are particularly susceptible to developing a dependency on feedback presented concurrently. The most prevalent hypothesis which accounts for this dependency suggests that participants substitute augmented feedback for sensory information as opposed to using it to enhance or augment sensory information. Participants learn to perform the skill using augmented feedback instead of sensory information and therefore become dependent on it. An alternative explanation suggested by Proteau, Marteniuk, Girouard, & Dugas (1987) argues that KR becomes part of the memory representation developed during skill acquisition. When KR is withdrawn, the memory representation is not sufficient to enable successful performance.

The task characteristics or skill-learning conditions that account for these positive, negative and neutral effects of augmented feedback on motor learning remain to be delineated (Magill, 1993). One factor that has been proposed to account for these
effects may be the degree to which sensory information can be detected. If sensory information available in the environment or in the movement response is readily detected, it is unlikely that augmented feedback is necessary for skill acquisition. If the sensory information available in the environment or from the movement outcome is impoverished or inadequate, then augmented feedback will either be necessary for any learning to occur or to enhance the learning that does occur. It is apparent from Magill’s review that task characteristics play an important role in determining the most effective form of augmented feedback, if any, to be provided in various skill learning situations.

Knowledge of Performance

The influence of KP on the acquisition and retention of skill has not been studied as extensively as has the influence of KR. Further, the questions which have been of most interest to researchers examining the role of KP in motor learning have been quite different from the questions of those studying KR. Most of the studies investigating KP have examined issues relating to mode of presentation and content. The graphical presentation of kinematic and kinetic information feedback, videotape replay and stop-action photography have been examined as effective means of delivering KP. Of particular interest in this review are those studies which have suggested a relationship between the content of the KP, the characteristics of the task and the acquisition of the skill (see Newell & Walter, 1981 for a review of several such studies).
One early example of anecdotal evidence suggesting a relationship between KP, task characteristics and skill acquisition involved the skill of rifle shooting. English (1942) and his colleagues employed a kinematic technique to teach army recruits to squeeze the stock of a rifle as well as the trigger with the whole hand. This study was conducted after efforts to instruct the recruits to squeeze the trigger and stock as if squeezing a sponge failed. English modified the stock of the rifle used by the recruits so that the recruits could watch the progress of fluid in a graded tube as concurrent augmented feedback while practicing the "trigger-squeeze" technique. Recruits were encouraged to squeeze the stock of the rifle simultaneously with the trigger to develop a slow smooth squeezing action on the trigger. After each shot at a target, recruits compared the level of fluid generated by their performance with the level reached by the expert marksman. Although no data were presented, English reported that "excellent results were obtained. Men given up as hopeless by their officers and non-commissioned officers showed rapid improvement in a large percentage of cases." (p. 4) After seven hours of drill in the laboratory, nearly all recruits trained using this technique were brought up to the minimum standards for efficiency in actual range tests.

In 1956, Howell employed kinetic augmented feedback to teach the sprint start for shorter running events. He compared the effectiveness of conventional coaching to the effectiveness of presenting participants with a force-time (graph) of their performance after each trial. Twenty participants were assigned to one of two groups: conventional coaching or kinetic feedback. Participants receiving kinetic feedback
were told that the ideal force-time curve was a rectangular shape indicative of instantaneous force production. Discrepancy scores were calculated as the difference in area between actual and optimal impulse curves. Participants practiced 84 trials over ten practice sessions. At the end of practice, participants receiving kinetic information feedback demonstrated significantly less error than participants receiving conventional coaching.

Hatze (1976) demonstrated that the introduction of kinematic feedback at the point in acquisition at which performance typically asymptotes can lead to significant performance improvements. Hatze had a single participant practice raising one leg with an attached 10 kg mass approximately 40 degrees in the sagittal plane as rapidly as possible. The participant performed 120 trials with movement time KR. The participant then practiced an additional 100 trials during which the movement time KR was replaced by a time-velocity curve generated by the hip and knee joints during movement execution. A computer-derived optimal time-velocity curve for the participant was superimposed on the actual time-velocity curve. The introduction of kinematic feedback resulted in an immediate reduction in movement time. At the end of the 100 trials employing this feedback, participant performance was very near the predicted optimum.

In the acquisition of ballistic skills, information derived from concurrent kinematic and/or kinetic feedback can only be used on the next trial. Lionvale (as cited in Newell & Walter, 1981) employed an auditory kinematic feedback presentation to teach the skill of casting for fly fishing. The auditory kinematic feedback represented
the rate of change of displacement of the elbow during the cast. Prior to practice, participants in the kinematic feedback group listened to a sound which represented the rate of change of displacement produced by a champion fly caster. As the crucial element of the cast was relatively short, participants in this experiment were only able to use the feedback to adjust the next response. Although the difference between kinematic and control groups was not statistically significant, the group with kinematic feedback produced better casting performance than the control group.

Having reviewed studies such as these, Newell and Walter (1981) hypothesized that kinematic and kinetic feedback should benefit the acquisition of any skill to the degree that information provided by this feedback is congruent with the task goal. Task criteria and other task related factors determine the most effective feedback for learning. As the movement pattern to be produced becomes increasingly complex (for example, requiring a sine wave pattern or a circular action at the shoulder point), kinematic and kinetic feedback may become increasingly useful.

However, Newell and Walter also suggest that, at some point, the number of degrees of freedom of the task may be such that kinematic or kinetic information on each of the biomechanical links may become overwhelming. A performer addresses the control of increasing degrees of freedom by organizing the various kinematic links into a single coordinated unit. Similarly, the task for the experimenter or instructor is to reduce or organize information feedback into a coherent unit which represents the movement criteria. As an example, Newell and Walter cite evidence that the most critical parameter for acquiring the skill of weight lifting is the vertical velocity of the
bar. They suggest that the presentation of augmented feedback on the vertical velocity of the bar in conjunction with a template from a champion lifter may be sufficient for skill acquisition; information at the level of the joints may not be needed. In other motor skills, a particular kinematic pattern may maximize force production. In such cases, it would be appropriate to provide kinematic rather than kinetic feedback. Still other skills such as writing a signature on a pressure pad may have dual kinematic and kinetic criteria. Newell and Walter concluded that determining the appropriate feedback to administer in such cases has interesting practical and theoretical applications.

**Augmented Feedback from a Task Perspective**

Both the KR and KP literature suggest a relationship between task characteristics and the effectiveness of augmented feedback in skill learning. From an empirical viewpoint, however, two questions need to be considered. First, is there any direct empirical evidence to support the hypothesis that task characteristics specify the most effective feedback for skill acquisition? Second, what are the task characteristics that specify feedback?

**Importance of Task Characteristics**

The most direct consideration of the relationship between task characteristics and augmented feedback has come from the motor behavior lab at the University of Illinois - Urbana-Champaign. Between 1983 and 1990, Karl Newell and his colleagues reported a series of experiments which examined the hypothesis that task
characteristics specify the appropriate feedback for learning. (These experiments are summarized in Table A.1).

The first two experiments (Newell, Quinn, Sparrow, & Walter, 1983) in this series from the Illinois lab contrasted the effectiveness of outcome KR to kinematic forms of KR in the acquisition of a rapid arm movement. The first experiment compared three forms of discrete kinematic KR to traditional movement-time KR and to the absence of KR. The three kinematic forms of KR included peak acceleration (PA), elapsed time from movement onset to the temporal onset of the acceleration peak (TP), and the velocity when crossing the target location (FV). Participants in this experiment learned to produce a horizontal flexion movement to locations 15, 30 and 45° forward of the start position. Results suggested that discrete kinematic KR provides information that is no more useful than movement time KR in the acquisition of the horizontal flexion. However, it should be cautioned that, due to a lack of a retention test, these results reflected acquisition of the skill only; that is, these results represented a comparison of the various forms of feedback on the short term performance changes associated with acquisition when those forms of feedback were available rather than the long-term changes associated with retention involving a common feedback form or no feedback (see Salmoni, Schmidt, & Walter, 1984).

The second (Newell et al., 1983) experiment contrasted continuous kinematic KR in the form of a velocity-time curve to movement-time KR and no KR. The task employed was identical to that used in Experiment 1. The results of this experiment suggested that kinematic FB may be more effective than traditional KR in the
Table A.1. Importance of Task Characteristics

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<td>Newell, K.M.</td>
<td>83</td>
<td>1</td>
<td>Kinematic information feedback for learning a rapid arm movement</td>
<td>SS</td>
<td>RAPID HORIZONTAL FLEXION</td>
<td>N</td>
<td>MT, PA, TP, &amp; FV</td>
<td>BETWEEN SS</td>
<td>1: MT 2: PA 3: TP 4: FV 5: No KR (NK)</td>
<td>Verbal</td>
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<td>10 trials</td>
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<td>To investigate the effectiveness of the presentation of outcome KR as compared to the presentation of kinematic forms of KR in the acquisition of motor skill. In particular, these studies compared outcome KR to discrete kinematic KR (Experiment 1) and to continuous velocity-time information (Experiment 2) in the acquisition of a rapid arm movement,</td>
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<td>Discrete kinematic KR provides information that is no more useful than movement time KR in the acquisition of a rapid arm movement requiring horizontal flexion at the shoulder.</td>
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<td>Nowell, K.M., Quinn, J.T., Sparrow, W.A., &amp; Walter, C.B.</td>
<td>83</td>
<td>2. Kinetic information feedback for learning isometric tasks</td>
<td>90</td>
<td>Rapid horizontal flexion, Horizontal angular displacement bar</td>
<td>MINIATE MT</td>
<td>N</td>
<td>MT, PA, TP, &amp; FV</td>
<td>1: No KR</td>
<td>2: MT</td>
<td>3: Graphics</td>
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<td>Day 1: 25 pretrial 50 trials Day 2: 50 trials</td>
<td>None</td>
<td>SIGN EFFECTS FEEDBACK, TRAILS (3) &gt; (2) &gt; (1) PA, TP and FV were also analyzed. Feedback type was found to have a significant effect on TP. Both KR groups had significantly higher TP than the no-KR group.</td>
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<td>Newell, K.M., Sparrow, W.A., &amp; Quinn, Jr., J.T.</td>
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<td>30</td>
<td>Isometric force production</td>
<td>Indentifiable handle with attached strain gages</td>
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<td>Absolute integrated impulse-velocity curve, impulse size, time to peak force, &amp; rate of force production</td>
<td>1: Graphics 2: Absolute impulse 3: Absolute impulse</td>
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<td>Newell, K.M., &amp;</td>
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<td>Assessed information and the acquisition of isometric tasks.</td>
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<td>Carlton, M.J.</td>
<td></td>
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<td>To examine the influence of task and organisational constraints on the effectiveness of kinetic information feedback and task criterion feedback. In particular, these studies examined the requirement that task criterion information be superimposed on kinetic feedback in the acquisition of a finger press isometric task when (Exp. 1) the shape of the criterion curve was familiar to participants and (Exp. 2) the shape of the criterion curve was unfamiliar to participants.</td>
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<tr>
<th>Purpose</th>
<th>Apparatus</th>
<th>Constraints</th>
<th>Measure(s)</th>
<th>Delivery</th>
<th>Units</th>
<th>Aco</th>
<th>Ret</th>
<th>Results</th>
<th>Results</th>
<th>Conclusions</th>
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<tbody>
<tr>
<td>N</td>
<td>Absolute integrated impulse error</td>
<td>Impulse size, time to peak force, and force duration</td>
<td>N, sec</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Absolute integrated impulse error, feedback</td>
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1. Impulse KR
2. Template + Force-time
3. Force-time + Impulse KR

1. Verbal
2. Graphic display
3. Graph + Verbal

N, sec T 100 25

Absolute integrated impulse error, feedback

Significant feedback (2), (3) > (1)

Significant feedback (2), (3) > (1)

Impulse KR does not improve performance given these task constraints.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>#</th>
<th>Title / Design</th>
<th>Set</th>
<th>Task</th>
<th>Goals</th>
<th>FB / Dependent Variable</th>
<th>Groups</th>
<th>Feedback</th>
<th>FB</th>
<th>GIT</th>
<th>Trials</th>
<th>Trials</th>
<th>Acquisition</th>
<th>Retention</th>
<th>Conclusions</th>
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<tbody>
<tr>
<td>Newell, K.M., &amp;</td>
<td>87a</td>
<td>2</td>
<td>***</td>
<td>24</td>
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<td></td>
<td></td>
<td>N</td>
<td>Absolute</td>
<td></td>
<td></td>
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<td></td>
<td>N must</td>
<td>T</td>
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<tr>
<td>Carlton, M.J.</td>
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<td>Presentation of the criterion curve facilitated the scaling of force production. It did not seem to impact the force-time profile itself. It seemed to remember the criterion profile from the instructions. Task and organisational constraints determine the degree to which kinematic feedback and criterion information facilitate the acquisition of isometric tasks.</td>
</tr>
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<table>
<thead>
<tr>
<th>Authors</th>
<th>Yr</th>
<th>#</th>
<th>Title / Description</th>
<th>Apparatus</th>
<th>Constraints</th>
<th>Dependent Measure(s)</th>
<th>Groups</th>
<th>FB</th>
<th>Feedback</th>
<th>CTR</th>
<th>Trials</th>
<th>Trials</th>
<th>Acquisition</th>
<th>Retention</th>
<th>Conclusions</th>
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<tr>
<td>Newell, K.M., Quinn, J.T., &amp; Carlton, M.J.</td>
<td>87k</td>
<td>1</td>
<td>KINEMATIC INFORMATION FEEDBACK AND TASK CONSTRAINTS</td>
<td>RAPID HORIZONTAL FLEXION</td>
<td>Horizontal Angular Displacement Bar</td>
<td>Minimize absolute integrated position error by moving the bar through two target positions at a constant rate of acceleration (0.00022 deg/4 sec)</td>
<td>4</td>
<td>N</td>
<td>By group 1: Movement time 2: Verbal integrated error 3: Position-time error 4: Velocity-position</td>
<td>T</td>
<td>75</td>
<td>25</td>
<td>SIGN, EFFECTS</td>
<td>SIGN, EFFECTS</td>
<td>THIS EXPERIMENT CONFIRMED PREVIOUS FINDINGS THAT FEEDBACK IN THE FORM OF A CONTINUOUS POSITION-TIME TRACE IS MORE EFFECTIVE THAN DISCRETE XR IN-ON THE GOAL OF THE TASK IS TO MINIMIZE ABSOLUTE INTEGRATED POSITION-TIME ERROR. IT ALSO DEMONSTRATES THAT THE PRESENTATION OF DISCRETE AS COMPARED TO CONTINUOUS INFORMATION IS NOT THE ISSUE. CONTINUOUS VELOCITY-POSITION INFORMATION DOES NOT FACILITATE ACQUISITION OR RETENTION OF THE POSITION-TIME TASK.</td>
</tr>
<tr>
<td>Newell, K.M., Quinn, J.T., &amp; Carlton, M.J.</td>
<td>87k</td>
<td>2</td>
<td>***</td>
<td>RAPID HORIZONTAL FLEXION</td>
<td>Horizontal Angular Displacement Bar</td>
<td>Maintain a constant velocity in a certain phase of the discrete movement</td>
<td>4</td>
<td>N</td>
<td>By group</td>
<td>Day 1: 75</td>
<td>Day 2: 50</td>
<td>SIGN, EFFECTS</td>
<td>No significant effects.</td>
<td>Movement time and absolute integrated error provide the necessary information to acquire and retain the task. implying that participants can perceive constant velocity of their limb movements.</td>
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<tr>
<td>Newell, K.M., Quinn, J.T., &amp; Carlton, M.J.</td>
<td>876</td>
<td>3***</td>
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<tr>
<td>22 Rapid Horizontal Flexion</td>
<td>Manage absolute integrated velocity-position error</td>
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<tr>
<td>Horizontal angular displacement bar</td>
<td>MT: 300 ms Range: 30°</td>
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<td>N</td>
<td>Absolute integrated velocity-position error</td>
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<tr>
<td>1: Position-time</td>
<td>1: Graphical display</td>
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<tr>
<td>2: Velocity-position</td>
<td>2: Graphical display</td>
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<tr>
<td>By Group</td>
<td>75</td>
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<tr>
<td>25 SIGN EFFECTS FEEDBACK, TRIALS FEEDBACK x TRIALS FEEDBACK (T &gt; T) NO GROUP DIFFERENCE ON BLOCKS 2 AND 6</td>
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<tr>
<td>25 SIGN EFFECTS FEEDBACK, TRIALS FEEDBACK (T &gt; T) GROUP DIFFERENCES WERE MAINTAINED. HOWEVER, PERFORMANCE OVER RETENTION DETERIORATED.</td>
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<td>Experiment 1 and Experiment 3 provide converging evidence that task constraints influence the effectiveness of information feedback. Results of these three experiments support the hypothesis that task constraints not only determine the optimal function for coordination and control (Kugler, Reisig, and Turvey, 1980, 1982; Newell, 1986) but also determine the nature of the information feedback required to learn a motor skill.</td>
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<table>
<thead>
<tr>
<th>Newell, K.M., Carlton, M.J., &amp; Antoniou, A.</th>
<th>90</th>
<th>1</th>
<th>THE INTERACTION OF CRITERION AND FEEDBACK INFORMATION IN LEARNING A DRAWING TASK</th>
</tr>
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<tbody>
<tr>
<td>To investigate the influence of feedback and criterion information on the learning of a two-dimensional drawing task as a function of task constraints and prior knowledge of task criterion.</td>
<td>42</td>
<td></td>
<td>2-DIMENSIONAL DRAWING TWO-LINE ARM BARI WITH TWO POTENTIOMETERS: ONE MOUNTED AT THE INITIAL AXIS, THE OTHER AT THE MOVABLE AXIS. PROVIDE A CRITERION CIRCLE. RADII: 10 CM INSTRUCTIONS INCLUDED GRAPH OF THE CRITERION SCALED TO TWO-FIFTHS ACTUAL SIZE TO BE DRAWN. SS USED THEIR DOMINANT ARM.</td>
</tr>
<tr>
<td>N</td>
<td>Absolute integrated error &amp; Variability of absolute integrated error</td>
<td>1.</td>
<td>KR</td>
</tr>
<tr>
<td>2.</td>
<td>Config-KR</td>
<td></td>
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<tr>
<td>3.</td>
<td>Config+Criterion+KR</td>
<td></td>
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</tr>
<tr>
<td>1.</td>
<td>Verbal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Verbal+Graph</td>
<td></td>
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<tr>
<td>3.</td>
<td>Verbal+Graph</td>
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<tr>
<td>CM²</td>
<td>T</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>SIGN, EFFECTS FEEDBACK, TRIALS FEEDBACK x TRIALS FEEDBACK (3) &gt; (2), (1) FEEDBACK x TRIALS (3) &gt; (2), (1) ON BLOCK 1. GROUP DIFFERENCES DISSIPATED OVER BLOCKS SO THAT THERE WERE NO DIFFERENCES AT THE END OF ACQUISITION.</td>
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<td></td>
<td></td>
<td></td>
<td>NO GROUP DIFFERENCES.</td>
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<td></td>
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<td>PRESENTATION OF THE CRITERION INFORMATION FACILITATED THE RATE OF ACQUISITION EARLY IN PRACTICE. HOWEVER, THIS PERFORMANCE ADVANTAGE DISSIPATED OVER ACQUISITION.</td>
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<tr>
<td></td>
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<td>FAMILIARITY WITH THE CIRCLE TOOK THE FEEDBACK NECESSARY TO LEARN THE SKILL TO A SINGLE DEGREE OF FREEDOM (THE RADIUS OF THE CIRCLE) RATHER THAN THE THREE DEGREES OF FREEDOM REQUIRED TO DESCRIBE THE DUE PATH. AS PARTICIPANTS WERE FAMILIAR WITH THE CIRCLE, PRESENTATION OF ERROR KR WAS SUFFICIENT FOR SKILL LEARNING.</td>
</tr>
<tr>
<td>Newell, K.M., Carlton, M.J., &amp; Antoniou, A.</td>
<td>90</td>
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<td>Absolute integrated error</td>
<td>1.</td>
<td>KR</td>
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</tr>
<tr>
<td>2.</td>
<td>Config-KR</td>
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<tr>
<td>3.</td>
<td>Config+Criterion+KR</td>
<td></td>
<td></td>
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<tr>
<td>1.</td>
<td>Verbal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Verbal+Graph</td>
<td></td>
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<tr>
<td>3.</td>
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<td></td>
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<tr>
<td>CM²</td>
<td>T</td>
<td>70</td>
<td>30</td>
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<td>(3) &gt; (2), (1)</td>
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<td>(3) &gt; (2), (1)</td>
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<tr>
<td>WHEN PARTICIPANTS ARE ASKED TO PRODUCE AN UNFAMILIAR GOAL, PRESENTATION OF CRITERION INFORMATION ENHANCES SKILL LEARNING.</td>
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<td>Absolute integrated error</td>
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<td></td>
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<tr>
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<td>Criterion+KR</td>
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<td>(3) &gt; (2), (1)</td>
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<td>(3) &gt; (2), (1)</td>
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<tr>
<td>IT IS THE AVAILABILITY OF BOTH CRITERION AND CONFUSION INFORMATION THAT ENHANCES LEARNING.</td>
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acquisition of motor skill when continuous kinematic information is employed. As with the first experiment, there was no retention test. Newell et al. concluded that these two experiments taken together suggest that the appropriate augmented feedback for skill acquisition needs to match the constraints imposed by the task criterion on the performance of the task.

Newell, Sparrow, & Quinn (1985) also investigated the hypothesis that the task goal specifies the most effective feedback for learning. They examined the effectiveness of presenting a continuous force-time trace during the acquisition of an isometric force production task when the force-time curve was (Experiment 2) and was not (Experiment 1) part of the specified goal of the task. In the first experiment, participants learned to generate a peak force of 30 N. Participants were assigned to one of two feedback groups: The first group received verbal KR indicating their peak force production; the second received verbal KR of peak force and a continuous force-time representation of their performance. A gaussian-shaped force-time template was superimposed on the force-time performance feedback. It was emphasized that the goal of the task was peak force and that the force-time performance curve did not have to match the force-time template. Results indicated that presentation of continuous force-time feedback when it is not part of the task criterion does not improve acquisition or retention of force production.

In the second experiment (Newell et al., 1985), a specific force-time curve was the goal of the task. It was hypothesized that discrete kinetic feedback would not be sufficient for skill acquisition and that presentation of the force-time curve would
facilitate learning. Participants were assigned to one of three feedback groups: graphics, absolute impulse error and absolute impulse. Participants assigned to the graphics group were presented the force-time history of their isometric action superimposed on a criterion template. Participants in the absolute impulse error group received a verbal report of the total absolute impulse error calculated as the sum of the area differences between the criterion and performance force-time curves. Participants in the absolute impulse group were given a verbal report of the magnitude of the impulse produced. Results showed that the continuous force-time FB group matched the criterion more accurately than the other groups. Newell et al. concluded that this set of experiments provided empirical evidence that task criteria specify the appropriate feedback for skill learning and that feedback should match the constraints imposed on response input.

The next set of experiments (Newell & Carlton, 1987) examined the effectiveness of presenting task criterion information in conjunction with kinetic feedback. These experiments considered the acquisition of a finger press isometric task when the shape of the criterion curve was familiar (Experiment 1) and unfamiliar (Experiment 2) to participants. In the first experiment, participants learned to produce a gaussian-shaped criterion impulse of 1 N.s under one of three feedback conditions. The “impulse KR” group received a verbal report of the impulse generated to the nearest 0.1 N.s after each response. The “template + force-time trace” group were shown a computer generated force-time trace of the just completed response superimposed with the criterion force-time template. The “force-time trace + impulse
KR” group received a graphical force-time history of their response without the criterion overlay and a verbal report of the impulse generated. The instructions given to all participants included a display of the criterion force-time trace. Analysis of the data indicated that impulse KR alone was not sufficient to optimize performance given these task constraints. However, there were no differences between the groups receiving force-time feedback suggesting that superimposition of the criterion trace did not enhance skill learning.

To test further the necessity of superimposing a criterion template on continuous kinetic feedback, participants in the second experiment (Newell & Carlton, 1987) were asked to produce an asymmetrical, unfamiliar force-time curve. It was hypothesized that participants in this experiment would benefit from the superimposition of the criterion template on the attained force-time performance. Participants were assigned to one of two feedback groups: “template + force-time trace” or “force-time trace + impulse KR”. The goal impulse of 5.84 N.s was created by summing two gaussian curves with characteristics identified in Table A.1. Acquisition results showed that the “template + force-time trace” group generated less error than the “force-time trace + impulse KR” group. Both groups maintained acquisition performance on the initial retention trials. However, there was a significant feedback by trial blocks interaction over retention due to a deterioration in performance by participants in the “template + force-time trace” group and a slight improvement in performance by participants in the “force-time trace + impulse KR” group. The explanation offered for the deterioration in retention performance was that...
more acquisition trials were probably needed (as compared to the first experiment) to maintain performance in this more difficult isometric task. Newell and Carlton concluded that the superimposition of task criterion information is beneficial to performance when the task criterion is unfamiliar and asymmetrical. Further, task constraints interact with characteristics of the learner to determine the degree to which kinetic and criterion information facilitate skill acquisition in isometric tasks.

A set of studies reported by Newell, Quinn, & Carlton (1987) extended beyond simply demonstrating the importance of task constraints in determining the most effective augmented feedback to investigating the nature of the relationship between task constraints and augmented feedback. This set of three studies tested the hypothesis by Newell and McGiniss (1985) that task constraints determine the control space from which to administer feedback. According to Newell and McGinnis, kinematic control spaces prescribe and describe the movement trajectories of a skill. There are four control spaces: the configuration space (position), the event space (position-time), the state space (velocity-position) and the state-time space (position-time ∪ velocity-position). These control spaces are not mutually exclusive. Rather, these spaces build upon one another by adding various kinematic dimensions. Newell and McGinnis suggested that there is a minimum control space from which each task can be sufficiently described and that there are optimum control spaces from which feedback should be administered.

In their first experiment, Newell, Quinn & Carlton (1987) had participants learn to move a horizontal displacement bar through two target positions 30° apart in
300 ms at a constant rate of acceleration. To achieve this goal, participants had to minimize absolute integrated position-time error. Participants were assigned to one of four experimental feedback groups: movement time KR reported verbally, absolute integrated position-time error reported verbally, continuous position-time history displayed graphically, or continuous velocity-time history displayed graphically. It was hypothesized that, because minimization of absolute integrated position-time error was the goal, participants receiving the continuous position-time history would perform best. The position-time history was the only feedback to provide all the information necessary to minimize absolute integrated position-time error. Results confirmed the hypothesis as well as previous findings that feedback in the form of a continuous position-time trace is more effective than discrete KR when the goal of the task is to minimize absolute integrated position-time error. This experiment also demonstrated that for these types of tasks the presentation of discrete as compared to continuous information is not the issue; continuous velocity-position information did not facilitate acquisition or retention of the position-time task.

In the second experiment (Newell et al., 1987), the task criterion was changed so that participants learned to move through the 30° range of motion in 300 ms at a constant velocity. It was hypothesized that, as the constant velocity criterion was more familiar to participants, the impact of the augmented feedback conditions would be different from the first experiment. Both the velocity-position (state) and position-time (event) control spaces provided information which corresponded directly to task goals. Further, if participants could perceive their own velocity, the movement
time KR also provided information sufficient to optimize performance. The experimental conditions and apparatus were same as those reported for Experiment 1. No significant effects were found for feedback condition in either acquisition or retention. Newell et al. concluded that movement time and absolute integrated error provided the information necessary to learn the task suggesting that participants can perceive constant velocity of their limb movements.

The third experiment in this set (Newell et al., 1987) was conducted to demonstrate that a change in task criterion dramatically changes the influence of augmented feedback on skill learning. Participants learned to produce a trajectory in Experiment 3 that was identical to the t-trajectory produced in Experiment 1. The goal of the task, however, was to minimize velocity-position error rather than position-time error. Only the position-time and velocity-position feedback conditions were used in this experiment. It was hypothesized that the results obtained in this experiment would be opposite those obtained in Experiment 1. As expected, the velocity-position group generated less error in both acquisition and retention. The result of these three experiments provide converging evidence that task constraints specify the appropriate representation for augmented feedback.

Newell, Carlton, & Antoniou (1990) expanded the investigation of the relationship between task constraints and augmented feedback to a two-dimensional drawing task. This set of experiments examined the acquisition of the drawing task as a function of task constraints and prior knowledge of task criterion. Experiment 1 was conducted to determine whether the presentation of criterion information in addition to
configuration feedback and discrete KR would facilitate the acquisition of the drawing task when the goal shape, a circle, was familiar to participants. Participants were assigned to one of three feedback groups: discrete error KR presented verbally; discrete error KR presented verbally plus continuous configuration information presented graphically; or discrete KR presented verbally plus configuration information presented graphically with a criterion template overlay. Results indicated that presentation of the criterion information facilitated the rate of acquisition early in practice. However, this performance advantage dissipated over acquisition.

Familiarity with the circle reduced the feedback necessary to learn the skill to a single degree of freedom (the radius of the circle) rather than the three degrees of freedom required to describe the goal trajectory. As participants were familiar with the circle, presentation of error KR was sufficient for skill learning.

In the second experiment (Newell et al., 1990), participants were asked to generate an unfamiliar abstract form. The experimental feedback groups were identical to those employed in Experiment 1. The group receiving the criterion template superimposed on the configuration feedback generated significantly less than the other groups in both acquisition and retention providing evidence that, when participants are asked to produce an unfamiliar goal, presentation of criterion information enhances skill learning.

Experiment 3 (Newell et al., 1990) was conducted to confirm that it was the combined presentation of criterion and configuration feedback that led to performance improvements. Participants learned to draw the same abstract shape employed in
Experiment 2 on a different scale and were assigned to one of three feedback groups: discrete error KR presented verbally plus continuous configuration information presented graphically, discrete error KR presented verbally plus the criterion template presented graphically, discrete error KR presented verbally plus continuous configuration information presented graphically with a criterion overlay. If presentation of the criterion information alone facilitates learning, then the performance of both groups receiving criterion information should reflect this effect. Sixty acquisition trials were followed by a transfer test in which participants were asked to draw the same abstract shape with the scale doubled in size. Results indicated that the group receiving both criterion and configuration information demonstrated considerably less error that the other groups. This advantage remained over the transfer test. These results confirmed the hypothesis that it was the combined presentation of criterion and configuration information that lead to earlier performance improvements.

Summary and Evaluation of Newell et al. Experiments

Taken together, these experiments by Newell et al. suggest that augmented feedback facilitates learning when the information provided by the feedback is congruent with task goals. Augmented feedback does not facilitate skill acquisition when the information provided is extraneous. In addition, these experiments suggest that it is important to provide task criterion information in conjunction with augmented feedback when the task criterion is unfamiliar to the learner.

The study of movement pattern feedback of the type presented in this series of experiments represents a shift away from the traditional focus of feedback research on
KR in learning simple skills. However, Schmidt and Young (1991) point out that in the real world, the task or environmental goal is often distinct from the kinematic pattern which is required to attain it. In the preceding experiments reported by Newell et al., the movement goal was often the movement pattern itself. This isomorphism between movement goal and movement pattern led Schmidt and Young to conclude that the findings of these experiments by Newell et al. have limited usefulness and generalizability. They reasoned that the kinematic information feedback employed in these experiments was reduced to typical outcome KR because of the nature of the task. As such, Schmidt and Young concluded that these experiments represent a very small subset of potential real-world experiences.

Nevertheless, these studies are strategic to the understanding of the relationship between augmented feedback and task characteristics for several reasons. First, these studies provide the first systematic, empirical evidence that task constraints may specify the appropriate feedback for skill learning. Second, these studies demonstrate the feasibility of providing movement-pattern information in laboratory tasks (Schmidt & Young, 1991). Finally, these studies emphasize the importance of presenting information on the goal of the task in conjunction with augmented feedback when the task goal is unfamiliar or abstract.

**Influence of Task Characteristics**

From the perspective of the practitioner, it is not sufficient to know that task constraints specify the appropriate feedback for learning. It is imperative to understand the nature of this relationship in order to structure learning environments which best
facilitate the acquisition of skill. Evidence from studies investigating KR suggests that the detectability of environmental information may play a prominent role in determining the effectiveness of augmented feedback. Evidence from studies investigating KP, as well as evidence from the Newell et al. studies cited previously, suggests that movement characteristics are also important. As such, one approach to understanding the relationship between augmented feedback and task characteristics might be to consider the influence of augmented feedback from the perspective of the external demands placed on the task by the environment and the internal demands placed on the task by the structure of the movement.

From the Perspective of External Task Demands

Several skill classification systems have been established which organize skills based on specific task characteristics such as the distinctiveness of the beginning and ending points of the movement, the topological dynamics of the task and the difficulty of the task (Magill, 1985; Newell & McGinnis, 1985; Naylor & Briggs, 1963; Robb, 1972). Of particular interest here is a popular classification system which distinguishes between tasks based on the stability of the environment in which the skills are performed.

Closed vs. Open Skills

Under this classification system, originally proposed by E. C. Poulton (1957), skills are classified as either closed or open. Skills performed in a stable, predictable environment are designated closed skills. Skills performed in a changing, unpredictable environment are designated open skills.
The definition of open skills commonly employed today is slightly different from the definition originally proposed by Poulton (1957). Under the original scheme, open skills included skills with unpredictable environmental requirements and skills with a very exacting series of requirements, whether predictable or unpredictable. As such, the original scheme proposed by Poulton took into account the accuracy demands of the movement as well as environmental requirements. Today, however, consideration of the exacting nature of skill requirements is often overlooked; skills classified using the closed-open designations are typically classified on the basis of environmental stability alone.

Knapp (1961) suggested that the designations closed and open not be considered a dichotomous classification but rather anchor points on a continuum of skills ranging from skills which are primarily habitual (closed) to skills which are primarily perceptual (open). Gentile (1972) proposed a model of skill acquisition which draws heavily from Knapp’s reformulation of Poulton’s original concept. Gentile (1972) suggested that closed skills at one end of the continuum take place under fixed, constant, stable, and stationary environmental conditions. The stimulus in closed skills waits to be acted upon. The target in archery, the pins in bowling, the ball in golf and the weight in weightlifting are all examples of stimuli in closed skills. In contrast, open skills at the other end of the closed-open continuum, take place in an environment that changes spatiotemporally. The stimulus in these skills changes unpredictably. The balls in tennis, baseball and racquetball are typical of the stimuli present in open skills.
The Knapp reformulation is not without its critics. Whiting (1975) identified difficulties with this reformulation related primarily to its emphasis on the predictability of the environment. First, Whiting pointed out that, in Poulton's original formulation, there was no such thing as an unpracticed closed skill. Skills having the potential to be closed have to be practiced to the extent that all relevant environmental signals becomes predictable. Whiting also pointed out that prediction is essentially personal. As such, skills can only be designated closed with respect to the person performing the skill. Second, Whiting opposed the characterizations of closed skills as habitual and open skills as perceptual. He suggested that many open skills which depend heavily on the environment for the selection and triggering of movement execution are ballistic. These ballistic skills come as close to being habitual as possible in that they are probably preprogrammed as a unit. According to Whiting, Poulton's original definition of closed and open skills reflects the steering function of environmental information rather than the nature of the movement made in relation to this information. Whiting refers to "closed" skills in "open" environments.

**Gentile's (1972) Model of Skill Acquisition**

Gentile addressed at least the first of Whiting's concerns by incorporating the closed-open classification system into a stages of learning model of skill acquisition. According to Gentile, skill learning comprises at least two stages: "getting the idea of the movement" and "fixation/diversification". The goal in the first stage is to determine a means-end relationship with respect to the task goal. In this stage, an individual learns to select an appropriate movement by distinguishing regulatory from
non-regulatory stimuli and to execute the selected movement as planned to successfully satisfy the goal of the task. The initial stage of learning is similar for both closed and open skills. In the second stage of learning, the individual attempts to refine his ability to attain the task goal. In this stage, the goal differs depending on the environment in which the skill is performed. For closed skills, the goal of the learner is to carry out the movement pattern as consistently and as effectively as possible. For open skills, the goal of the learner is to develop a response repertoire which will lead to the successful attainment of the goal under many different conditions.

It is in this second stage of learning that the closed-open skill classification taxonomy suggests a prescription for information feedback. As the primary objective of an individual learning a closed skill is to develop a consistent movement pattern which satisfies the task criterion, Gentile hypothesized that KP, in the form of movement pattern information, should be the most effective form of information feedback for these skills. On the other hand, the movement pattern of open skills must change to fit the spatial-temporal characteristics of the environment. Gentile hypothesized that KR would be the most effective form of augmented feedback for open skills because it emphasizes movement outcome rather than movement pattern. Relatively few studies have been conducted to test the effectiveness of these prescriptions.

One early study comparing the effectiveness of KP and KR in the acquisition of a closed skill investigated the skill of shot-putting. Hampton (as cited in Newell & Walter, 1981 & del Rey, 1972) hypothesized that augmented KP in the presence of
intrinsic KR would best facilitate the acquisition of this skill. In addition to allowing for the normally-occurring (intrinsic) KP and KR, Hampton either provided augmented KP in the form of an eight-sequenced picture or decreased the normally occurring KR by employing a vision screening device through which the shot was put. Four experimental conditions reflected combinations of the two levels of both feedback conditions. Hampton found support for his hypothesis that augmented KP would be the most effective form of feedback for increasing the distance the shot was put.

Del Rey (1971) investigated the effectiveness of augmented KP in the presence of intrinsic KR on the acquisition of a classical fencing lunge. Participants were assigned to one of four experimental conditions: (a) closed - no augmented KP, (b) closed - augmented KP, (c) open - no augmented KP, and (d) open - augmented KP. In the closed conditions, participants learned to lunge to a single stationary target. In the open conditions, participants were forced to choose between two targets. Augmented KP consisted of a videotape replay of the subject’s movement pattern. Del Rey hypothesized that participants assigned to the closed conditions would benefit more from the combination of intrinsic KR and augmented KP than participants assigned to the open conditions. She further hypothesized that participants assigned to the closed condition would benefit more from augmented KP alone than participants assigned to the open condition. Del Rey examined the effects of augmented KP in the presence of intrinsic KR on form, accuracy and latency. She concluded that the results supported Gentile’s hypothesis. KP led to better form and higher accuracy scores for participants
in the closed conditions than it did for participants in the open conditions. Del Rey found no evidence, however, that participants in the closed condition benefited from augmented KP alone more than participants in the open condition.

Videotaped replay is sometimes employed as augmented KR rather than augmented KP for open skills. In these cases, videotape is used to record the environmental changes produced by the movement (i.e., the movement outcome) or the environmental conditions present at the time the performer selected a particular movement pattern (i.e., the regulatory stimuli). Del Rey and Kyvallos (as cited in del Rey 1972), in a pilot study, examined the effectiveness of videotape replays in training players how to handle fast-break situations in women’s basketball. The video tape replays were used (1) to restructure the environmental conditions of the fast break in order to point out relevant events in the environment and (2) to show players the environmental consequences of their movement choices. In the first three practice sessions, elements in the environment that demand selective attention in fast break situations were pointed out to the players. In subsequent practice sessions, play during fast break situations was terminated by a bell. The players answered questions about the fast break and then viewed a replay of the fast break on a monitor. This procedure provided the players an opportunity to see the environmental conditions under which their movement decisions had been made and to see the consequences of their decisions. Actual games were used to evaluate the effectiveness of the videotaped replay technique. Initial observations indicated that employing videotaped replay as augmented KR facilitated the acquisition of the open fast break.
Wallace and Hagler (1979) tested the prediction that KP is an effective form of feedback for the acquisition of closed skills. Participants learned to perform a basketball set-shot with the nondominant arm. All participants were allowed the visual feedback on task outcome inherent to the task. In addition, all participants received an objective outcome rating that measured how close the ball had come to swishing through the basket. One group, however, received augmented KP about stance or body motion; the other group received verbal encouragement (SR). The verbal reinforcement was offered in attempt to neutralize any motivational influence the first group may have received from the augmented KP. In the retention trials, KP and SR were withdrawn. However, participants continued to receive both the inherent and augmented outcome feedback. Results suggested that both groups improved significantly during acquisition. More importantly, however, the group receiving KP performed significantly better than the group receiving verbal reinforcement in retention. The results of this experiment by Wallace and Hagler were among the first published results to indicate that KP can have a strong, positive influence on the relatively permanent changes associated with learning.

One of the most recent studies investigating the effectiveness of KP in the acquisition and retention of closed skills was conducted by Boyce (1991). A total of 135 students in nine riflery classes learned a shooting task under one of three conditions: (a) instructional strategy with KP presented after every trial, (b) instructional strategy with KP presented after every fifth trial and (c) no instructional strategy with no KP. Participants in the instructional strategy groups were told to
squeeze the rifle shot off within 7 s of holding their breath without jerking the trigger and to start over if they exceeded the 7 s limit. KP regarding the instructional strategy was administered by peers who timed the trigger pull with a stopwatch. Participants completed one set of pretest trials followed by four sets of acquisition trials. Each set consisted of five trials. Results indicated that (a) the presence of the instructional strategy and KP facilitated overall acquisition performance when compared to the control group, (b) the effects of the two schedules of KP did not differ statistically, and (c) shooting practice in all three conditions improved. The results of this study are limited, however, in that there was no transfer or retention test. As such, the findings are applicable only to the short term performance changes associated with acquisition.

Summary and Evaluation from the Perspective of External Demands

The preceding five experiments were conducted to test hypotheses made in Gentile’s (1972) model of skill acquisition that KP facilitates the acquisition of closed skills and that KR facilitates the acquisition of open skills. These experiments provide some support for these hypotheses. However, this support is limited by several deficiencies. One major deficiency is the lack of retention tests. A second deficiency is the failure to directly contrast the influence of KR to KP. Finally, the stage of learning of the participants was not sufficiently considered. It is apparent that more research is needed, particularly in light of the Newell et al. evidence that task characteristics specify the appropriate augmented feedback for learning.

In 1987, Gentile proposed a new skill taxonomy which may provide the basis for future research. The new taxonomy expands on the closed-open skill classification
system by considering both environmental context and function of the action. Further, it elaborates on environmental context by considering the motion of regulatory aspects of the environment as well as intertrial variability.

The first dimension of the new taxonomy proposed by Gentile (1987) considers environmental context. This dimension comprises two perspectives: intertrial variability and motion of regulatory objects. The intertrial variability perspective reflects the closed-open continuum and thus the predictability (consistency) of the environment. The consideration of the motion of regulatory conditions, however, is new. Regulatory conditions in the environment are those features of the environment to which a movement must conform if the movement is to be successful (Gentile, 1987). When these conditions are fixed, spatial features of the environment control spatial features of the movement. Timing of movement, however, is not specified by these regulatory conditions. Riser height is an example of a fixed regulatory condition in the skill of stair climbing. When regulatory conditions are in motion, both the spatial and timing aspects of the movement are specified by the environment. The movement is paced by the environment. Interceptive actions such as hitting a thrown ball are examples of movements with regulatory conditions in motion.

Considered together, intertrial variability and the motion of regulatory objects yield four distinct task categories describing environmental context: (1) closed tasks, (2) consistent motion tasks, (3) variable motionless tasks, and (4) open tasks. Closed tasks involve regulatory objects that are stationary and do not vary from one movement attempt to another. These tasks require the least interaction with the
environment placing emphasis on the performer as the center of control during
learning. Walking down an empty corridor is an example of a closed task. Variable
motionless tasks involve regulatory objects that are stationary but that may vary in
position, configuration, and spatial features from one movement attempt to the next.
Washing cups of various shapes and sizes is an example of a variable motionless task.
Consistent motion tasks involve objects which move consistently over repeated
movement attempts. These tasks depend on external electrical or mechanical devices
to generate the motion. Hitting a ball thrown by a ball pitching machine is an example
of a consistent motion task. Open tasks require the greatest interaction with the
environment. These complex tasks place a heavy demand on the performer. Hitting a
ball thrown by a pitcher is an example of an open task.

The second dimension of the new taxonomy introduced by Gentile (1987)
considers the function of the action. The function of the action is classified from two
perspectives: orientation of the body and manipulation of objects. From the
perspective of body orientation, tasks are classified as either body stability tasks or
body transport tasks. Body stability tasks place low information processing demands
on the performer as the regulatory features of the environment are immediately
accessible. The regulatory environment of body transport tasks constantly expands in
accord with the rate of motion of the body. As such, information processing demands
are high. From the perspective of object manipulation, action either requires or does
not require the manipulation of objects. Actions unencumbered by objects allow the
upper limbs to be yoked to the postural system and, therefore, allow flexibility in
maintaining body stability. Actions which require the manipulation of objects, on the other hand, decrease the options for maintaining body stability and require the performer to attend to both body stability and object manipulation simultaneously.

The taxonomy derived by combining the environmental context and function of the action perspectives of the new classification system comprises sixteen task categories. These task categories are summarized in the Table A.2. Each task category places additional demands on the performer. As the number of affirmative responses in the table increases so does task complexity.

Gentile (1987) suggests several practical applications for this skill taxonomy. First, the taxonomy can be used to evaluate progress in motor skill acquisition. Secondly, the taxonomy can aid in the selection of appropriate activities for therapeutic or educational purposes. Finally, the taxonomy might further the understanding of skill acquisition. Processes underlying the acquisition of skills classified under the various skill categories might differ significantly. Most importantly, from the perspective of this review, interventions designed to facilitate skill acquisition might be best determined by the task characteristics inherent in each of the task categories.

From the Perspective of Internal Task Demands

Much of what is known about augmented feedback is based on research investigating the influence of KR on skill learning. Yet, KR research has not led to an adequate understanding of the role of feedback in the real world. Schmidt and Young
Table A.2 The Gentile (1987) Taxonomy of Tasks

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Environmental Context</th>
<th>Function of the Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internal Variability</td>
<td>Motion</td>
</tr>
<tr>
<td>Consistent Motionless (CLOSED)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Stability</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Body Stability + Manipulation</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Body Transport</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Body Transport + Manipulation</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Variable Motionless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Stability</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Body Stability + Manipulation</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Body Transport</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Body Transport + Manipulation</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Consistent Motion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Stability</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Body Stability + Manipulation</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Body Transport</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Body Transport + Manipulation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Variable Motion (OPEN)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Stability</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Body Stability + Manipulation</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Body Transport</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Body Transport + Manipulation</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
(1991) proposed that three factors have limited the applicability of KR research to practical teaching and learning situations. First, KR in the real world is often redundant with outcome information available from intrinsic feedback. It is redundant, for example, for a coach to tell a player attempting a set shot that the shot has missed the basket when the player can clearly see the outcome of the shot. In the laboratory, KR is typically not redundant because the intrinsic outcome information available to the participant has been masked in order to examine the influence of artificially administered KR on learning. This masking of intrinsic outcome information allows various manipulations of KR to be studied rather easily; it also limits the relevance of the research to real world settings. A second factor that limits the applicability of KR research is that, except in the simplest of tasks, KR is often descriptive rather than prescriptive. It does not typically provide information on how to adjust a response in subsequent attempts. In contrast, much of the feedback used in practical learning situations is prescriptive information regarding a particular aspect of the movement pattern. An instructor teaching the forward roll to a young dancer, for example, might tell the dancer following a failed attempt: “Keep your chin to your chest”. A third difficulty with KR research is that many of the studies from which the principles of KR have emerged have employed the simplest tasks with only one degree of freedom which must be controlled. In contrast, most motor skills require a number of degrees of freedom to be coordinated or controlled.

Of the three criticisms directed at the KR research by Schmidt and Young (1991), the most significant is the failure to take into account multiple degree of
freedom tasks. Research frameworks and hypotheses that consider both of the first two criticisms are in place. Magill’s (1993) examination of the KR research from the perspective of the positive, negative and neutral effects KR has on learning considers redundancy. Several models of skill acquisition and theories of motor learning consider prescriptive vs. descriptive feedback in relation to the stage of learning of the performer.

**Task Organization vs. Task Complexity**

From the perspective of the skill classification system proposed by Naylor (as cited in Naylor & Briggs, 1963), the failure of augmented feedback research to consider anything but the simplest of tasks is twofold. Naylor defined task difficulty as a function of both task complexity and task organization. Complexity is determined by the number of component parts or dimensions of a task and the information processing and/or memory-storage demands of each dimension of the task considered independently. Highly complex tasks, such as dance routines and floor exercise routines, have many dimensions and require much attention. Low complexity tasks such as rifle shooting and weight lifting have very few dimensions. Task organization is determined by the interrelationship between the dimensions of a task. Tasks having independent dimensions would be considered low organization tasks. A dance routine, although high in complexity, would be considered low in organization. Tasks having interdependent dimensions, such as the laboratory tasks used in studies investigating bimanual coordination, would be considered high in organization.
The effectiveness of augmented feedback on skill acquisition has not been studied sufficiently for either highly complex nor highly organized skills. It is possible that the principles underlying the effectiveness of augmented feedback differentiate between tasks of high complexity and tasks of high organization. An interaction between task complexity and task organization has been shown to exist with respect to the effectiveness of part vs. whole training methods. It would not be surprising, therefore, to find a similar interaction between complexity and organization with respect to augmented feedback. It is interesting to note that many of the authors who have indicated the need to study tasks that are more ecologically valid have not considered the distinction between complexity and organization (e.g., Schmidt & Young, 1991). Although much work remains to be done to understand the influence of augmented feedback in the acquisition and retention of highly complex and highly organized tasks, a few studies have been conducted which may provide some initial insight.

**Multiple degree of freedom tasks.**

One such experiment involving a highly organized task was reported by den Brinker, Stabler, Whiting, and van Wieringen (1986). Eighty-one participants having no previous ski experience learned a slalom skiing task under one of three feedback conditions. Each feedback condition reflected one aspect of performance: amplitude, fluency, or frequency. Training and test trials were conducted on four successive days. Early in practice, the performance of each group was better on the aspect of the task on which the group was given KR. After a few days, however, the group receiving
amplitude KR outperformed the other groups on all aspects of the skiing task. Den Brinker et al. concluded that it is better in the early stages of learning to direct attention to form rather than tempo. Additionally, fluency should be allowed to emerge naturally as a direct consequence of successively solving the same movement problem.

Swinnen, Walter, Pauwels, Meugen's and Beirinkx (1990) investigated the role of information feedback in the acquisition of a highly organized bimanual coordination task requiring the dissociation of upper limb movements. Participants participated in two experimental sessions consisting of 60 trials each. In the first session, participants practiced a unidirectional movement with the nondominant limb and subsequently a double reversal movement with the dominant limb. In the second session, participants were assigned to one of two groups: (a) kinematic feedback or (b) no feedback. Both groups practiced the unidirectional movement concurrently with the double reversal movements. However, participants in the kinematic feedback group were shown the displacement patterns of both limbs after every fourth trial. The authors found that although the participants had practiced the unimanual versions of each movement, the degree of coupling under bimanual practice was higher than what would be expected under conditions of complete independence. Participants in the kinematic feedback group were more successful in decoupling the limbs. However, these participants also exhibited higher overall timing error. Swinnen et al. suggested that leaving a preferred coordination pattern is accompanied by greater temporal inconsistency and inaccuracy.
This study provided initial evidence that augmented feedback can facilitate the acquisition of highly organized bimanual coordination tasks.

Swinnen, Walter, Lee and Serrien (1993) conducted a series of three studies to further investigate the role of augmented feedback in the acquisition of bimanual coordination tasks requiring different upper limb actions to be performed simultaneously.

The first experiment investigated the role of kinematic feedback in structural decoupling. Twenty-four participants learned to perform a unidirectional movement with the nondominant arm while simultaneously performing a double reversal movement with the dominant arm. Participants were assigned to one of two feedback groups: kinematic feedback and no feedback. A picture of the goal movement was displayed in front of all participants at all times. All participants received information about the deviations of each limb from the target MT of 600 ms after every fourth trial. However, participants in the kinematic feedback group were also shown the angular displacement of both limbs superimposed against the same time scale. Results indicated that provision of kinematic feedback facilitated interlimb decoupling. The difference between the two groups persisted across five months of no practice.

In the second experiment, Swinnen et al (1993) compared the effectiveness of kinematic feedback to outcome KR in the acquisition of the same bimanual task. Sixty-four participants participated in the experiment. Participants were assigned to one of four possible feedback conditions: (a) kinematic KP, (b) goal KR, (c) no FB, or (c) kinematic KP + goal KR. The experimental procedure followed was similar to that
employed in the first experiment. Results supported the findings of the first experiment that presentation of augmented feedback facilitates interlimb decoupling. The group receiving the combination of kinematic and goal feedback produced the best results. Goal KR, however, was nearly as successful as kinematic feedback in facilitating the acquisition of the task. Swinnen et al suggested two possible explanations for these findings: (1) A plateau in performance may have masked the differences between the groups and (2) the kinematic feedback may not have been sensitive enough to convey the information needed by the participants to further decouple the limbs.

A third experiment by Swinnen et al (1993) was conducted to investigate the effectiveness of various forms of kinematic feedback on the acquisition of the bimanual coordination task and to investigate the proposition that the kinetic feedback provided in the second experiment was not sensitive enough. The task employed in this experiment was similar to the tasks employed in the first two experiments with exception that the amplitude covered by the movement of each limb was increased from 85 degrees to 90 degrees. Seventy-two participants were assigned to four experimental groups: (a) displacement FB, (b) no FB, (c) velocity FB, and (d) a unimanual control condition. Both kinematic feedback groups were more successful in reducing interlimb coupling than the no feedback control. However, neither metrical or structural decoupling was different between the two groups. Swinnen et al. concluded that it was difficult to decouple the interlimb movement patterns beyond that previously demonstrated with displacement information alone, despite the fact that
complete decoupling was not evident. The findings of these three experiments by Swinnen et al (1993) suggest presentation of augmented feedback facilitates the acquisition of multiple degree of freedom tasks. Further, these results indicate that KR may have more potential for the acquisition of multiple degree of freedom tasks than previously hypothesized.

Kernodle and Carlton (1992) conducted an experiment to compare the effectiveness of four information feedback conditions on the acquisition of a multiple degree of freedom task - the overhand throw. Forty-eight participants learned to throw a nerf ball as far as possible with the nondominant arm. Participants were randomly assigned to one of the four feedback groups: KR, KP in the form of videotape replay, KP plus attention-focusing cues, and KP plus transitional information. Kernodle and Carlton examined the effects of the various feedback conditions on throwing distance and movement form. The task, as employed in this experiment, allowed the effects on distance and form to be analyzed independently of one another. A correct form did not necessarily result in a long throw and, conversely, a long throw did not necessarily imply a correct form. Results indicated that the presentation of KR alone or KP in the form of videotape replay without attention focusing cues may not be sufficient to learn multiple degree of freedom skills. These results may provide some explanation for the results of Swinnen et al (1993).

Young and Schmidt (1992) investigated the relative effectiveness of different types of kinematic information (positional vs. temporal) and different types of response descriptors (mean vs. variability) on the acquisition and retention of a
coincident timing batting task. In the first of two experiments, Young and Schmidt investigated the effectiveness of several different kinematic variables with respect to both outcome and form. The goal of the task was to maximize an overall performance score which reflected timing and spatial error. Sixty participants were assigned to one of five feedback groups: (a) KR-only, (b) KR + mean reversal position, (c) KR + variability of reversal positions, (d) KR + mean onset of temporal swing, or (e) KR + variability of the forward swing onset. On the second day of acquisition, groups receiving kinematic feedback in addition to KR performed more proficiently than the group receiving KR only. The only kinematic variable to enhance performance during retention, however, was the mean reversal position feedback. Young and Schmidt cautioned against assuming that variables that enhance acquisition also enhance learning.

Young and Schmidt (1992) conducted a second experiment to investigate whether or not kinematic feedback was influence by some of the same scheduling parameters that influence KR. Forty-two participants were assigned to one of three experimental conditions: (a) single trial feedback on reversal position presented after every trial, (b) average reversal position presented after every five trials, and (c) average reversal positions of five trials presented in a faded distribution. Participants completed 200 acquisition trials, followed by two sets of 20 retention trials. The first set of retention trials was administered one day after practice. The second set was administered one week after practice. Results from this experiment indicate that feedback schedule interacts with the effectiveness of kinematic feedback in roughly
the same way that it interacts with KR. Averaged schedules led to more effective performance as compared to the every trial format.

**Summary and Evaluation from the Perspective of Internal Demands**

The results of these experiments investigating the influence of augmented feedback in multiple degree of freedom tasks provide support for several of the propositions presented throughout this review. The study by den Brinker, Stabler, Whiting, and Van Wieringen (1986), for example, supports the contention by Newell and Walter (1981) that as the number of degrees of freedom of a task increases augmented feedback can be organized into a coherent critical parameter in the same way that the biomechanical links required to perform the task can be organized into a coherent coordinative structure. Both experiments by Swinnen et al. (1986, 1993) provide evidence that the decoupling of inherent interlimb constraints, required by some highly organized tasks, is difficult to achieve. Augmented feedback can facilitate this decoupling. However, "getting the idea of the movement" may be particularly difficult for these tasks; the influence of the stage of learning of the individual might be more pronounced. Evidence provided by Kernodle and Carlton (1992) suggests that the presentation of augmented feedback in the form of KP or KR alone may not be sufficient to facilitate the acquisition of multiple degree of freedom tasks. Attention focusing cues may be needed. The Kernodle and Carlton experiment also supports the proposition by Magill (1993) that the ability of the learner to detect and to use environmental information may interact with effectiveness of the presentation of augmented feedback. Taken together, these experiments indicate that the criticism by
Schmidt and Young (1991) that much of what is known about augmented feedback can not be generalized to real world situations because it based on the simplest tasks is valid. These experiments emphasize the need for research investigating the influence of augmented feedback in the acquisition of highly organized and highly complex skills and the need for research which considers the stage of learning of the individual. These experiments also indicate that the results of such research may provide better insight into the principles accounting for the influence of augmented feedback on the acquisition of skill.

Implications for Motor Skill Acquisition

The most prevalent theme that has emerged from this review is the need for more research. Nevertheless, the studies conducted to date yield several guidelines for skill learning situations.

1. If augmented feedback is to be effective, the learner must clearly understand the task criterion. From the perspective of Gentile's model of skill acquisition, this comes as no surprise. Gentile suggested that the first stage of learning for any skill is "getting the idea of the movement". In the real world, however, task goals are often presented or discussed at the beginning of acquisition only. Augmented feedback is subsequently provided without repetition of the criterion information. Evidence from studies reviewed here indicates that presentation of criterion along with the feedback is important if the goal of the task is unfamiliar or ambiguous. For difficult tasks, the presentation of attention focusing cues in addition to augmented feedback may be required.
2. Subtle changes in task goals, whether local performance goals or overall task goals, may influence the effectiveness of the feedback presented. Evidence from Newell, Quinn, & Carlton (1987) suggests that even if the overall goal of the task (movement trajectory, for example) remains the same, a change in a short term performance goal (minimizing position-time error vs. minimizing velocity-position error, for example) will influence the usefulness of the feedback being provided.

3. KP is the most appropriate form of feedback for tasks requiring movement pattern consistency. KR is the most appropriate form of feedback for tasks executed in environments which change significantly from one attempt to the next. Evidence from Swinnen et al (1993) suggest that this prescription for information feedback may not be as strong as initially hypothesized. However, a tendency toward this prediction holds true.

4. The ability to readily detect regulatory stimuli appears to influence the effectiveness of augmented feedback. If regulatory stimuli are easily detected, augmented feedback may not be needed for skill acquisition. If the regulatory stimuli available in the environment are not easily detected, augmented feedback may facilitate learning to the degree that it facilitates the detection of these stimuli. Augmented feedback may hinder skill learning to the degree that it impairs the student’s ability to use or to learn to use the regulatory information available.

5. Augmented feedback should reflect the degrees of freedom of the task criterion. In some cases, a one-to-one correspondence between the degrees of freedom of the task and the dimensions of the augmented feedback may be required. In other
cases, it may be possible to find critical feedback parameters which organize
information feedback into coherent units in the same way that various kinematic links
are organized into coordinative structures.

These guideline suggest that the one of the most important roles of the
instructor or coach is to thoroughly analyze the task to determine the most effective
presentation of augmented feedback. The task should be analyzed from the
perspectives of the task criterion, the external demands placed on the task by the
environment and the internal demands placed on the task by the movement structure.

Topics for Future Research

The prevalent theme of this review has been that more research is needed to
further understand the relationship between the effectiveness of augmented feedback
and task characteristics. Several deficiencies in the present body of knowledge have
been identified. Several hypotheses for future research have been delineated:

1. The stage of learning of the individual interacts with the effectiveness of
augmented feedback. Much of the existing research has not considered the stage of
learning of the individual. Gentile (1987) has made the case, however, that the practice
environment should be structured to consider the stage of learning of the performer.
Early in practice, augmented feedback which aids the performer in “getting the idea of
the movement” and in detecting regulatory stimuli may be appropriate. Later, feedback
which facilitates movement consistency or movement diversification would be
appropriate. It might be expected that the interaction between the stage of learning of
the performer and the effectiveness of augmented feedback would be more
pronounced in highly organized tasks that require the establishment of new movement patterns and the decoupling of existing ones.

2. Augmented feedback may operate differently under various levels of task difficulty. Highly complex and highly organized skills have not been studied sufficiently. Without more research investigating the effectiveness of augmented feedback in multiple degree of freedom tasks, it is impossible to know whether the principles underlying augmented feedback differentiate between tasks of high complexity and tasks of high organization. It is interesting to note that, for cognitive skills, highly organized tasks are considered less difficult than tasks of low organization. It has been hypothesized that a high level of interdependency between task parts facilitates skill acquisition. Evidence from the Swinnen et al. (1986, 1993) studies indicates that this might not be the case for motor skills. A highly organized task which requires interlimb decoupling may be more difficult than a less organized task.

3. Augmented feedback can be organized into coherent units which facilitate the acquisition of skill in the same way that coordinate structures facilitate the control of movement. Guidelines for organizing and presenting appropriate feedback for learning multiple degree of freedom tasks remain to be defined. However, evidence provided by den Brinker et al (1986) suggests that feedback on critical aspects of the task may facilitate the acquisition of all aspects of the task. This may be particularly important for highly complex and highly organized skills where the degrees of freedom involved may be overwhelming.
References to Appendix A


APPENDIX B. HUMAN CONSENT FORM

I understand that my participation in this experiment is purely voluntary and that I can withdraw at any time without penalty.

SSN: __________________________________________

Name: __________________________________________

Signature: ________________________________________

Date: ____________________________________________

Course/Section: __________________________________

Instructor: ________________________________________

Gender: _______ Handedness: ___
APPENDIX C. COMPUTER PROGRAMS FOR EXPERIMENT 1

Data Collection Programs Written in Quick Basic

Main Program: CAFTAF

DECLARE SUB INSTRUCT4()
DECLARE SUB INSTRUCT3()
DECLARE SUB INSTRUCT2()
DECLARE SUB INSTRUCT1()
DECLARE SUB PRACTICE()
DECLARE SUB SCAN()
DECLARE SUB TEMPLATE()
DECLARE SUB PROMPT()
DECLARE SUB ABORT()
DECLARE SUB BASDASG(DASG.MODE%, ByVal dummy%, DASG.FLAG%)
DECLARE SUB INITDASG()
DECLARE SUB TRIAL()

REM ------------------------------
REM ---- Sample DASG data collection routine
REM ----
REM ---- Author: Cindy Hadden
REM ---- Date: April, 1993
REM ------------------------------

REM ------------------------------
REM ---- Initialize variables
REM ------------------------------

DIM D% (16) 'DASGPARMS
DIM DASGERR$(28) 'DASGerror messages

COMMON SHARED D%, DASGERR()
COMMON SHARED DASG.MODE%, DASG.FLAG%
COMMON SHARED PARTICIPANTS$, STUDY$, DAY%, FILENAME$
COMMON SHARED NUMBER.BLOCKS%, NUMBER.TRIALS.PER.BLOCK%,
    TRIAL.COUNTER%, BCOUNTER%
COMMON SHARED NUMBER.ITERATIONS.PER.TRIAL%,
    NUMBER.SAMPLES.PER.ITERATION%, TOTAL.ITERATIONS.PER.BLOCK%
COMMON SHARED NUMBER.SAMPLES.PER.TRIAL%, TOTAL.SAMPLES.PER.BLOCK%
COMMON SHARED TYPE.TASKS$, SLEEP.SECONDS%, RELATIVE.PHASE%
COMMON SHARED DEFAULT.FEEDBACK.COLOR%, DEFAULT.TEMPLATE.COLOR%
COMMON SHARED CONCURRENT.FEEDBACK.FLAG%, TERMINAL.FEEDBACK.FLAG%
COMMON SHARED TEMPLATE.FLAG%, SCAN.FLAG%
COMMON SHARED RADIUS%, START.ANGLE%, END.ANGLE%, ASPECT

REM $DYNAMIC
DASG.MODE% = 0: DASG.FLAG% = 0

REM ------------------------------
REM ---- Initialize error messages
REM
OPEN "C:\cindy\programs\dsagerrs.dat" FOR INPUT AS #1
FOR I% = 0 TO 28
  INPUT #1, DASGERR$(I%)
NEXT I%
REM
REM ---- Clear screen
REM
SCREEN 0, 0, 0: WIDTH 80: KEY OFF: CLS
REM
REM ---- Initialize the uCDAS-16G board for data collection
REM
CALL INITDASG
REM
REM ---- Prompt for subject's initials
REM
LOCATE 1, 1: PRINT "Welcome to the experiment ")
ANSWERS = "N"

LOCATE 4, 1: PRINT SPACES$(79)
LOCATE 4, 1: INPUT "Please enter your initials  ==> ", PARTICIPANTS
PARTICIPANTS$ = UCASES(PARTICIPANTS)
LOCATE 5, 1: PRINT SPACES$(79)
LOCATE 5, 1: PRINT "Are your initials "; PARTICIPANTS
LOCATE 5, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS$ = UCASES(ANSWERS)
DO WHILE (ANSWERS$ <> "Y")
  LOCATE 4, 1: PRINT SPACES$(79)
  LOCATE 5, 1: PRINT SPACES$(79)
  LOCATE 4, 1: INPUT "Please enter your initials  ==> ", PARTICIPANTS
  PARTICIPANTS$ = UCASES(PARTICIPANTS)
  LOCATE 5, 1: PRINT "Are your initials "; PARTICIPANTS
  LOCATE 5, 32: INPUT " (Y or N) ==> ", ANSWERS
  ANSWERS$ = UCASES(ANSWERS)
LOOP

LOCATE 5, 1: PRINT SPACES$(79)
LOCATE 5, 1: INPUT "Please enter condition  ==> ", STUDY$
STUDY$ = UCASES(STUDY$)
LOCATE 6, 1: PRINT SPACES$(79)
LOCATE 6, 1: PRINT "Is the condition name "; STUDY$
LOCATE 6, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS$ = UCASES(ANSWERS)
DO WHILE (ANSWERS$ <> "Y")
  LOCATE 5, 1: PRINT SPACES$(79)
LOCATE 6, 1: PRINT SPACES(79)
LOCATE 5, 1: INPUT "Please enter condition ==> ", STUDYS
STUDYS = UCASE$(STUDYS)
LOCATE 6, 1: PRINT "Is the condition name "; STUDYS
LOCATE 6, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)
LOOP

LOCATE 6, 1: PRINT SPACES(79)
LOCATE 6, 1: INPUT "Please enter day (5 for retention) ==> ", DAY%
LOCATE 7, 1: PRINT SPACES(79)
IF DAY% = 99 THEN
   DAY% = 0
   STUDYS = "R"
END IF
LOCATE 7, 1: PRINT "Is this day "; DAY%
LOCATE 7, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)
DO WHILE (((DAY% < 0) OR (DAY% > 20)) OR (ANSWERS <> "Y"))
   LOCATE 8, 1: PRINT "ERROR: DAY must be greater than 1 and less than 20."
   LOCATE 6, 1: PRINT SPACES(79)
   LOCATE 7, 1: PRINT SPACES(79)
   LOCATE 6, 1: INPUT "Please enter day (1-20) ==> ", DAY%
   IF DAY% = 99 THEN
      DAY% = 0
      STUDYS = "R"
   END IF
   LOCATE 7, 1: PRINT "Is this day "; DAY%
   LOCATE 7, 32: INPUT " (Y or N) ==> ", ANSWERS
   ANSWERS = UCASE$(ANSWERS)
LOOP

DEFAULT.FEEDBACK.COLOR% = 5
DEFAULT.TEMPLATE.COLOR% = 12
TEMPLATE.FLAG% = 0
SCAN.FLAG% = 1
SLEEP.SECONDS% = 2
NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 1
NUMBER.DATAPTS.PETRIAL% = INT(NUMBERSAMPLES.PETRIAL% / 2) + 1

DIM SHARED SAMPLE%(NUMBERTRIALS.PETBLOCK%, NUMBER.DATAPTS.PETRIAL%, 3)
DIM SHARED LED%(NUMBERSAMPLES.PETRIAL%)

DIM SHARED NOTES(2)

NOTES$(0) = "0"
NOTES$(1) = "48"

DIM SHARED DURATION!(2)

DURATION!(0) = 0
DURATION!(1) = 6.5

REM --------------------------------------------------------------
REM ----- Warn about disk space
REM --------------------------------------------------------------

CLS
COLOR 12, 0

LOCATE 10, 1
PRINT SPACE$(10), "WARNING: This experiment fills up the hard drive. Output is"
PRINT SPACE$(10), " is stored in the directory C:\CAFTAF. Please transfer"
PRINT SPACE$(10), " output data to a diskette and delete files from the"
PRINT SPACE$(10), " hard drive at the conclusion of this experiment."
PRINT SPACE$(79): PRINT SPACE$(79): PRINT SPACE$(79)
INPUT "Press ENTER key to continue", Z$

COLOR 15, 0
CLS

SLEEP (2)

REM --------------------------------------------------------------
REM ----- Practice if appropriate
REM --------------------------------------------------------------

IF DAY% = 1 THEN
CALL INSTRUCT1

TYPE.TASK$ = "C"

TYPE.FEEDBACK$ = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 0
RELATIVE.PHASE% = 0
CALL PRACTICE

END IF

PSTUDYS = STUDYS
IF (STUDYS = "1" OR STUDYS = "2") AND DAY% = 5 THEN STUDYS = "R1"
IF (STUDYS = "1" OR STUDYS = "2") AND DAY% = 6 THEN STUDYS = "R1"
IF (STUDYS = "3" OR STUDYS = "4") AND DAY% = 5 THEN STUDYS = "R2"
IF (STUDYS = "3" OR STUDYS = "4") AND DAY% = 6 THEN STUDYS = "R2"

IF (STUDYS = "R1" OR STUDYS = "R2") THEN SCAN.FLAG% = 0
IF STUDYS = "D" THEN SCAN.FLAG% = 1

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
REM -------------------------------
REM  Perform Scanning Block as appropriate
REM -------------------------------

IF SCAN.FLAG% = 1 THEN

IF DAY% = 1 THEN CALL INSTRUCT3

FILESTRS = "C:\CAFTAIA" + PARTICIPANTS
FILENAME$ = FILESTRS + LTRIM$(STR$(DAY%)) + "S1" + ".DAT"

OPEN FILENAMES FOR APPEND AS #3
WRITE #3, PARTICIPANTS, "Study", PSTUDYS, STUDYS, "Day", DAY%, "SCAN 1", "Task",
TYPE.TASKS, "Feedback", TYPE.FEEDBACKS

SCREEN 0, 0, 0: WIDTH 80: CLS
LOCATE 10, 34: PRINT "Scanning Block": SLEEP (1)

NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 1

TRIAL.COUNTER% = 0

NUMBER.DATA.POINTS.PER.TRIAL% = INT(NUMBER.SAMPLES.PER.TRIAL% / 2) + 1

ERASE SAMPLE%: REDIM SHARED SAMPLE%(NUMBER.TRIALS.PER.BLOCK%, NUMBER.DATA.POINTS.PER.TRIAL%, 3)

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ERASE LED%: REDIM SHARED LED%(NUMBERSAMPLES.PERTRIAL%)

TYPE.TASKS = "C"

TYPE.FEEDBACKS = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 0

CALL SCAN
CLOSE #3
END IF

SELECT CASE STUDY$
CASE "1"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 20

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASKS = "D"

TYPE.FEEDBACKS = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "2"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 20

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASKS = "D"

TYPE.FEEDBACKS = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "3"

NUMBER.ITERATIONS.PER.TRIAL% = 20
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
  (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
  NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
  NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASKS = "C"

TYPE.FEEDBACKS = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "4"

NUMBER.ITERATIONS.PER.TRIAL% = 20
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
  (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
  NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
  NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASKS = "C"

TYPE.FEEDBACKS = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1

TEMPLATEFLAG% = 1
RELATIVE.PHASE% = 90

CASE "R1"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 10

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASK$ = "D"

CASE "R2"

NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASK$ = "C"

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RELATIVE PHASE% = 90

CASE "D"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 2

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%

NUMBER.BLOCKS% = 2

TYPE.TASKS = "D"

TYPE.FEEDBACKS = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

SCAN.FLAG% = 1

CASE ELSE

CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0
TEMPLATE.FLAG% = 1

CALL PROMPT

IF RELATIVE.PHASE% = -1 THEN TEMPLATE.FLAG% = 0

IF TYPE.TASKS = "C" THEN

NUMBER.TRIALS.PER.BLOCK% = 1
NUMBER.ITERATIONS.PER.TRIAL% = NUMBER.TRIALS.PER.BLOCK%
NUMBER.SAMPLES.PER.ITERATION% = NUMBER.SAMPLES.PER.TRIAL%

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% *
(NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%

SLEEP.SECONDS% = NUMBER.ITERATIONS.PER TRIAL% * 2

ELSE

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = NUMBER.SAMPLES.PER.TRIAL% 
NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * 
(NUMBER.SAMPLES.PER.ITERATION% + 10)
TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * 
NUMBER.TRIALS.PER.BLOCK%
SLEEP.SECONDS% = 2
END IF

END SELECT

REM ---------------------------------------------------------------
REM ---- Loop for each block
REM ---------------------------------------------------------------

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
IF DAY% = 1 THEN CALL INSTRUCT4
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
FOR BCOUNTER% = 1 TO NUMBER.BLOCKS%

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
LOCATE 10, 34: PRINT "Learning Block"

SLEEP (1)
FILESTRS = "C:\CAFTAAR" + PARTICIPANTS$ 
FILENAME$ = FILESTRS + LTRIM$(STR$(DAY%)) + "B" + LTRIM$(STR$(BCOUNTER%)) 
+.DAT"

OPEN FILENAMES FOR APPEND AS #3
WRITE #3, PARTICIPANTS, "Study", PSTUDYS, STUDY$, "Day", DAY%, "BLOCK", 
BCOUNTER%, "Task", TYPE.TASKS$, "Feedback", TYPE.FEEDBACK$

LOCATE 10, 1: PRINT SPACES(79)
LOCATE 10, 1: PRINT SPACES(25), "Block BCOUNTER% ; of" ; NUMBER.BLOCKS%
SLEEP (2): CLS

NUMBER.DATA.POINTS.PER.TRIAL% = INT(NUMBER.SAMPLES.PER.TRIAL% / 2) + 1
ERASE SAMPLE%: REDIM SHARED SAMPLE%(NUMBER.TRIALS.PER.BLOCK%, 
NUMBER.DATA.POINTS.PER.TRIAL%, 3)
ERASE LED%: REDIM SHARED LED%(NUMBER.SAMPLES.PER.TRIAL%)

FOR L% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
LED.TEST% = L% MOD NUMBER.SAMPLES.PER.ITERATION%
IF (LED.TEST% = 0) THEN
LED% (L%) = 1
ELSE
    LED% (L%) = 0
END IF
NEXT L%

SLEEP (2)

FOR TRIAL.COUNTER% = 1 TO NUMBER.TRIALS.PER.BLOCK%
    CALL TRIAL
NEXT TRIAL.COUNTER%

SCREEN 0, 0, 0: WIDTH 80: CLS

LOCATE 10, 1: PRINT SPACE$(79)
LOCATE 10, 1: PRINT SPACE$(34); "Please wait."

FOR TRIAL.COUNTER% = 1 TO NUMBER.TRIALS.PER.BLOCK%
    iii% = 0
    FOR iii% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
        iii% = iii% MOD 2
        SAMPLE_INDEX% = INT(iii% / 2)
        IF iii% = 0 THEN WRITE #3, BCOUNTER%, TRIAL.COUNTER%, iii%, 0,
            SAMPLE%(TRIAL.COUNTER%, SAMPLE_INDEX%, 0), 1,
            SAMPLE%(TRIAL.COUNTER%, SAMPLE_INDEX%, 1), 2,
            SAMPLE%(TRIAL.COUNTER%, SAMPLE_INDEX%, 2)
    NEXT iii%
NEXT TRIAL.COUNTER%
CLOSE #3
NEXT BCOUNTER%

REM -----------------------------------------------------------------------------
REM ---- Perform Scanning Block as appropriate
REM -----------------------------------------------------------------------------

IF (STUDY$ = "R1" OR STUDY$ = "R2") THEN SCAN_FLAG% = 1

IF SCAN_FLAG% = 1 THEN

SCREEN 0, 0, 0: WIDTH 80: CLS

FILESTR$ = "C:\CAFTA\" + PARTICIPANTS$ 
FILENAME$ = FILESTR$ + LTRIM$(STR$(DAY%)) + "S2" + ".DAT"

OPEN FILENAMES FOR APPEND AS #3 
WRITE #3, PARTICIPANTS$, "Study", PSTUDY$, STUDY$, "Day", DAY%, "SCAN 2", "Task", 
    TYPE.TASK$, "Feedback", TYPE.FEEDBACK$

TRIAL.COUNTER% = 0

SCREEN 0, 0, 0: WIDTH 80: CLS
LOCATE 10, 34: PRINT "Scanning Block": SLEEP (1)

NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER_SAMPLES.PER.ITERATION% = 1200

NUMBER_SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER_SAMPLES.PER.ITERATION% + 10)
NUMBER_TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER_TRIALS.PER.BLOCK%
TOTAL_SAMPLES.PER.BLOCK% = NUMBER_SAMPLES.PER.TRIAL% * NUMBER_TRIALS.PER.BLOCK%
NUMBER_BLOCKS% = 1

NUMBER_DATA.POINTS.PER.TRIAL% = INT(NUMBER_SAMPLES.PER.TRIAL% / 2) + 1

ERASE_SAMPLE%: DIM SHARED SAMPLE%(NUMBER_TRIALS.PER.BLOCK%,
NUMBER_DATA.POINTS.PER.TRIAL%, 3)
ERASE_LED%: DIM SHARED LED%(NUMBER_SAMPLES.PER.TRIAL%)

TYPE.TASKS = "C"
TYPE.FEEDBACKS = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 0

CALL SCAN

CLOSE #3
END IF

REM -----------------------------------------------------------------------------
REM ---- End program gracefully
REM *-----------------------------------------------------------------------------

SCREEN 0, 0, 0: WIDTH 80: KEY OFF: COLOR 15, 0: CLS
LOCATE 1, 1: PRINT "Thank you for participating in this experiment."
SLEEP (5): CLS : SYSTEM

REM $STATIC
Subroutine: ABORT

SUB ABORT
  LOCATE 22, 1: PRINT "Error #"; DASG.FLAG%; "in mode "; DASG.MODE%
  PRINT DASGERR$(DASG.FLAG%)
  SYSTEM
END SUB
Subroutine: INITDASG

SUB INITDASG

XBEST! = 0
YBEST! = 0

REM........................................................................................................
REM ----- Initialize the I/O location of the uCDAS-16G board
REM........................................................................................................

DASG.MODE% = 0: DASG.FLAG% = 0
D% (0) = 0
OPEN "C:\METRABYTDASG.ADR" FOR INPUT AS #2
INPUT #2, D%(0)
CLOSE #2
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM........................................................................................................
REM ----- Terminate any previous data collection
REM........................................................................................................

DASG.MODE% = 7: DASG.FLAG% = 0
D% (0) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM........................................................................................................
REM ----- Turn off LED's
REM........................................................................................................

DASG.MODE% = 13: DASG.FLAG% = 0
D% (0) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM........................................................................................................
REM ----- Set CHANNELs to be scanned
REM........................................................................................................

DASG.MODE% = 1: DASG.FLAG% = 0
D% (0) = 1
D% (1) = 2
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM........................................................................................................
REM ----- Initialize timer
REM........................................................................................................

XBEST = 2!: IF XBEST > 32767 THEN XBEST = XBEST - 65537!
YBEST = 5000!: IF YBEST > 32767 THEN YBEST = YBEST - 65537!

DASG.MODE% = 17: DASG.FLAG% = 0
D%(0) = XBEST
D%(1) = YBEST
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

END SUB
Subroutine: INSTRUCT1

SUB INSTRUCT1

CLS
PRINT "INSTRUCTIONS": PRINT SPACE$(79)
PRINT "The apparatus used in this experiment works much like a large Etch-a-Sketch."
PRINT "Your goal is to use this apparatus to learn to draw an elliptical shape that best fits the rectangular shape (square, for example) that will be presented to you. Press enter now to see an example of a target rectangular shape.", Z$

RELATIVE.PHASE% = 90
SCREEN 7: WIDTH 80: COLOR 15, 0
TEMPLATE FLAG% = 1
CALL TEMPLATE
WIDTH 80: COLOR 15, 0
LOCATE 22, 1
PRINT "Press enter again to see the shape that you should draw when presented"
INPUT "this target", Z$
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
SCREEN 7: WIDTH 80: COLOR 15, 0
WINDOW (-200, -200)-(380, 380)
CIRCLE (90, 90), 45, 5
LOCATE 24, 1
INPUT "Press enter for further instructions.", Z$
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0
PRINT "You will draw figures by moving the metal arms located to your right and left."
PRINT "The metal arm to your right controls the horizontal direction. The metal arm to your left controls the vertical direction. If both arms are moved toward your center at the same time, the figure you draw will slant to the right. If your arms are moved in opposition so that one arm moves toward your center while the other arm moves away from you, the figure you draw will slant to the left."
PRINT SPACE$(79)
PRINT "In just a moment, you will be given an opportunity to familiarize yourself with this apparatus. You will be given 5 blocks of practice trials. A computer beep will sound to indicate that you should begin moving the arms. It will sound a second time to indicate that you should stop moving the arms. During the practice trials, you should verify for yourself that the statements made above with respect to horizontal/vertical and left/right directions are true."
PRINT SPACE$(79)
PRINT "If you have any questions regarding the apparatus, please ask the experimenter"
PRINT "now. When you are ready to begin your practice trials, press enter."
INPUT "", Z$

END SUB
Subroutine: INSTRUCT2

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
SELECT CASE BCOUNTER%
CASE 1
  PRINT "In this block of practice trials, you should move the metal arm to ", Z$ 
  PRINT "your left (labelled ARM 2) to verify for yourself that it controls "
  PRINT "movement in the vertical direction. Then, move the metal arm to your"
  PRINT "right (labelled ARM 1) to verify that it controls movement in "
  PRINT "the horizontal direction."
  PRINT SPACE$(79)
  PRINT "Note that the red stripes indicate the boundaries of your movement."
  PRINT "The arms should be moved back and forth between the vertical red ", Z$ 
  PRINT "stripes, adjacent to the blue stoppers, and the slanted red stripes,"
  PRINT "pointing to the center. It is important that you use the entire "
  PRINT "range of motion (red line to red line) if your figure is to be the "
  PRINT "appropriate size."
  PRINT SPACE$(79)
  PRINT "If you have any questions regarding this set of instructions, please"
  PRINT "ask the experimenter now. When you are ready, press enter to begin ", Z$
  PRINT "a set of practice trials in which you should verify that the right arm"
  PRINT "controls movement in the horizontal direction and the left arm controls"
  INPUT "movement in the vertical direction.", Z$
CASE 2
  PRINT "In this block of practice trials, you should move both arms at the"
  PRINT "same time. Verify that moving both arms to you and then away from"
  PRINT "you at the same time draws a line to the right. Then, verify that "
  PRINT "moving both arms at the same time, but in direct opposition, will "
  PRINT "draw a line to the left. The arms should be moved in pendulum like"
  PRINT "fashion."
  PRINT SPACE$(79)
  PRINT "If you have any questions regarding this set of instructions, please"
  INPUT "ask the experimenter now. When you are ready, press enter to continue.", Z$
CASE 3
  PRINT "The movements that you will be asked to make are very rapid (less"
  PRINT "than 1 second). In this next set of practice trials, notice how "
  PRINT "a tone sounds periodically. The first tone is a signal to begin."
  PRINT "Subsequent tones indicate that you should have completed one "
  PRINT "iteration of the elliptical figure. If you are presented with the"
  PRINT "diamond rectangular shape shown previously, for example, each time "
  PRINT "the tone sounds you should have drawn one circle."
  PRINT SPACE$(79)
  PRINT "If you have any questions regarding this set of instructions, please"
  INPUT "ask the experimenter now. When you are ready, press enter to continue.", Z$
CASE 4
  PRINT "In this set of practice trials, you should attempt to draw many "
  PRINT "elliptical figures. Remember both arms should move constantly. "
  PRINT "At no time should the left arm move without the right and vice versa."
  PRINT "If you see horizontal lines in the resulting figure, you will know "
  PRINT "that you moved your right arm while holding the left arm stationary."
  PRINT "If you see vertical lines in the resulting figure, you will know "
PRINT "that you moved your left arm while holding your right arm stationary."
PRINT SPACES$(79)
PRINT "If you have any questions regarding this set of instructions, please"
INPUT "ask the experimenter now. When you are ready, press enter to continue.", Z$
CASE 5
  PRINT "This is your last set of practice trials before we begin the experiment."
  PRINT "Please use this set of practice trials as you see fit."
  PRINT SPACES$(79)
  PRINT "If you have any questions regarding the apparatus, please ask the"
  INPUT "experimenter now. When you are ready, press enter to continue.", Z$
CASE ELSE
  INPUT "Press enter to continue.", Z$
END SELECT

END SUB
Subroutine: INSTRUCT3

SUB INSTRUCT3
PRINT "The following group of trials is called the SCANNING BLOCK. You will"
PRINT "be asked to perform a SCANNING BLOCK of trials at the beginning and end of"
PRINT "each day of practice. In a SCANNING BLOCK of trials, you will be presented "
PRINT "seven different rectangular figures. After a rectangular figure is presented,"
PRINT "you should attempt to draw an elliptical figure which best fits the rectangular"
PRINT "figure. You should attempt to draw the elliptical figure",
NUMBER.ITERATIONS.PER.TRIAL%
PRINT "times. A tone will sound to signal you to begin your attempts to draw the "
PRINT "elliptical figure. It will sound again each time you should have completed one "
PRINT "iteration of the elliptical figure. Remember that the movement is very fast."
PRINT SPACE$(79)
PRINT "To begin, please position both arms on the vertical tape lines such that they "
PRINT "are adjacent to the blue markers. After you have completed a trial, return the arms"
PRINT "to this position so that you will be ready for the next trial. If you have "
PRINT "any questions regarding the SCANNING BLOCK, please ask the experimenter."
INPUT "now. When you are ready, press enter to begin.", Z$
END SUB
Subroutine: INSTRUCT4

SUB INSTRUCT4

PRINT "The next 10 blocks of trials are known as LEARNING BLOCKS. In a LEARNING"  
PRINT "BLOCK of trials, you will be presented with the same rectangular figure"  
PRINT "repeatedly. Your goal is to LEARN to draw the elliptical figure which best"  
PRINT "fits this rectangular figure. Each time you are presented the rectangular "  
PRINT "figure, you should make", NUMBER.ITERATIONS.PER.TRIAL%, "attempt(s) to draw the"  
PRINT "elliptical"  
PRINT "figure which best fits this rectangular figure."
PRINT SPACE$(79)
IF TERMINAL.FEEDBACK.FLAG% = 1 THEN
   PRINT "In the LEARNING BLOCK, the results of your attempts to draw an elliptical figure"  
   PRINT "will not be shown until AFTER you complete your movement."
   PRINT SPACE$(79)
END IF
PRINT "The black lines indicate the starting position for LEARNING trials. If you "  
PRINT "have any questions regarding LEARNING BLOCKS, please ask the experimenter"
INPUT "now. When you are ready to begin, press enter.", Z$  

END SUB
Subroutine: PRACTICE

SUB PRACTICE

FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
    LED%(I%) = 0
NEXT I%

LED%(0) = 1
LED%(NUMBER.SAMPLES.PER.TRIAL% - 2) = 1

CLS
FOR BCOUNTER% = 1 TO 5
    IF BCOUNTER% = 3 THEN
        FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
            LED.TEST% = I% MOD NUMBER.SAMPLES.PER.ITERATION%
            IF (LED.TEST% = 0) THEN
                LED%(I%) = 1
            ELSE
                LED%(I%) = 0
            END IF
        NEXT I%
    END IF
    NEXT I%
END IF

SCREEN 0, 0, 0: WIDTH 80
LOCATE 10, 1: PRINT SPACE$(79)
LOCATE 10, 1: PRINT SPACE$(14), "Block "; I%; " of 5 practice blocks."
CALL INSTRUCT2
SLEEP (2): CLS
TRIAL.COUNTER% = 1
CALL TRIAL

NEXT BCOUNTER%

SCREEN 0, 0, 0: WIDTH 80: CLS
END SUB
Subroutine: PROMPT

SUB PROMPT

REM ----------------------------------------------------------
REM ---- Prompt for task characteristics
REM ----------------------------------------------------------
CLS

LOCATE 1, 1: PRINT "Experiment: ", STUDY$
LOCATE 2, 1: PRINT "Participant: ", PARTICIPANTS
LOCATE 3, 1: PRINT "Day: ", DAY%

TYPE.FEEDBACK$ = " ">
LOCATE 6, 1: PRINT SPACE$(79)
LOCATE 6, 1: INPUT "Please enter feedback type (C,T,N) ==> ", TYPE.FEEDBACK$
TYPE.FEEDBACK$ = UCASE$(TYPE.FEEDBACK$)
DO WHILE ((TYPE.FEEDBACK$ <> "C") AND (TYPE.FEEDBACK$ <> "T") AND
(TYPE.FEEDBACK$ <> "N"))
LOCATE 7, 1: PRINT SPACE$(79)
LOCATE 7, 1: PRINT "ERROR: Feedback type invalid. Enter C - concurrent, T - terminal, 
N - None."
LOCATE 6, 1: PRINT SPACE$(79)
LOCATE 6, 1: INPUT "Please enter feedback type (C,T,N) ==> ", TYPE.FEEDBACK$
TYPE.FEEDBACK$ = UCASE$(TYPE.FEEDBACK$)
LOOP

LOCATE 7, 1: PRINT SPACE$(79)
LOCATE 7, 1: INPUT "Please enter task type (C or D) ==> ", TYPE.TASK$
TYPE.TASK$ = UCASE$(TYPE.TASK$)
DO WHILE ((TYPE.TASK$ <> "C") AND (TYPE.TASK$ <> "D"))
LOCATE 8, 1: PRINT SPACE$(79)
LOCATE 8, 1: PRINT "ERROR: Task type invalid. Enter C for continuous or D for discrete."
LOCATE 7, 1: PRINT SPACE$(79)
LOCATE 7, 1: INPUT "Please enter task type (C or D) ==> ", TYPE.TASK$
TYPE.TASK$ = UCASE$(TYPE.TASK$)
LOOP

LOCATE 8, 1: PRINT SPACE$(79)
LOCATE 8, 1: INPUT "Please enter relative phase (-1,0,90,180) ==> ", RELATIVE.PHASE%
DO WHILE ((RELATIVE.PHASE% <> -1) AND (RELATIVE.PHASE% <> 0) AND
(RELATIVE.PHASE% <> 90) AND (RELATIVE.PHASE% <> 180))
LOCATE 9, 1: PRINT SPACE$(79)
LOCATE 9, 1: PRINT "ERROR: Relative phase invalid. Enter -1 (no relative phase), 0, 90,
or 180."
LOCATE 8, 1: PRINT SPACE$(79)
LOCATE 8, 1: INPUT "Please enter relative phase (-1,0,90,180) ==> ", RELATIVE.PHASE%
LOOP

LOCATE 9, 1: PRINT SPACE$(79)
LOCATE 9, 1: INPUT "Please enter number of blocks ==> ", NUMBER.BLOCKS%
LOCATE 10, 1: PRINT SPACES$(79)
LOCATE 10, 1: PRINT "Please enter number of trials  ==> ",
    NUMBER.TRIALS.PER.BLOCK%

LOCATE 11, 1: PRINT SPACES$(79)
LOCATE 11, 1: PRINT "Please enter number of samples  ==> ",
    NUMBER.SAMPLES.PER.TRIAL%

END SUB
Subroutine: SCAN

SUB SCAN

FOR 1% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
LED.TEST% = 1% MOD NUMBER.SAMPLES.PER.ITERATION%
IF (LED.TEST% = 0) THEN
    LED%(I%) = 1
ELSE
    LED%(I%) = 0
END IF
NEXT 1%

FOR RELATIVE.PHASE% = 0 TO 180 STEP 30

CLS : SCREEN 7

RADIUS% = 45
ASPECT = RELATIVE.PHASE% / 90
START.ANGLE% = RELATIVE.PHASE% / 90 * 1.571
END.ANGLE% = START.ANGLE%

REM CALL TARGET
CALL TEMPLATE

WINDOW (200, 200)-(1200, 1200): SLEEP (3): CLS

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

FOR 1% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = LED%(I%): D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
NOTE.INDEX% = LED%(I%)
SOUND 1046.5, DURATION!(NOTE.INDEX%)
REM PLAY "MB T 200 L 16 N " + NOTE$(NOTE.INDEX%)

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1% = D%(0)

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2% = D%(0)

PSET (CHANNEL1%, CHANNEL2%), DEFAULT.FEEDBACK.COLOR% * SCAN.FLAG%
ODD% = I% MOD 2
SAMPLE.INDEX% = INT(I% / 2)

IF ODD% = 0 THEN
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 0) = LED%(I%)
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1) = CHANNEL1%
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2) = CHANNEL2%
END IF

NEXT I%

II% = 0
FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
    II% = I% MOD 2
    SAMPLE.INDEX% = INT(I% / 2)
    IF II% = 0 THEN WRITE #3, "SCAN", RELATIVE.PHASE%, I%, 0,
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 0), 1, SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1), 2, SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2)
    NEXT I%

NEXT RELATIVE.PHASE%

CLS

END SUB
Subroutine: TARGET

SUB TARGET

WINDOW (-200, -200)-(380, 380)
CIRCLE (90, 90), RADIUS%, 12, , ASPECT

END SUB
Subroutine: TEMPLATE

SUB TEMPLATE

WINDOW (-200, -200)-(380, 380)

I! = 0

FOR I = 1 TO 359

IF I! <= 180 THEN X! = I!
IF I! > 180 THEN X! = 360 - I!

J! = I! + RELATIVE.PHASE%
IF J! <= 180 THEN y! = J!
IF J! > 180 AND J! <= 360 THEN y! = 360 - J!
IF J > 360 THEN y! = J! - 360

PSET (X!, y!), DEFAULT.TEMPLATE.COLOR% * TEMPLATE.FLAG%

NEXT I

END SUB
Subroutine: TRIAL

SUB TRIAL

SCREEN 7

CALL TEMPLATE

WINDOW (200, 200)-(1200, 1200): SLEEP (3): CLS

REM ..................................................
REM ----- Turn off LED's
REM ..................................................

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)

IF DASG.FLAG% <> 0 THEN CALL ABORT

FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
REM ..............................................
REM ----- Turn on LED
REM ..............................................

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = LED%(I%): D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
NOTE.INDEX% = LED%(I%)
SOUND 1046.5, DURATION!(NOTE.INDEX%)

REM ..............................................
REM ----- Collect data from CHANNEL 1
REM ..............................................

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)

IF DASG.FLAG% <> 0 THEN CALL ABORT

CHANNEL1% = D%(0)

REM ..............................................
REM ----- Collect data from CHANNEL 2
REM ..............................................

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)

IF DASG.FLAG% <> 0 THEN CALL ABORT

CHANNEL2% = D%(0)

REM ..............................................
REM ----- Plot displacement data (Concurrent)
REM ..............................................
PSET (CHANNEL1%, CHANNEL2%), DEFAULT.FEEDBACK.COLOR% * 
CONCURRENT.FEEDBACK.FLAG%

REM -----------------------------
REM ----- Transfer data to an array
REM -----------------------------

ODD% = I% MOD 2
SAMPLE.INDEX% = INT(I% / 2)

IF ODD% = 0 THEN
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 0) = LED%(I%)
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1) = CHANNEL1%
    SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2) = CHANNEL2%
END IF

NEXT I%

WINDOW (350, 350)-(1050, 1050): SLEEP (SLEEP.SECONDS%): CLS

FOR I% = 0 TO NUMBER_SAMPLES.PER_TRIAL% - 1

SAMPLE.INDEX% = INT(I% / 2)

CHANNEL1% = SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1)
CHANNEL2% = SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2)

PSET (CHANNEL1%, CHANNEL2%), DEFAULT.FEEDBACK.COLOR% *
TERMINAL.FEEDBACK.FLAG%

NEXT I%

SLEEP (SLEEP.SECONDS%): CLS

END SUB
Data Preparation Programs Written in REXX

Data was prepared for analysis via a series of computer programs written in REXX. These programs include CAFTAF02, CAFTAF03, PLRN01, PSCN01 and PSCN02. Programs were executed in the following sequence to prepare learning trial data for analysis:

1. PLRN01 (invokes CAFTAF02)

2. CAFTAF03

Programs were executed in the following sequence to prepare scanning trial data for analysis:

1. PSCN01

2. PSCN02 (CAFTAF02)

3. CAFTAF03
CAFTAF02

Purpose: Find critical events for each trial including stimulus onset, minimum value and corresponding sample number for each channel, and maximum value and corresponding sample number for each channel.

```rexx
00010000/* REXX EXEC */
00010102
00011000/"========================================================="/
00012000/* Administrative Information Systems */
00013000/* Louisiana State University */
00014000/* University Calendar of Events */
00015000/"========================================================="/
00016000/* */
00017000/* */
00018000/* Clist Name: CAFTAF02 */
00019000/* */
00020000/* Date: March, 1993 */
00021000/* */
00022000/* Function: Parse input data */
00023000/* */
00024000/* Author: Cindy Hadden */
00025000/* */
00026000/* Subroutines: */
00027000/* */
00028000/*----------------------------------------------------------*/
000290000000_CONTROL:
00030000100PARSE ARG PARTICIPANT DAY BLOCK
00031000
000320000150000STIMULUS = 0
000330000151000CHANNEL1 = 0
000340000152000CHANNEL2 = 0
000350000153000RECORD_NAME = 'ORECORD'
000360000154000MEMBER = PARTICIPANT'D'3'DAY'B3'BLOCK
000370000155000MEMBER = STRIP(MEMBER,B,'')
000380000156000MEMBER = PARTICIPANT'D'DAY'M3'BLOCK
000390000157000TRIAL = 0
000400000158000CALL 900_ALLOC_OUTPUT_FILE
000410000159000CALL 910_INPUT_DATA
00042000015A000NBR_OF_INPUT_RECORDS = INPUT.0
00043000015B000DO II = 1 TO NBR_OF_INPUT_RECORDS
00044000015C000PREVIOUS_TRIAL = TRIAL
00045000015D000CALL 920_PARSE_INPUT_RECORD
00046000015E000IF (TRIAL *= PREVIOUS_TRIAL 3 SAMPLE = 0) THEN DO
00047000015F000IF PREVIOUS_TRIAL *= 0 THEN CALL 940_MINMAX
000480000160000CHANNEL1_MINIMUM_VALUE = 0
000490000161000CHANNEL1_MAXIMUM_VALUE = 0
000500000162000CHANNEL2_MINIMUM_VALUE = 0
```

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00200000  CHANNEL2_MAXIMUM_VALUE = 0
00210000  EVENT_TRIAL = TRIAL
00220000  END
00230000  CALL 930_FIND_CRITICAL_POINTS
00240000  END
00250000  CALL 940_MINMAX
00260000  DO WHILE (QUEUED() ^= 0)
00270000  PARSE PULL ORECORD
00280000  "ISPEXEC LMPUT DATAID('DATAIDN') MODE(INVAR)
            DATALOC('RECORD_NAME') DATALEN(80) MEMBER('OMEMBER')"
00290000  END
00300000
00310000  "ISPEXEC LMMREP DATAID('DATAIDN') MEMBER('OMEMBER')"
00320000
00330000  CALL 960_FREE_OUTPUT_FILE
00340000  RETURN
00350000  /*-----------------------------*/
00360000  90_ALLOC_OUTPUT_FILE:
00370000  OUTPUT_DATA_SET = 'HPCINDY.CAFTAF.33PARTICIPANT33'.DATA'
00380000  DSAT '33OUTPUT_DATA_SET33' RC(TALLOC) NOPRINT
00390000  DATA_SET_FLAG = RC
00400000  IF DATA_SET_FLAG = 0 THEN DO
00410000  "ALLOC F(BLOCK) D S ('OUTPUT_DATA_SET') CATALOG
            UNIT(PERM)",
00420000  "DIR(40) LRECL(80) BLKSIZE(6320) SPACE(1,1)
            RECFM(F B)",
00430000  "CYLINDERS"
00440000  "FREE F(SOCK)"
00450000  END
00460000  "ISPEXEC LMINIT DATAID(DATAIDN)
            DATASET('OUTPUT_DATA_SET') ENQ(SHROW)
            ISPEXEC LMOPEN DATAID('DATAIDN') OPTION(OUTPUT)"
00480000  RETURN
00490000  /*-----------------------------*/
00500000  91_INPUT_DATA:
00510000  "ALLOC F(INPUT) D S ('CINDY.CAFTAF.33PARTICIPANT33'.DATA('33MEMBER33')) SHR"
00520000  "EXEC10 * DISKR INPUT (STEM INPUT. FINIS)"
00530000  "FREE F(INPUT)"
00532000  RETURN
00533000  /*-----------------------------*/
00534000  92_PARSE_INPUT_RECORD:
00535000  INPUT_RECORD = INPUT.II
00536000  IF II = 1 THEN DO
00537000  PARSE VAR INPUT.II PARTICIPANT , ' FILLER1 ' , ' CONDITION ' ,'
00538000  PARTICIPANT = STRIP(PARTICIPANT,B,'"')
00539000  CONDITION = STRIP(CONDITION,B,'"')
00540000  PHASE = STRIP(PHASE,B,'"')
00541000  FILLER3 = STRIP(FILLER3,B,'"')
00541100  IF FILLER3 = 'BLOCK' THEN DO
00541200  PARSE VAR INPUT.II FILLER1 , ' FILLER2 ' , ' FILLER3 '
00541300  ' FILLER4 ' , ' FILLER5 ' , ' FILLER6 ' , ' FILLER7 '
00541400  ' BLOCK ' , ' FILLER8 ' , ' TASK_TYPE ' , ' FILLER9 ' , ' FEEDBACK'
00541300  END
00541400  ELSE DO
00541500  PARSE VAR INPUT.II FILLER1 , ' FILLER2 ' , ' FILLER3'

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FILLER4', 'FILLER5', 'FILLER6', 'BLOCK',
FILLER7', 'TASK_TYPE', 'FILLER8', 'FEEDBACK

00541600 END
00541700 TASK_TYPE = STRIP(TASK_TYPE,B,'''
00541800 FEEDBACK = STRIP(FEEDBACK,B)
00541900 FEEDBACK = STRIP(FEEDBACK,B,'''
00542000 END
00543000 IF II »= 1 THEN DO
00544000 PARSE VAR INPUT.II BLOCK ',', TRAIL ',', SAMPLE ',',
FILLER1 ',', STIMULUS ',', FILLER2 ',', CHANNEL1 ',',
FILLER3 ',', CHANNEL2
00544100 END
00544200 RETURN
00544300 /*-----------------------------------------------*/
00544400 
0054441000_FIND_CRITICAL_POINTS:
00544500
00544600 IF STIMULUS = 1 THEN DO
00544700 EVENT = 'STIMULUS'
00544800 EVENT_CHANNEL_NBR = 0
00544900 EVENT_SAMPLE_NBR = SAMPLE
00545000 EVENT_SAMPLE_VALUE = STIMULUS
00545100 CALL 950_QUEUE_EVENT
00545200 END
00545300
00545400 IF CHANNEL1 < CHANNEL1_MINIMUM_VALUE ^ SAMPLE = 0 THEN DO
00545500 CHANNEL1_MINIMUM_VALUE = CHANNEL1
00545600 CHANNEL1_MINIMUM_VALUE_SAMPLE_NBR = SAMPLE
00545700 END
00545800
00545900 IF CHANNEL1 > CHANNEL1_MAXIMUM_VALUE ^ SAMPLE = 0 THEN DO
00546000 CHANNEL1_MAXIMUM_VALUE = CHANNEL1
00546100 CHANNEL1_MAXIMUM_VALUE_SAMPLE_NBR = SAMPLE
00546200 END
00546300
00546400 IF CHANNEL2 < CHANNEL2_MINIMUM_VALUE ^ SAMPLE = 0 THEN DO
00546500 CHANNEL2_MINIMUM_VALUE = CHANNEL2
00546600 CHANNEL2_MINIMUM_VALUE_SAMPLE_NBR = SAMPLE
00546700 END
00546800
00546900 IF CHANNEL2 > CHANNEL2_MAXIMUM_VALUE ^ SAMPLE = 0 THEN DO
00547000 CHANNEL2_MAXIMUM_VALUE = CHANNEL2
00547100 CHANNEL2_MAXIMUM_VALUE_SAMPLE_NBR = SAMPLE
00547200 END
00547300
00547400 IF CHANNEL1 < CHANNEL1_MINIMUM_VALUE ^ SAMPLE = 0 THEN DO
00547500 CHANNEL1_MINIMUM_VALUE = CHANNEL1
00547600 CHANNEL1_MINIMUM_VALUE_SAMPLE_NBR = SAMPLE
00547700 END
00547800
00547900 IF CHANNEL1 > CHANNEL1_MAXIMUM_VALUE ^ SAMPLE = 0 THEN DO
00548000 CHANNEL1_MAXIMUM_VALUE = CHANNEL1
00548100 CHANNEL1_MAXIMUM_VALUE_SAMPLE_NBR = SAMPLE
00548200 END
00548300
00548400 IF CHANNEL2 < CHANNEL2_MINIMUM_VALUE ^ SAMPLE = 0 THEN DO
00548500 CHANNEL2_MINIMUM_VALUE = CHANNEL2
00548600 CHANNEL2_MINIMUM_VALUE_SAMPLE_NBR = SAMPLE
00548700 END
00548800
00548900 IF CHANNEL2 > CHANNEL2_MAXIMUM_VALUE ^ SAMPLE = 0 THEN DO
00549000 CHANNEL2_MAXIMUM_VALUE = CHANNEL2
00549100 CHANNEL2_MAXIMUM_VALUE_SAMPLE_NBR = SAMPLE
00549200 END
00549300
00549400 IF CHANNEL1 < CHANNEL1_MINIMUM_VALUE ^ SAMPLE = 0 THEN DO
00549500 CHANNEL1_MINIMUM_VALUE = CHANNEL1
00549600 CHANNEL1_MINIMUM_VALUE_SAMPLE_NBR = SAMPLE
00549700 END
00549800
00549900 IF CHANNEL1 > CHANNEL1_MAXIMUM_VALUE ^ SAMPLE = 0 THEN DO
005499100 CHANNEL1_MAXIMUM_VALUE = CHANNEL1
005499200 CHANNEL1_MAXIMUM_VALUE_SAMPLE_NBR = SAMPLE
005499300 END
00550000
00550100 RETURN
00550200 /*-----------------------------------------------*/
00550300_MINMAX:
00550400
00550500 EVENT_TRIAL = PREVIOUS_TRIAL
00550600 EVENT = 'MINIMUM1'
00550700 EVENT_CHANNEL_NBR = 1
00550800 EVENT_SAMPLE_NBR = CHANNEL1_MINIMUM_VALUE_SAMPLE_NBR
00550900 EVENT_SAMPLE_VALUE = CHANNEL1_MINIMUM_VALUE
00551000 CALL 950_QUEUE_EVENT
00551100
00551200 EVENT_TRIAL = PREVIOUS_TRIAL
00551300 EVENT = 'MAXIMUM1'
00551400 EVENT_CHANNEL_NBR = 1
00551500 EVENT_SAMPLE_NBR = CHANNEL1_MAXIMUM_VALUE_SAMPLE_NBR
00551600 EVENT_SAMPLE_VALUE = CHANNEL1_MAXIMUM_VALUE

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00551700 CALL 950_QUEUE_EVENT
00551800
00551900 EVENT_TRIAL = PREVIOUS_TRIAL
00552000 EVENT = 'MINIMUM2'
00552100 EVENT_CHANNEL_NBR = 2
00552200 EVENT_SAMPLE_NBR = CHANNEL2_MINIMUM_VALUE_SAMPLE_NBR
00552300 EVENT_SAMPLE_VALUE = CHANNEL2_MINIMUM_VALUE
00552400 CALL 950_QUEUE_EVENT
00552500
00552600 EVENT_TRIAL = PREVIOUS_TRIAL
00552700 EVENT = 'MAXIMUM2'
00552800 EVENT_CHANNEL_NBR = 2
00552900 EVENT_SAMPLE_NBR = CHANNEL2_MAXIMUM_VALUE_SAMPLE_NBR
00553000 EVENT_SAMPLE_VALUE = CHANNEL2_MAXIMUM_VALUE
00553100 CALL 950_QUEUE_EVENT
00553200
00553300 RETURN
00553400/*--------------------------------------------------*/
00553500950_QUEUE_EVENT:
00553600 QUEUE_PARTICIPANT = "PARTICIPANT="33SUBSTR(PARTICIPANT,1,3)
00553700 QUEUE_DAY = "DAY="33DAY
00553800 QUEUE_BLOCK = 'BLOCK='33SUBSTR(BLOCK,1,2)
00553900 QUEUE_TRIAL = 'TRIAL='33SUBSTR(EVENT_TRIAL,1,2)
00554000 QUEUE_EVENT = 'EVENT='33SUBSTR(EVENT,1,10)
00554100 QUEUE_EVENT_CHANNEL_NBR = "CHANNEL="33EVENT_CHANNEL_NBR
00554200 QUEUE_EVENT_SAMPLE_NBR = "NBR="33SUBSTR(EVENT_SAMPLE_NBR,1,4)
00554300 QUEUE_EVENT_SAMPLE_VALUE= "VAL="33SUBSTR(EVENT_SAMPLE_VALUE,1,3)
00554400 QUEUE_RECORD = QUEUE_PARTICIPANT QUEUE_DAY QUEUE_BLOCK
QUEUE_TRIAL QUEUE_EVENT QUEUE_EVENT_CHANNEL_NBR
QUEUE_EVENT_SAMPLE_NBR QUEUE_EVENT_SAMPLE_VALUE
00554500 QUEUE QUEUE_RECORD
00554600 RETURN
00554700/*--------------------------------------------------*/
00554800960_FREE_OUTPUT_FILE:
00554900 "ISPEXEC LMCLOSE DATAID("DATAIDN")"
00555000 "ISPEXEC LMFREE DATAID("DATAIDN")"
00556000 RETURN
CAFTAF03

Purpose: Normalize data. Set each sample point to a value ranging from 0 to 1 by dividing the actual sample value by 2 * range of sample values for that channel trial.

00010000/* REXX EXEC */

00011000/*--------------------------------------*/
00012000/* Administrative Information Systems */
00013000/* Louisiana State University */
00014000/* University Calendar of Events */
00015000/*--------------------------------------*/
00016000/* */
00017000/* */
00018000/* Clist Name: CAFTAF03 */
00019000/* */
00020000/* Date: March, 1993 */
00030000/* */
00040000/* Function: Parse input data */
00050000/* */
00060000/* Author: Cindy Hadden */
00070000/* */
00080000/* Subroutines: */
00090000/*--------------------------------------*/
00100000
00110000000_CONTROL:
00120000
00121002PULL ARGUMENT
00130002PARSE VAR ARGUMENT PARTICIPANT DAY START_BLOCK END_BLOCK
00140000
00150000STIMULUS = 0
00151000CHANNEL1 = 0
00152000CHANNEL2 = 0
00153000RMEMBER_PREFIX = PARTICIPANT'D'3'DAY3'B'
00154000CMEMBER_PREFIX = STRIP(RMEMBER_PREFIX,B,'''')
00155000CMEMBER_PREFIX = PARTICIPANT'D'3'DAY3'R'
00155100CMEMBER_PREFIX = STRIP(CMEMBER_PREFIX,B,'''')
00155200RECORD_NAME = 'ORECORD'
00155300TRIAL = 0
00155400
00155500CALL 900_ALLOC_OUTPUT_FILE
00155600DO I = START_BLOCK TO END_BLOCK
00155700RMEMBER = RMEMBER_PREFIX33I
00155800CMEMBER = CMEMBER_PREFIX33I
00155900CALL 910_INPUT_RAW_DATA
00156000CALL 920_INPUT_CRITICAL_POINTS
00156100
00156200NBR_OF_TRIALS = TRIAL_DATA..0
00156300NBR_OF_INPUT_RECORDS = RAW_DATA.0
00156400TRIAL = 0
00156500PREVIOUS_TRIAL = 0
00156600DO II = 1 TO NBR_OF_INPUT_RECORDS
00156700CALL 940_PARSE_INPUT_RECORD
00156800IF TRIAL *!= PREVIOUS_TRIAL THEN CALL
00156900930_PROCESS_TRIAL_DATA

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00156900 IF II *= 1 THEN CALL 950_PROCESS_RAW_DATA
00157000 IF II *= 1 THEN CALL 960_QUEUE_DATA
00158000 PREVIOUS_TRIAL = TRIAL
00159000 END
00160000 DO WHILE (QUEUED() *= 0)
00170000 PARSE PULL ORECORD
00180000 "ISPEXEC LMPUT DATAID("DATAIDN") MODE(INVAR)
            DATALOC("RECORD_NAME") DATALEN(80) MEMBER("RMEMBER") "
00190000 END
00200000 "ISPEXEC LMMREP DATAID("DATAIDN") MEMBER("RMEMBER")"
00210000END
00220000CALL 970_FREEFILE
00230000RETURN
00240000="/--------------------------------------------------"
0025000090_ALLOC_OUTPUT_FILE:
00260000 OUTPUT_DATA_SET = "HPCINDY.CAFTAF.33PARTICIPANT33".NDATA"
00270000 "DSAT '33OUTPUT_DATA_SET33' RC(TALLO) NOPRINT"
00280000 DATA_SET_FLAG = RC
00290000 IF DATA_SET_FLAG = 0 THEN
00300000 DO
00310000 "ALLOC F(BLOCK) DS('OUTPUT_DATA_SET') CATALOG"
00320000 "UNIT(PERM)"
00330000 "DIR(40) LRECL(80) BLKSIZE(6320) SPACE(30,1)"
00340000 "BLOCK"
00350000 END
00360000 "ISPEXEC LMINIT DATAID(DATAIDN) DATASET('OUTPUT_DATA_SET') ENQ(SHRW)"
00370000 "ISPEXEC LMOPEN DATAID("DATAIDN") OPTION(OUTPUT)"
00380000 RETURN
00390000="/--------------------------------------------------"
0040000091_ALLOC_INPUT_RAW_DATA:
00410000 "ALLOC F(INPUT) DS('CINDY.CAFTAF.33PARTICIPANT33').DATA("33RMEMBER33")'
00420000 "EXEC10 * DISKR INPUT (STEM RAW_DATA. FINIS)"
00430000 "FREE F(INPUT)"
00440000 RETURN
00450000="/--------------------------------------------------"
0046000092_ALLOC_INPUT_CRITICAL_POINTS:
00470000 "ALLOC F(INPUT) DS('HPCINDY.CAFTAF.33PARTICIPANT33'.DATA("33CMEMBER33")')
00480000 "EXEC10 * DISKR INPUT (STEM TRIAL_DATA. FINIS)"
00490000 "FREE F(INPUT)"
00500000 RETURN
00510000="/--------------------------------------------------"
0052000093_PARSE_INPUT_RECORD:
00530000 PARSE VAR TRIAL_DATA.TRIAL FILLER1 FILLER2 FILLER3
            FILLER4 MINIMUM1_SAMPLE MINIMUM1_VALUE MAXIMUM1_SAMPLE
            MAXIMUM1_VALUE MINIMUM2_SAMPLE MINIMUM2_VALUE
            MAXIMUM2_SAMPLE MAXIMUM2_VALUE
00531000 RANGE1 = MAXIMUM1_VALUE - MINIMUM1_VALUE
00532000 RANGE2 = MAXIMUM2_VALUE - MINIMUM2_VALUE
00533000 RETURN
00534000="/--------------------------------------------------"
00534100_PARSE_INPUT_RECORD:
00534200 INPUT_RECORD = RAW_DATA.II
00534300 IF II = 1 THEN DO
00534400 /*--------------------------------------------------*/
PARSE VAR RAW_DATA.II PARTICIPANT '',' FILLER1 ','
CONDITION '',' PHASE '',' FILLER2 ','' DAY '',' FILLER3 ','
PARTICIPANT = STRIP(PARTICIPANT,B,'''')
CONDITION = STRIP(CONDITION,B,'''')
PHASE = STRIP(PHASE,B,'''')
FILLER3 = STRIP(FILLER3,B,'''')
IF FILLER3 = 'BLOCK' THEN DO
PARSE VAR RAW_DATA.II FILLER1 ',' FILLER2 ',' FILLER3
 '',' FILLER4 ',' FILLER5 ',' FILLER6 ',' FILLER7 ','
 BLOCK ',' FILLER8 ',' TASK_TYPE ',' FILLER9 ','
 FEEDBACK
END
ELSE DO
PARSE VAR RAW_DATA.II FILLER1 ',' FILLER2 ',' FILLER3
 '',' FILLER4 ',' FILLER5 ',' FILLER6 ',' FILLER7 ','
 BLOCK ',' FILLER8 ',' TASK_TYPE ',' FILLER9 ','
 FEEDBACK
END
TASK_TYPE = STRIP(TASK_TYPE,B,'''')
FEEDBACK = STRIP(FEEDBACK,B)
FEEDBACK = STRIP(FEEDBACK,B,'''')
IF II •= 1 THEN DO
PARSE VAR RAW_DATA.II BLOCK ',' TRIAL ',' SAMPLE ','
 FILLER1 ',' STIMULUS ',' FILLER2 ',' CHANNEL1 ','
 FILLER3 ',' CHANNEL2
END
RETURN
/*-----------------------------------------------*/
CHANNEL1 = CHANNEL1 - MINIMUM1_VALUE
CHANNEL1 = RANGE1 - CHANNEL1
IF MINIMUM1_SAMPLE <= MAXIMUM1_SAMPLE THEN DO
IF SAMPLE > MINIMUM1_SAMPLE & SAMPLE <
 MAXIMUM1_SAMPLE THEN CHANNEL1 = 2*RANGE1 - CHANNEL1
IF SAMPLE > MINIMUM1_SAMPLE & SAMPLE >=
 MAXIMUM1 SAMPLE THEN CHANNEL1 = 2*RANGE1 + CHANNEL1
END
ELSE DO
IF SAMPLE < MAXIMUM1_SAMPLE THEN
CHANNEL1 = -1*CHANNEL1
IF SAMPLE > MINIMUM1_SAMPLE THEN
CHANNEL1 = 2*RANGE1 - CHANNEL1
END
RP1 = CHANNEL1 / (2 * RANGE1)
CHANNEL2 = CHANNEL2 - MINIMUM2_VALUE
CHANNEL2 = RANGE2 - CHANNEL2
IF MINIMUM2_SAMPLE <= MAXIMUM2_SAMPLE THEN DO
IF SAMPLE > MINIMUM2_SAMPLE &
 SAMPLE < MAXIMUM2_SAMPLE THEN
CHANNEL2 = 2*RANGE2 - CHANNEL2
IF SAMPLE > MINIMUM2_SAMPLE &
 SAMPLE >= MAXIMUM2_SAMPLE THEN
CHANNEL2 = 2*RANGE2 + CHANNEL2
END
ELSE DO
IF SAMPLE < MAXIMUM2_SAMPLE THEN
CHANNEL2 = -1*CHANNEL2
IF SAMPLE > MINIMUM2_SAMPLE THEN
CHANNEL2 = 2*RANGE2 - CHANNEL2
END
RP2 = CHANNEL2 / (2 * RANGE2)
RP = ABS(RP1 - RP2)
RETURN

/* --------------------------------------------------*/
96 QUEUE_DATA:
QUEUE_PARTICIPANT = "S=")SUBSTR(PARTICIPANT,1,3)
QUEUE_DAY = "D=")3DAY
QUEUE_BLOCK = "B=")SUBSTR(BLOCK,1,2)
QUEUE_TRIAL = "T=")SUBSTR(TRIAL,1,2)
QUEUE_SAMPLE = "SAMPLE=")SUBSTR(SAMPLE,1,4)
QUEUE_CHANNEL1 = "CH1=")SUBSTR(CHANNEL1,1,3)
QUEUE_CHANNEL2 = "CH2=")SUBSTR(CHANNEL2,1,3)
QUEUE_RP1 = "RP1=")SUBSTR(RP1,1,5)
QUEUE_RP2 = "RP2=")SUBSTR(RP2,1,5)
QUEUE_RP = "RP=")SUBSTR(RP,1,4)
QUEUE_RECORD = QUEUE_PARTICIPANT ' ' QUEUE_DAY ' ' QUEUE_BLOCK ' ' QUEUE_TRIAL ' ' QUEUE_SAMPLE ' ' QUEUE_CHANNEL1 ' ' QUEUE_CHANNEL2 ' ' QUEUE_RP1 ' ' QUEUE_RP2 ' ' QUEUE_RP

/* --------------------------------------------------*/
97 FREE_OUTPUT_FILE:
"ISPEXEC LMCLOSE DATAID("DATAIDN")"
"ISPEXEC LMFREE DATAID("DATAIDN")"
RETURN

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PLRNO1

Purpose: Invoke CAFTAF02 to determine critical events and then summarize critical events into one observation.

```rexx
00010000/* REXX EXEC */
00010100
000103 00/*======================================================*/
00010400/* Administrative Information Systems */
00010500/* Louisiana State University */
00010600/* University Calendar of Events */
00010700/*======================================================*/
00010800/* */
00010900/* */
00011000/* Clist Name: PLRNO1 */
00011100/* */
00011200/* Date: March, 1993 */
00011300/* */
00011400/* Function: Parse learning trial data */
00011500/* */
00011600/* Author: Cindy Hadden */
00011700/* */
00011800/* Subroutines: */
00011900/*----------------------------------------------------------*/
00012000
00013 000000_CONTROL:
00014000
00015000PULL ARGUMENT
00016000
00017000PARSE VAR ARGUMENT PARTICIPANT DAY NUMBER_OF_BLOCKS
00018000NUMBER_OF_BLOCKS = STRIP(NUMBER_OF_BLOCKS,B)
00019000
00020000DO I = 1 TO NUMBER_OF_BLOCKS
00021000MEMBER = PARTICIPANT^^ 'D' ^^ 'M' ^ ^  'I
00022000SUMMARY = PARTICIPANT^^ 'R' ^3  'I
00023000SUMMARY_INDEX = 0
00024000CALL CAFTAF02 PARTICIPANT DAY I
00025000CALL 910_INPUT_EVENTS
00026000NUMBER_OF_EVENTS = EVENT.0
00027000TRIAL=0
00028000PREVIOUS_TRIAL = 0
00029000CHANNEL1_EVENT_F0UND = ' N'
00030000DO II = 1 TO NUMBER_OF_EVENTS
00031000CALL 920_PROCESS_EVENTS
00032000IF TRIAL *= PREVIOUS_TRIAL & TRIAL *= 1 THEN DO
00033000PTRIAL = PREVIOUS_TRIAL
00034000SUMMARY_INDEX = SUMMARY_INDEX + 1
00035000SUMMARY_INDEX = PARTICIPANT^^ 'D' ^^ 'I
00036000SUMMARY_INDEX = PARTICIPANT^^ 'R' ^3  'I
00037000SUMMARY_INDEX = PARTICIPANT^^ 'MINIMUM1_NBR'^3  'MINIMUM1_VAL'^3  'MAXIMUM1_NBR'^3  'MAXIMUM1_VAL'^3  'MINIMUM2_NBR'^3  'MINIMUM2_VAL'^3  'MAXIMUM2_NBR'^3  'MAXIMUM2_VAL
```

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00141400  MINIMUM1_NBR = 0
00141500  MINIMUM1_VAL = 0
00141600  MAXIMUM1_NBR = 0
00141700  MAXIMUM1_VAL = 0
00141800  MINIMUM2_NBR = 0
00141900  MINIMUM2_VAL = 0
00142000  MAXIMUM2_NBR = 0
00142100  MAXIMUM2_VAL = 0
00142200  END
00142300  IF EVENT = 'MINIMUM1' THEN DO
00142400    MINIMUM1_NBR = NBR
00142500    MINIMUM1_VAL = VAL
00142600  END
00142700  IF EVENT = 'MAXIMUM1' THEN DO
00142800    MAXIMUM1_NBR = NBR
00142900    MAXIMUM1_VAL = VAL
00143000  END
00144000  IF EVENT = 'MINIMUM2' THEN DO
00144100    MINIMUM2_NBR = NBR
00144200    MINIMUM2_VAL = VAL
00144300  END
00144400  IF EVENT = 'MAXIMUM2' THEN DO
00144500    MAXIMUM2_NBR = NBR
00144600    MAXIMUM2_VAL = VAL
00144700  END
00144800  PREVIOUS_TRIAL = TRIAL
00144900  END
00145000
00145100  SUMMARY_INDEX = SUMMARY_INDEX + 1
00145200  SUMMARY_RECORD.SUMMARY_INDEX = PARTICIPANT
00145300  CALL 930_OUTPUT_SUMMARY_FILE
00145400  END
00145500
00145600  EXIT
00145700/*-----------------------------------------------*/
00145800 910_INPUT_EVENTS:
00145900  "ALLOC F(INPUT)
00146000  "EXEC10 * DISKR INPUT (STEM EVENT. FINIS)"
00146100  "FREE F(INPUT)"
00146200  RETURN
00146300 /*-----------------------------------------------*/
00146400 920_PROCESS_EVENTS:
00146500  PARSE VAR EVENT.II PARTICIPANT DAY BLOCK TRIAL EVENT
00146600  EVENT_CHANNEL_NBR EVENT_SAMPLE_NBR EVENT_SAMPLE_VALUE
00146700  INTERPRET PARTICIPANT
00146800  INTERPRET DAY
00146900  INTERPRET BLOCK
00147000  INTERPRET TRIAL
00147100  INTERPRET EVENT
00147200  INTERPRET EVENT_CHANNEL_NBR
00147300  INTERPRET EVENT_SAMPLE_NBR
00147400  INTERPRET EVENT_SAMPLE_VALUE
00147500

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RETURN
*--------------------------------------------------*/
OUTPUT_SUMMARY_FILE:
SUMMARY_RECORD.0 = SUMMARY_INDEX
"ALLOC F(SUMMARY)
DS('HPCINDY.CAPTAF."33PARTICIPANT33".DATA("33SUMMARY33")')
SHR"
"EXECIO * DISKW SUMMARY (STEM SUMMARY_RECORD. FINIS)"
"FREE F(SUMMARY)"
RETURN
PSCNO1

Purpose: Parse scanning block into individual trials

00010000/* REXX EXEC */
00010100
00010200/*=============================================*/
00010300/* Administrative Information Systems */
00010400/* Louisiana State University */
00010500/* University Calendar of Events */
00010600/*=============================================*/
00010700/* */
00010800/* */
00010900/* Clist Name: PSCNO1 */
00011000/* */
0001110000000_CONTROL:
0001120000040000
0001130000041000PULL ARGUMENT
0001140000042000PARSE VAR ARGUMENT PARTICIPANT DAY BLOCK
0001150000043000
0001160000044000STIMULUS = 0
0001170000045000CHANNEL1 = 0
0001180000046000CHANNEL2 = 0
0001190000047000
0001200000048000IMEMBER = PARTICIPANT'D'DAY'S'SBLOCK
0001210000049000IMEMBER = STRIP(IMEMBER,B,'''')
0001220000050000
0001230000051000IF DAY = 1 & BLOCK = 1 THEN BLOCK = 1
0001240000052000IF DAY = 1 & BLOCK = 2 THEN BLOCK = 2
0001250000053000IF DAY = 2 & BLOCK = 1 THEN BLOCK = 3
0001260000054000IF DAY = 2 & BLOCK = 2 THEN BLOCK = 4
0001270000055000IF DAY = 5 & BLOCK = 2 THEN BLOCK = 5
0001280000056000IF DAY = 6 & BLOCK = 2 THEN BLOCK = 6
0001290000057000ITRIAL = 0
0001300000058000ISAMPLE = 0
0001310000059000
0001320000060000IF RECORD_NAME = 'ORECORD'
0001330000061000OMEMBER = PARTICIPANT'D'DAY'B'BBLOCK
0001340000062000OMEMBER = STRIP(OMEMBER,B,'''')
0001350000063000
0001360000064000173

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CALL 900_INPUT_DATA

NBR_OF_INPUT_RECORDS = INPUT.

DO II = 1 TO NBR_OF_INPUT_RECORDS
   CALL 910_PROCESS_INPUT_RECORD
END

CALL 960_ALLOC_OUTPUT_FILE

DO WHILE ( QUEUED() * = 0 )
   PARSE PULL OR RECORD
   "ISPEXEC LMPUT DATAID("DATAIDN") MODE(INVAR)
      DATALOC("RECORD_NAME") DATALEN(80) MEMBER("OMEMBER") "
END

CALL 970_FREE_OUTPUT_FILE
RETURN

900_INPUT_DATA:
   "ALLOC F (INPUT)
      D S ('CINDY.CAFTAF."33PARTICIPANT 33".DATA("33IMEMBER33") ')
      SHR"
   EXECIO * DISKR INPUT (STEM INPUT. FINIS)"
   FREE P(INPUT)"
RETURN

910_PROCESS_INPUT_RECORD:
   INPUT_RECORD = INPUT.II
   IF II = 1 THEN DO
      PARSE VAR INPUT.II QUEUE_RECORD
      CALL 920_QUEUE_EVENT
   END
   IF II * = 1 THEN DO
      PARSE VAR INPUT.II IBLOCK ',', ITrial ',', ISAMPLE ',', FILLER
      IF ITrial = 90 & ISAMPLE >= 1210 & ISAMPLE <=12000 THEN DO
         TRIAL = TRUNC(ISAMPLE/1210)
         IF ISAMPLE=1210 THEN ISAMPLE=0
         IF ISAMPLE=2420 THEN ISAMPLE=0
         IF ISAMPLE=3630 THEN ISAMPLE=0
         IF ISAMPLE=4840 THEN ISAMPLE=0
         IF ISAMPLE=6050 THEN ISAMPLE=0
         IF ISAMPLE=7260 THEN ISAMPLE=0
         IF ISAMPLE=8470 THEN ISAMPLE=0
         IF ISAMPLE=9680 THEN ISAMPLE=0
         IF ISAMPLE=10890 THEN ISAMPLE=0
         QUEUE_RECORD =
            BLOCK33"',"33TRIAL33","33ISAMPLE33","33FILLER"
      END
   END
   CALL 920_QUEUE_EVENT
RETURN

920_QUEUE_EVENT:
RETURN

960_ALLOC_OUTPUT_FILE:
00553000 OUTPUT_DATA_SET = "CINDY.CAFTAF." ^ "PARTICIPANT" ^ "DATA"
00554000 "ISPEXEC LMINIT DATAID(DATAIDN)
            DATASET('"OUTPUT_DATA_SET"') ENQ(SHRW)"
00554100 "ISPEXEC LMOPEN DATAID("DATAIDN") OPTION(OUTPUT)"
00554200 RETURN
00554300 /* --------------------------------------------------*/
0055440097 0_FREE_OUTPUT_FILE:
00554500 "ISPEXEC LMCLOSE DATAID("DATAIDN")"
00554600 "ISPEXEC LMFREE DATAID("DATAIDN")"
00554700 RETURN
PSCN02

Purpose: Invoke CAFTAF02 to determine critical events and then summarize critical events into one observation.

```
00010000/* REXX EXEC */
00010100
00010200/* Administrative Information Systems */
00010300/* Louisiana State University */
00010400/* University Calendar of Events */
00010500/*-------------------------------*/
00010700/* Date: November, 1997 */
00010800/* Function: Determine critical points for scan trials */
00010900/* Author: Cindy Hadden */
00011000/* Subroutines:*/
00011100/* CALL CAFTAF02 PARTICIPANT DAY BLOCK */
00011200/* CALL 910_INPUT_EVENTS */
00011300/* CALL 920_PROCESS_EVENTS */
00011400/* IF TRIAL ^= PREVIOUS_TRIAL & TRIAL ^= 1 THEN DO */
00011500/* SUMMARY_INDEX = SUMMARY_INDEX + 1 */
00011600/* SUMMARY_RECORD.SUMMARY_INDEX = PARTICIPANT^
00011700/* 'D' 'DAY' 'M' 'BLOCK */
00011800/* 'MINIMUM1_NBR' 'MINIMUM1_VAL' 'MAXIMUM1_NBR' 'MAXIMUM1_VAL' */
00011900/* 'MINIMUM2_NBR' 'MINIMUM2_VAL' 'MAXIMUM2_NBR' 'MAXIMUM2_VAL' */
00012000/* MINIMUM1_NBR = 0 */
00012100/* MINIMUM1_VAL = 0 */
00012200/* MAXIMUM1_NBR = 0 */
00012300/* MAXIMUM1_VAL = 0 */
```

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MINIMUM2_VAL = 0
MAXIMUM2_NBR = 0
MAXIMUM2_VAL = 0

IF EVENT = 'MINIMUM1' THEN DO
  MINIMUM1_NBR = NBR;
  MINIMUM1_VAL = VAL;
END;

IF EVENT = 'MAXIMUM1' THEN DO
  MAXIMUM1_NBR = NBR;
  MAXIMUM1_VAL = VAL;
END;

IF EVENT = 'MINIMUM2' THEN DO
  MINIMUM2_NBR = NBR;
  MINIMUM2_VAL = VAL;
END;

IF EVENT = 'MAXIMUM2' THEN DO
  MAXIMUM2_NBR = NBR;
  MAXIMUM2_VAL = VAL;
END;

PREVIOUS_TRIAL = TRIAL;

SUMMARY_INDEX = SUMMARY_INDEX + 1;
SUMMARY_RECORD.SUMMARY_INDEX = PARTICIPANT^DAY^BLOCK^TRIAL^MINIMUM1_NBR^MINIMUM1_VAL^MAXIMUM1_NBR^MAXIMUM1_VAL^MINIMUM2_NBR^MINIMUM2_VAL^MAXIMUM2_NBR^MAXIMUM2_VAL;

CALL 930_OUTPUT_SUMMARY_FILE;

EXIT;

910_INPUT_EVENTS:
ALLOC F (INPUT)
D S ('HPCINDY.CAFTAF', 'PARTICIPANT', 'DATA(3MEMBERS')
SHR"
EXECIO * DISKR INPUT (STEM EVENT, FINIS)
FREE F (INPUT)"
RETURN;

920_PROCESS_EVENTS:
PARSE VAR EVENT.II PARTICIPANT DAY BLOCK TRIAL EVENT
  EVENT_CHANNEL_NBR EVENT_SAMPLE_NBR EVENT_SAMPLE_VALUE

CALL 930_OUTPUT_SUMMARY_FILE:

ALLOC F (SUMMARY)
DS('HPCINDY.CAFTAP.'PARTICIPANT' .DATA('SUMMARY'))
SHR"
00182700 "EXECIO * DISKW SUMMARY (STEM SUMMARY_RECORD. FINIS)"
00182800 "FREE F(SUMMARY)"
00182900RETURN
00183000
APPENDIX D. ANOVA TABLES FOR EXPERIMENT 1

ANOVA Summary Table for RMSE

Table D.1 ANOVA Table for RMSE in Acquisition

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>23</td>
<td>1670.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>1</td>
<td>529.47</td>
<td>529.47</td>
<td>10.21</td>
<td>0.0042</td>
</tr>
<tr>
<td>Residual between</td>
<td>22</td>
<td>1141.02</td>
<td>51.86</td>
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Table D.2 ANOVA Table for RMSE in Retention

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### ANOVA Summary Table for SD of RMSE

#### Table D.3 ANOVA Table for SD of RMSE in Acquisition

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ANOVA Summary Table for Absolute Delta of Relative Phase

Table D.5 ANOVA Table for Delta of Relative Phase in Acquisition

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Table D.6 ANOVA Table for Delta of Relative Phase in Retention

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ANOVA Summary Table for SD of Relative Phase

Table D.7 ANOVA Table for SD of Relative Phase in Acquisition

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Table D.8 ANOVA Table for SD of Relative Phase in Retention

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182
### ANOVA Summary Table for Duration

#### Table D.9 ANOVA Table for Duration in Acquisition

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ANOVA Summary Table for Standard Deviation of Duration

Table D.11 ANOVA Table for SD of Duration in Acquisition

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Table D.12 ANOVA Table for SD of Duration in Retention

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Table D.13 ANOVA Table for Range of Motion 1 in Acquisition

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<td>14798.46</td>
<td>2114.07</td>
<td>4.34</td>
<td>0.0031</td>
</tr>
<tr>
<td>Residual within</td>
<td>154</td>
<td>74953.90</td>
<td>486.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>191</td>
<td>378205.57</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table D.14 ANOVA Table for Range of Motion 1 in Retention

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>23</td>
<td>449451.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>1</td>
<td>158006.25</td>
<td>158006.25</td>
<td>11.93</td>
<td>0.0023</td>
</tr>
<tr>
<td>Residual between</td>
<td>22</td>
<td>291445.08</td>
<td>13247.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>120</td>
<td>48757.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>5</td>
<td>654.42</td>
<td>130.88</td>
<td>0.31</td>
<td>0.8411</td>
</tr>
<tr>
<td>Block*Feedback</td>
<td>5</td>
<td>1166.83</td>
<td>233.37</td>
<td>0.55</td>
<td>0.6709</td>
</tr>
<tr>
<td>Residual within</td>
<td>110</td>
<td>46936.42</td>
<td>426.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>498209.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table D.15 ANOVA Table for Range of Motion 2 in Acquisition

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>23</td>
<td>308215.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>1</td>
<td>47517.81</td>
<td>47517.81</td>
<td>4.01</td>
<td>0.0577</td>
</tr>
<tr>
<td>Residual between</td>
<td>22</td>
<td>260698.04</td>
<td>11849.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>168</td>
<td>100977.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>7</td>
<td>5243.56</td>
<td>749.08</td>
<td>1.41</td>
<td>0.246</td>
</tr>
<tr>
<td>Block*Feedback</td>
<td>7</td>
<td>13902.37</td>
<td>1986.05</td>
<td>3.74</td>
<td>0.0133</td>
</tr>
<tr>
<td>Residual within</td>
<td>154</td>
<td>81831.14</td>
<td>531.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>191</td>
<td>409192.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table D.16 ANOVA Table for Range of Motion 2 in Retention

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>23</td>
<td>439207.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>1</td>
<td>131950.56</td>
<td>131950.56</td>
<td>9.45</td>
<td>0.0056</td>
</tr>
<tr>
<td>Residual between</td>
<td>22</td>
<td>307256.76</td>
<td>13966.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>120</td>
<td>66531.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>5</td>
<td>886.53</td>
<td>177.31</td>
<td>0.31</td>
<td>0.7788</td>
</tr>
<tr>
<td>Block*Feedback</td>
<td>5</td>
<td>1837.98</td>
<td>367.60</td>
<td>0.63</td>
<td>0.5640</td>
</tr>
<tr>
<td>Residual within</td>
<td>110</td>
<td>63806.99</td>
<td>580.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>505738.82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of Significant Findings for Experiment 1

Table D.17 Summary of Significant Findings in Acquisition

<table>
<thead>
<tr>
<th>Factor</th>
<th>Variable</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback</td>
<td>RMSE</td>
<td>F(1,22) = 10.21</td>
<td>0.0042</td>
</tr>
<tr>
<td>Block</td>
<td>RMSE</td>
<td>F(7,154) = 10.72</td>
<td>0.0001</td>
</tr>
<tr>
<td>Feedback</td>
<td>SD of RMSE</td>
<td>F(1,22) = 7.21</td>
<td>0.0135</td>
</tr>
<tr>
<td>Block</td>
<td>SD of RMSE</td>
<td>F(7,154) = 17.68</td>
<td>0.0001</td>
</tr>
<tr>
<td>Feedback</td>
<td>(\Delta) of RPI</td>
<td>F(1,22) = 10.14</td>
<td>0.0043</td>
</tr>
<tr>
<td>Block</td>
<td>(\Delta) of RPI</td>
<td>F(7,154) = 10.75</td>
<td>0.0001</td>
</tr>
<tr>
<td>Feedback</td>
<td>SD of RP</td>
<td>F(1,22) = 5.40</td>
<td>0.0298</td>
</tr>
<tr>
<td>Block</td>
<td>SD of RP</td>
<td>F(7,154) = 13.51</td>
<td>0.0001</td>
</tr>
<tr>
<td>Block</td>
<td>Duration</td>
<td>F(7,154) = 11.77</td>
<td>0.0001</td>
</tr>
<tr>
<td>Block</td>
<td>SD of Duration</td>
<td>F(7,154) = 17.21</td>
<td>0.0001</td>
</tr>
<tr>
<td>Feedback</td>
<td>Range of Motion 1</td>
<td>F(1,22) = 4.65</td>
<td>0.0422</td>
</tr>
<tr>
<td>Block x Feedback</td>
<td>Range of Motion 1</td>
<td>F(7,154) = 4.34</td>
<td>0.0031</td>
</tr>
<tr>
<td>Block x Feedback</td>
<td>Range of Motion 2</td>
<td>F(7,154) = 3.74</td>
<td>0.0133</td>
</tr>
</tbody>
</table>

Table D.18 Summary of Significant Findings in Retention

<table>
<thead>
<tr>
<th>Factor</th>
<th>Variable</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback</td>
<td>SD of RMSE</td>
<td>F(1,22) = 2.03</td>
<td>0.0353</td>
</tr>
<tr>
<td>Feedback</td>
<td>Range of Motion 1</td>
<td>F(1,22) = 11.93</td>
<td>0.0023</td>
</tr>
<tr>
<td>Feedback</td>
<td>Range of Motion 2</td>
<td>F(1,22) = 9.45</td>
<td>0.0056</td>
</tr>
</tbody>
</table>
APPENDIX E. SELECTED TRIALS FOR EXPERIMENT 1

Concurrent Group

Figure E.1 Selected Trials for Experiment 1 Concurrent Participant AAC
Figure E.2 Selected Trials for Experiment 1 Concurrent Participant BAJ

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Figure E.3 Selected Trials for Experiment 1 Concurrent Participant CAW
Figure E.4 Selected Trials for Experiment 1 Concurrent Participant DSS
Figure E.5 Selected Trials for Experiment 1 Concurrent Participant EES
Figure E.6 Selected Trials for Experiment 1 Concurrent Participant EGA
Figure E.7 Selected Trials for Experiment 1 Concurrent Participant HCC

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Figure E.8 Selected Trials for Experiment 1 Concurrent Participant JMM
Figure E.9 Selected Trials for Experiment 1 Concurrent Participant LAB
Figure E.10 Selected Trials for Experiment 1 Concurrent Participant LAO
Figure E.11 Selected Trials for Experiment 1 Concurrent Participant MKH
Figure E.12 Selected Trials for Experiment 1 Concurrent Participant MMS
Figure E.13 Selected Trials for Experiment 1 Terminal Participant BLN
Figure E.14 Selected Trials for Experiment 1 Terminal Participant CLS
Figure E.15 Selected Trials for Experiment 1 Terminal Participant JWW
Figure E.16 Selected Trials for Experiment 1 Terminal Participant MAM
Figure E.17 Selected Trials for Experiment 1 Terminal Participant MDW

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Figure E.18 Selected Trials for Experiment 1 Terminal Participant MNW
Figure E.19 Selected Trials for Experiment 1 Terminal Participant NMK
Figure E.20 Selected Trials for Experiment 1 Terminal Participant SDB
Figure E.21 Selected Trials for Experiment 1 Terminal Participant SJN
Figure E.22 Selected Trials for Experiment 1 Terminal Participant SLS
Figure E.23 Selected Trials for Experiment 1 Terminal Participant SMK

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Figure E.24 Selected Trials for Experiment 1 Terminal Participant TRH
APPENDIX F. SELECTED SCAN TRIALS FOR EXPERIMENT 1

Concurrent Group

Figure F.1 Selected Scan Trials for Experiment 1 Concurrent Participant AAC
Figure F.2 Selected Scan Trials for Experiment 1 Concurrent Participant BAJ
Figure F.3 Selected Scan Trials for Experiment 1 Concurrent Participant CAW
Figure F.4 Selected Scan Trials for Experiment 1 Concurrent Participant DSS
Figure F.5 Selected Scan Trials for Experiment 1 Concurrent Participant EES
Figure F.6 Selected Scan Trials for Experiment 1 Concurrent Participant EGA
Figure F.7 Selected Scan Trials for Experiment 1 Concurrent Participant HCC
Figure F.8 Selected Scan Trials for Experiment 1 Concurrent Participant JMM
Figure F.9 Selected Scan Trials for Experiment 1 Concurrent Participant LAB
Figure F.10 Selected Scan Trials for Experiment 1 Concurrent Participant LAO
Figure F.11 Selected Scan Trials for Experiment 1 Concurrent Participant MKH
Figure F.12 Selected Scan Trials for Experiment 1 Concurrent Participant MMS
Figure F.13 Selected Scan Trials for Experiment 1 Terminal Participant BLN
Figure F.14 Selected Scan Trials for Experiment 1 Terminal Participant CLS
Figure F.15 Selected Scan Trials for Experiment 1 Terminal Participant JWW
Figure F.16 Selected Scan Trials for Experiment 1 Terminal Participant MAM
Figure F.17 Selected Scan Trials for Experiment 1 Terminal Participant MDW
Figure F.18 Selected Scan Trials for Experiment 1 Terminal Participant MNW
Figure F.19 Selected Scan Trials for Experiment 1 Terminal Participant NMK
Figure F.20 Selected Scan Trials for Experiment 1 Terminal Participant SDB
Figure F.21 Selected Scan Trials for Experiment 1 Terminal Participant SJN
Figure F.22 Selected Scan Trials for Experiment 1 Terminal Participant SLS
Figure F.23 Selected Scan Trials for Experiment 1 Terminal Participant SMK
Figure F.24 Selected Scan Trials for Experiment 1 Terminal Participant TRH
APPENDIX G. CHAPTER 3 COMPUTER PROGRAMS

Data Collection Programs Written in Quick Basic

Main Program: CAFTAF2

DECLARE SUB ABORT()
DECLARE SUB INITDASG()
DECLARE SUB INITFB()
DECLARE SUB INITSUBJ()
DECLARE SUB INSTRUCT1()
DECLARE SUB INSTRUCT2()
DECLARE SUB PRACTICE()
DECLARE SUB PROMPT()
DECLARE SUB STIMULUS1()
DECLARE SUB STIMULUS2()
DECLARE SUB TRIAL()

DECLARE SUB BASDASG (DASG.MODE%, BYVAL dummy%, DASG.FLAG%)

REM ----------------------------------------------
REM Sample DASG data collection routine
REM -----
REM ---- Author: Cindy Hadden
REM ---- Date: January, 1998
REM ----------------------------------------------

REM ----------------------------------------------
REM ------ Initialize variables
REM ----------------------------------------------

DIM D%(16) 'DASGPARMS
DIM DASGERR$(28) 'DASGerror messages

COMMON SHARED D%( ), DASGERR%( )
COMMON SHARED DASG.MODE%, DASG.FLAG%
COMMON SHARED PARTICIPANTS, STUDY$, DAY%, FILENAMES
COMMON SHARED NUMBER.BLOCKS%, NUMBER.TRIALS.PER.BLOCK%,
      TRIAL.COUNTER%, B_COUNTER%
COMMON SHARED NUMBER.ITERATIONS.PER.TRIAL%,
      NUMBER.SAMPLES.PER.ITERATION%, TOTAL.ITERATIONS.PER.BLOCK%
COMMON SHARED TYPE.TASK$, SLEEP.SECONDS%, RELATIVE.PHASE%
COMMON SHARED DEFAULT.FEEDBACK.COLOR%, DEFAULT.TEMPLATE.COLOR%
COMMON SHARED CONCURRENT.FEEDBACK.FLAG%, TERMINAL.FEEDBACK.FLAG%
COMMON SHARED TEMPLATE.FLAG%
COMMON SHARED RADIUS%, START.ANGLE%, END.ANGLE%, ASPECT
COMMON SHARED CHANNEL1.RANGE%, CHANNEL1.HIGH%, CHANNEL1.LOW%
COMMON SHARED CHANNEL2.RANGE%, CHANNEL2.HIGH%, CHANNEL2.LOW%
COMMON SHARED FEEDBACK.DIAMETER%
REM $DYNAMIC
DASG.MODE% = 0: DASG.FLAG% = 0
REM
REM ---------------------------------------------------------------------------
REM ---- Initialize error messages
REM ---------------------------------------------------------------------------

OPEN "C:\cindy\programs\dsagerrs.dat" FOR INPUT AS #1
FOR I% = 0 TO 28
    INPUT #1, DASGERR$(I%)
NEXT I%
REM
REM ---------------------------------------------------------------------------
REM ---- Clear screen
REM ---------------------------------------------------------------------------

SCREEN 0, 0, 0: WIDTH 80: KEY OFF: CLS
REM
REM ---------------------------------------------------------------------------
REM ---- Initialize the uCDAS-16G board for data collection
REM ---------------------------------------------------------------------------

CALL INITDASG
CALL INITSUBJ
CALL INITFB

DEFAULT.FEEDBACK.COLOR% = 5
DEFAULT.TEMPLATE.COLOR% = 12
TEMPLATE.FLAG% = 0
SLEEP.SECONDS% = 2

NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * 
    (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * 
    NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * 
    NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 1

NUMBER.DATA.POINTS.PER.TRIAL% = INT(NUMBER.SAMPLES.PER.TRIAL% / 2) + 1

DIM SHARED SAMPLE%(NUMBER.TRIALS.PER.BLOCK%,
    NUMBER.DATA.POINTS.PER.TRIAL%, 3)
DIM SHARED LED%(NUMBER.SAMPLES.PER.TRIAL%)

DIM SHARED NOTES(2)

NOTES$(0) = "0"
NOTES$(1) = "48"

DIM SHARED DURATION!(2)

DURATION!(0) = 0
DURATION!(1) = 6.5

REM ---------------------------------------------------------------
REM ----- Warn about disk space
REM ---------------------------------------------------------------

CLS
COLOR 12, 0

LOCATE 10, 1
PRINT SPACE$(10), "WARNING: This experiment fills up the hard drive. Output is"
PRINT SPACE$(10), " is stored in the directory C:\CAFTAF. Please transfer"
PRINT SPACE$(10), " output data to a diskette and delete files from the"
PRINT SPACE$(10), " hard drive at the conclusion of this experiment."
PRINT SPACE$(79): PRINT SPACE$(79): PRINT SPACE$(79)
INPUT "Press ENTER key to continue", Z$

COLOR 15, 0
CLS
SLEEP (2)

REM ---------------------------------------------------------------
REM ----- Practice if appropriate
REM ---------------------------------------------------------------

IF DAY% = 1 THEN

TYPE.TASK$ = "D"

TYPE.FEEDBACK$ = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

IF STUDY$ = "2" THEN

TYPE.FEEDBACK$ = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1
END IF

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 0

CALL INSTRUCT1
CALL PRACTICE

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END IF

PSTUDYS = STUDYS
IF (STUDYS = "1" OR STUDYS = "2") AND DAY% = 7 THEN STUDYS = "R1"
IF (STUDYS = "1" OR STUDYS = "2") AND DAY% = 8 THEN STUDYS = "R1"
IF (STUDYS = "3" OR STUDYS = "4") AND DAY% = 7 THEN STUDYS = "R2"
IF (STUDYS = "3" OR STUDYS = "4") AND DAY% = 8 THEN STUDYS = "R2"
IF (STUDYS = "5" OR STUDYS = "6") AND DAY% = 7 THEN STUDYS = "R3"
IF (STUDYS = "5" OR STUDYS = "6") AND DAY% = 8 THEN STUDYS = "R3"

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS

SELECT CASE STUDYS
  CASE "1"
    NUMBER.ITERATIONS.PER.TRIAL% = 1
    NUMBER.SAMPLES.PER.ITERATION% = 1200
    NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
    NUMBER.TRIALS.PER.BLOCK% = 20
    TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    NUMBER.BLOCKS% = 8
    TYPE.TASK$ = "D"
    TYPE.FEEDBACK$ = "C"
    CONCURRENT.FEEDBACK.FLAG% = 1
    TERMINAL.FEEDBACK.FLAG% = 0
    TEMPLATE.FLAG% = 1
    RELATIVE.PHASE% = 90
  CASE "2"
    NUMBER.ITERATIONS.PER.TRIAL% = 1
    NUMBER.SAMPLES.PER.ITERATION% = 1200
    NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
    NUMBER.TRIALS.PER.BLOCK% = 20
    TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    NUMBER.BLOCKS% = 8

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TYPE.TASK$ = "D"

TYPE.FEEDBACK$ = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "3"

NUMBER.ITERATIONS.PER.TRIAL% = 20
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASK$ = "C"

TYPE.FEEDBACK$ = "C"
CONCURRENT.FEEDBACK.FLAG% = 1
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "4"

NUMBER.ITERATIONS.PER.TRIAL% = 20
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 8

TYPE.TASK$ = "C"

TYPE.FEEDBACK$ = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1
TEMPLATE_FLAG% = 1
RELATIVE_PHASE% = 90

CASE "5"

NUMBER_ITERATIONS_PER_TRIAL% = 1
NUMBER_SAMPLES_PER_ITERATION% = 1200

NUMBER_SAMPLES_PER_TRIAL% = NUMBER_ITERATIONS_PER_TRIAL% * 
(Number_SAMPLES_PER_ITERATION% + 10)
NUMBER_TRIALS_PER_BLOCK% = 20

TOTAL_ITERATIONS_PER_BLOCK% = NUMBER_ITERATIONS_PER_TRIAL% * 
NUMBER_TRIALS_PER_BLOCK%
TOTAL_SAMPLES_PER_BLOCK% = NUMBER_SAMPLES_PER_TRIAL% * 
NUMBER_TRIALS_PER_BLOCK%
NUMBER_BLOCKS% = 8

TYPE_TASK$ = "D"

TYPE_FEEDBACK$ = "C"
CONCURRENT_FEEDBACK_FLAG% = 1
TERMINAL_FEEDBACK_FLAG% = 0

TEMPLATE_FLAG% = 1
RELATIVE_PHASE% = 90

CASE "6"

NUMBER_ITERATIONS_PER_TRIAL% = 1
NUMBER_SAMPLES_PER_ITERATION% = 1200

NUMBER_SAMPLES_PER_TRIAL% = NUMBER_ITERATIONS_PER_TRIAL% * 
(Number_SAMPLES_PER_ITERATION% + 10)
NUMBER_TRIALS_PER_BLOCK% = 20

TOTAL_ITERATIONS_PER_BLOCK% = NUMBER_ITERATIONS_PER_TRIAL% * 
NUMBER_TRIALS_PER_BLOCK%
TOTAL_SAMPLES_PER_BLOCK% = NUMBER_SAMPLES_PER_TRIAL% * 
NUMBER_TRIALS_PER_BLOCK%
NUMBER_BLOCKS% = 8

TYPE_TASK$ = "D"

TYPE_FEEDBACK$ = "C"
CONCURRENT_FEEDBACK_FLAG% = 1
TERMINAL_FEEDBACK_FLAG% = 0

TEMPLATE_FLAG% = 1
RELATIVE_PHASE% = 90

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CASE "7"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 10

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASK$ = "D"

TYPE.FEEDBACK$ = "N"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "R1"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 10

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASK$ = "D"

TYPE.FEEDBACK$ = "N"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "R2"
NUMBER.ITERATIONS.PER.TRIAL% = 10
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * 
                         (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * 
                            NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * 
                            NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASKS = "C"
TYPE.FEEDBACKS = "N"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE-PHASE% = 90

CASE "R3"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * 
                         (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 20

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * 
                            NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * 
                            NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 3

TYPE.TASKS = "D"
TYPE.FEEDBACKS = "N"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE "D"

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = 1200

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * 
                         (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 2

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
NUMBER.BLOCKS% = 2

TYPE.TASK$ = "D"
TYPE.FEEDBACK$ = "T"
CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 1

TEMPLATE.FLAG% = 1
RELATIVE.PHASE% = 90

CASE ELSE

CONCURRENT.FEEDBACK.FLAG% = 0
TERMINAL.FEEDBACK.FLAG% = 0
TEMPLATE.FLAG% = 1

CALL PROMPT

IF RELATIVE.PHASE% = -1 THEN TEMPLATE.FLAG% = 0

IF TYPE.TASK$ = "C" THEN

NUMBER.TRIALS.PER.BLOCK% = 1
NUMBER.ITERATIONS.PER.TRIAL% = NUMBER.TRIALS.PER.BLOCK%
NUMBER.SAMPLES.PER.ITERATION% = NUMBER.SAMPLES.PER.TRIAL%

NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
NUMBER.TRIALS.PER.BLOCK% = 1

TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%

SLEEP.SECONDS% = NUMBER.ITERATIONS.PER.TRIAL% * 2

ELSE

NUMBER.ITERATIONS.PER.TRIAL% = 1
NUMBER.SAMPLES.PER.ITERATION% = NUMBER.SAMPLES.PER.TRIAL%
NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% *
NUMBER.TRIALS.PER.BLOCK%  
SLEEP.SECONDS% = 2  
END IF

END SELECT

REM ------------------------------
REM ----- Loop for each block
REM --------------------------

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
IF DAY% = 1 THEN CALL INSTRUCT2
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS

FOR BCOUNTER% = 1 TO NUMBER.BLOCKS%

IF ((BCOUNTER% = 3 OR DAY% > 1) AND (STUDYS = "5")) THEN
  TYPE.FEEDBACK$ = "T"
  CONCURRENT.FEEDBACK.FLAG% = 0
  TERMINAL.FEEDBACK.FLAG% = 1
  IF DAY% = 1 THEN
    CLS
    PRINT "Feedback will now be presented after the movement."
    INPUT "Press enter to continue.", Z$
  END IF
END IF

IF ((BCOUNTER% = 3 OR DAY% > 1) AND (STUDYS = "6")) THEN
  TYPE.FEEDBACK$ = "N"
  CONCURRENT.FEEDBACK.FLAG% = 0
  TERMINAL.FEEDBACK.FLAG% = 0
  IF DAY% = 1 THEN
    CLS
    PRINT "Feedback will no longer be presented."
    INPUT "Press enter to continue.", Z$
  END IF
END IF

SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0: CLS
FILESTR$ = "C:\CAFTA\" + PARTICIPANTS
FILENAME$ = FILESTR$ + LTRIM$(STR$(DAY%)) + "B" + LTRIM$(STR$(BCOUNTER%)) + ".DAT"

OPEN FILENAME$ FOR APPEND AS #3
WRITE #3, PARTICIPANTS, "Study", PSTUDYS, STUDYS, "Day", DAY%, "BLOCK", 
  BCOUNTER%, "Task", TYPE.TASK$, "Feedback", TYPE.FEEDBACK$, "Range1", 
  CHANNEL1.RANGE%, "Range2", CHANNEL2.RANGE%

LOCATE 10, 1: PRINT SPACES(79)
LOCATE 10, 1: PRINT SPACE$(25), "Block ", B COUNTER%; " of "; NUMBER.BLOCKS%
SLEEP (2): CLS

NUMBER.DATA.POINTS.PER.TRIAL% = INT(NUMBER.SAMPLES.PER.TRIAL% / 2) + 1

ERASE SAMPLE%: REDIM SHARED SAMPLE%(NUMBER.TRIALS.PER.BLOCK%,
          NUMBER.DATA.POINTS.PER.TRIAL%, 3)
ERASE LED%: REDIM SHARED LED%(NUMBER.SAMPLES.PER.TRIAL%)

FOR L% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
    LED.TEST% = L% MOD NUMBER.SAMPLES.PER.ITERATION%
    IF (LED.TEST% = 0) THEN
        LED%(L%) = 1
    ELSE
        LED%(L%) = 0
    END IF
    NEXT L%

SLEEP (2)

FOR TRIAL.COUNTER% = 1 TO NUMBER.TRIALS.PER.BLOCK%
    CALL TRIAL
    NEXT TRIAL.COUNTER%

SCREEN 0, 0, 0: WIDTH 80: CLS

LOCATE 10, 1: PRINT SPACE$(79)
LOCATE 10, 1: PRINT SPACE$(34); "Please wait."

FOR TRIAL.COUNTER% = 1 TO NUMBER.TRIALS.PER.BLOCK%
    iii% = 0
    FOR iii% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
        iii% = iii% MOD 2
        SAMPLE.INDEX% = INT(iii% / 2)
        IF iii% = 0 THEN WRITE #3, B COUNTER%, TRIAL.COUNTER%, iii%, 0,
                       SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 0), 1,
                       SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1), 2,
                       SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2)
    NEXT iii%
    NEXT TRIAL.COUNTER%
    CLOSE #3
    NEXT B COUNTER%

REM -----------------------------------------------
REM ---- End program gracefully
REM -----------------------------------------------

SCREEN 0, 0, 0: WIDTH 80: KEY OFF: COLOR 15, 0: CLS
LOCATE 1, 1: PRINT "Thank you for participating in this experiment."
SLEEP (5): CLS : SYSTEM

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Subroutine: ABORT

SUB ABORT
    LOCATE 22, 1: PRINT "Error "; DASG.FLAG%; " in mode "; DASG.MODE%
    PRINT DASGERR$(DASG.FLAG%)
    SYSTEM
END SUB
Subroutine: INITDASG

SUB INITDASG

XBEST! = 0
YBEST! = 0

REM -------- Initialize the I/O location of the uCDAS-16G board
REM

DASG.MODE% = 0; DASG.FLAG% = 0
D% (0) = 0
OPEN "C:\METRABYT\DASG.ADR" FOR INPUT AS #2
INPUT #2, D%(0)
CLOSE #2
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM -------- Terminate any previous data collection
REM

DASG.MODE% = 7; DASG.FLAG% = 0
D% (0) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM -------- Turn off LED's
REM

DASG.MODE% = 13; DASG.FLAG% = 0
D%(0) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM -------- Set CHANNELs to be scanned
REM

DASG.MODE% = 1; DASG.FLAG% = 0
D%(0) = 1
D%(1) = 2
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

REM -------- Initialize timer
REM

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XBEST = 2!: IF XBEST > 32767 THEN XBEST = XBEST - 65537!
YBEST = 5000!: IF YBEST > 32767 THEN YBEST = YBEST - 65537!

DASG.MODE% = 17: DASG.FLAG% = 0
D%(0) = XBEST
D%(1) = YBEST
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT

END SUB
Subroutine: INITFB

SUB INITFB

REM ........................................................................
REM  Calibrate Data Collection Device
REM ........................................................................

REM ..........................
REM  Calibrate high values
REM ..........................

CLS
ANSWERS = "N"

LOCATE 4, 1: PRINT "Move arms to outer red lines."
LOCATE 5, 1: INPUT "Press enter to sample data.", Z$

REM ...........................................
REM  Collect data from CHANNEL 1
REM ...........................................

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1.HIGH% = D%(0)

REM ...........................................
REM  Collect data from CHANNEL 2
REM ...........................................

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2.HIGH% = D%(0)

CLS

LOCATE 4, 1: PRINT "The value of Channel 1 is "; CHANNEL1.HIGH%
LOCATE 5, 1: PRINT "The value of Channel 2 is "; CHANNEL2.HIGH%
LOCATE 6, 1: INPUT "Is this correct (Y or N) ==> ", ANSWERS

ANSWERS = UCASES(ANSWERS)
DO WHILE (ANSWERS <> "Y")
  CLS
  LOCATE 4, 1: PRINT "Move arms to outer red lines."
  LOCATE 5, 1: INPUT "Press enter to sample data.", Z$

REM ...........................................
REM  Collect data from CHANNEL 1
REM ...........................................

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DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1.HIGH% = D%(0)

REM ---------------------------------------------
REM Collect data from CHANNEL 2
REM ---------------------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2.HIGH% = D%(0)

CLS

LOCATE 4, 1: PRINT "The value of Channel 1 (Right) is "; CHANNEL1.HIGH%
LOCATE 5, 1: PRINT "The value of Channel 2 (Left) is "; CHANNEL2.HIGH%
LOCATE 6, 1: INPUT "Is this correct (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)

LOOP

REM ---------------------------------------------
REM Calibrate low values
REM ---------------------------------------------

CLS
ANSWERS = "N"

LOCATE 4, 1: PRINT "Move arms to inner red lines."
LOCATE 5, 1: INPUT "Press enter to sample data.", ZS
REM ---------------------------------------------
REM Collect data from CHANNEL 1
REM ---------------------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1.LOW% = D%(0)

REM ---------------------------------------------
REM Collect data from CHANNEL 2
REM ---------------------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)

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IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2.LOW% = D%(0)

CLS

LOCATE 4, 1: PRINT "The value of Channel 1 is "; CHANNEL1.LOW%
LOCATE 5, 1: PRINT "The value of Channel 2 is "; CHANNEL2.LOW%
LOCATE 6, 1: INPUT "Is this correct (Y or N) ==> ", ANSWERS

ANSWERS$ = UCASE$(ANSWERS$)
DO WHILE (ANSWERS$ <> "Y")
CLS
LOCATE 4, 1: PRINT "Move arms to inner red lines."
LOCATE 5, 1: INPUT "Press enter to sample data", Z$

REM -------------------------------
REM ---- Collect data from CHANNEL 1
REM -------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1.LOW% = D%(0)

REM -------------------------------
REM ---- Collect data from CHANNEL 2
REM -------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0: D%(1) = 0: D%(2) = 0: D%(3) = 0: D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2.LOW% = D%(0)

CLS

LOCATE 4, 1: PRINT "The value of Channel 1 (Right) is "; CHANNEL1.LOW%
LOCATE 5, 1: PRINT "The value of Channel 2 (Left) is "; CHANNEL2.LOW%
LOCATE 6, 1: INPUT "Is this correct (Y or N) ==> ", ANSWERS
ANSWERS$ = UCASE$(ANSWERS$)

LOOP

CHANNEL1.RANGE% = CHANNEL1.HIGH% - CHANNEL1.LOW%
CHANNEL2.RANGE% = CHANNEL2.HIGH% - CHANNEL2.LOW%

CLS

FEEDBACK.DIAMETER% = CHANNEL1.RANGE%
IF FEEDBACK.DIAMETER% < CHANNEL2.RANGE% THEN FEEDBACK.DIAMETER% = CHANNEL2.RANGE%

252
LOCATE 4, 1: PRINT "The range of Channel 1 is "; CHANNEL1.RANGE%
LOCATE 5, 1: PRINT "The range of Channel 2 is "; CHANNEL2.RANGE%
LOCATE 6, 1: PRINT "The feedback diameter is "; FEEDBACK.DIAMETER%
LOCATE 7, 1: INPUT "Press enter to continue.", Z$
Subroutine: INITSUBJ

SUB INITSUBJ
REM -------------------------------------------------------------
REM ---- Prompt for subject's initials
REM -------------------------------------------------------------

LOCATE 1, 1: PRINT "Welcome to the experiment 
ANSWERS = "N"

LOCATE 4, 1: PRINT SPACE$(79)
LOCATE 4, 1: INPUT "Please enter your initials ==> ", PARTICIPANTS
PARTICIPANTS = UCASE$(PARTICIPANTS)$
LOCATE 5, 1: PRINT SPACE$(79)
LOCATE 5, 1: PRINT "Are your initials "; PARTICIPANTS
LOCATE 5, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)$
DO WHILE (ANSWERS <> "Y")
LOCATE 4, 1: PRINT SPACE$(79)
LOCATE 5, 1: PRINT SPACE$(79)
LOCATE 4, 1: INPUT "Please enter your initials ==> ", PARTICIPANTS
PARTICIPANTS = UCASE$(PARTICIPANTS)$
LOCATE 5, 1: PRINT "Are your initials "; PARTICIPANTS
LOCATE 5, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)$
LOOP

LOCATE 5, 1: PRINT SPACE$(79)
LOCATE 5, 1: INPUT "Please enter condition ==> ", STUDY$
STUDY$ = UCASE$(STUDY)$
LOCATE 6, 1: PRINT SPACE$(79)
LOCATE 6, 1: PRINT "Is the condition name "; STUDY$
LOCATE 6, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)$
DO WHILE (ANSWERS <> "Y")
LOCATE 5, 1: PRINT SPACE$(79)
LOCATE 6, 1: PRINT SPACE$(79)
LOCATE 5, 1: INPUT "Please enter condition ==> ", STUDY$
STUDY$ = UCASE$(STUDY)$
LOCATE 6, 1: PRINT "Is the condition name "; STUDY$
LOCATE 6, 32: INPUT " (Y or N) ==> ", ANSWERS
ANSWERS = UCASE$(ANSWERS)$
LOOP

LOCATE 6, 1: PRINT SPACE$(79)
LOCATE 6, 1: INPUT "Please enter day ==> ", DAY$
LOCATE 7, 1: PRINT SPACE$(79)
IF DAY$ = 99 THEN
    DAY$ = 0
    STUDY$ = "R"
END IF
LOCATE 7, 1: PRINT "Is this day "; DAY$
LOCATE 7, 32: INPUT " (Y or N) ==> ", ANSWERS

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ANSWERS = UCASE$(ANSWERS)
DO WHILE (((DAY% < 0) OR (DAY% > 20)) OR (ANSWERS <> "Y"))
  LOCATE 8, 1: PRINT SPACES$(79)
  IF ((DAY% < 1) OR (DAY% > 20)) THEN LOCATE 8, 1: PRINT "ERROR: DAY must be greater than 1 and less than 20."
  LOCATE 6, 1: PRINT SPACES$(79)
  LOCATE 7, 1: PRINT SPACES$(79)
  LOCATE 6, 1: INPUT "Please enter day (1-20) ==> ", DAY%
  IF DAY% = 99 THEN
    DAY% = 0
    STUDY$ = "R"
  END IF
  LOCATE 8, 1: PRINT SPACES$(79)
  LOCATE 7, 1: PRINT "Is this day "; DAY%
  LOCATE 7, 32: INPUT " (Y or N) ==> ", ANSWERS
  ANSWERS = UCASE$(ANSWERS)
LOOP
END SUB
Subroutine: INSTRUCT1

SUB INSTRUCT1
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0
CLS
PRINT "INSTRUCTIONS": PRINT SPACES(79)
PRINT "The apparatus used in this experiment works much like a large Etch-a-Sketch."
PRINT "Your goal is to use this apparatus to inscribe a circle in a square. To "
PRINT "inscribe a circle in a square is to draw a circle inside a square so as to "
PRINT "touch as many points on the square as possible. In this experiment the square"
PRINT "will be oriented as a diamond. Press enter to see an example of a circle that"
INPUT "inscribes a square.", Z$
RELATIVE.PHASE%  =  90
TEMPLATE.FLAG%  =  1
SCREEN 7: WIDTH 80: COLOR 15, 0
CLS
CALL STIMULUS1
CIRCLE (650, 650), 90 / 1.2, 5
LOCATE 24, 1: INPUT "Press enter to continue.", Z$
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0
CLS
PRINT "In this experiment, the square and circle will not be presented at the same"
PRINT "time. The square will presented, the screen will be cleared, and then you "
PRINT "should attempt to draw a circle that inscribes the square. Press enter to see "
PRINT "an example of the target followed by an example of the circle you should draw "
INPUT "in response to that target.", Z$
SCREEN 7: WIDTH 80: COLOR 15, 0
CLS
CALL STIMULUS1
LOCATE 24, 1: INPUT "Press enter to see what your response should be.", Z$
CLS
CIRCLE (650, 650), 90 / 1.2, 5
LOCATE 24, 1
INPUT "Press enter for further instructions.", Z$
SCREEN 0, 0, 0: WIDTH 80: COLOR 15, 0
PRINT "You will draw figures by moving the metal arms located to your right and left."
PRINT "The arm to your right controls movement in the horizontal direction. The metal "
PRINT "arm to your left controls the vertical direction. If both arms are moved "
PRINT "toward your center at the same time, the figure you draw will slant to the"
PRINT "right. If your arms are moved in opposition so that one arm moves toward "
PRINT "your center while the other arm moves away from you, the figure you draw "
PRINT "will slant to the left."
PRINT SPACES(79)
PRINT "In just a moment, you will be given an opportunity to familiarize yourself"
PRINT "with this apparatus. You will be given 10 practice trials. A computer beep "
PRINT "will sound to indicate that you should begin moving the arms. It will sound a"
PRINT "a second time to indicate that you should stop. The time allotted is very short."
PRINT "A target will be presented during the practice trials. However, you should use "
PRINT "these trials to familiarize yourself with the apparatus. Verify, for example,"
PRINT "that the statements made above with respect to movement direction are true."
PRINT SPACES(79)
IF STUDY$ = "2" THEN
PRINT "Feedback will be presented after you complete your movement."
PRINT SPACES$(79)
END IF
PRINT SPACES$(79)
PRINT "If you have any questions regarding the apparatus, please ask the experimenter"
PRINT "now. When you are ready to begin your practice trials, press enter."
INPUT " ", Z$
Subroutine: INSTRUCT2

SUB INSTRUCT2
PRINT "The next 8 blocks of trials are known as LEARNING BLOCKS. In a LEARNING"
PRINT "BLOCK of trials, you will be presented with the same square target on every"
PRINT "trial. Your goal is to LEARN to draw the circle which inscribes this target."
PRINT
PRINT "Each time the target is presented, you should listen for the start tone"
PRINT "and then make", NUMBER.ITERATIONS.PER.TRIAL%, "attempt(s) to inscribe the square."
PRINT SPACE$(79)
IF STUDY$ = "2" THEN
    PRINT "The results of your attempt will be shown AFTER you complete your movement."
    PRINT SPACE$(79)
END IF
PRINT "The black lines indicate the starting position for LEARNING trials. If you "
PRINT "have any questions regarding LEARNING BLOCKS, please ask the experimenter"
INPUT "now. When you are ready to begin, press enter.", ZS

END SUB
Subroutine: PRACTICE

SUB PRACTICE
  CLS
  FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
    LED.TEST% = I% MOD NUMBER.SAMPLES.PER.ITERATION%
    IF (LED.TEST% = 0) THEN
      LED%(I%) = 1
    ELSE
      LED%(I%) = 0
    END IF
  NEXT I%
  SCREEN 0, 0, 0: WIDTH 80
  LOCATE 10, 1: PRINT SPACE$(79)
  LOCATE 10, 1: PRINT SPACE$(14), "Practice Trials"
  SLEEP (2): CLS
  FOR BCOUNTER% = 1 TO 10
    SCREEN 0, 0, 0: WIDTH 80
    LOCATE 10, 1: PRINT SPACE$(79)
    LOCATE 10, 1: PRINT SPACE$(14), "Practice Trial "; BCOUNTER%
    LOCATE 24, 1: INPUT " ", Z$
    SLEEP (2): CLS
    TRIAL.COUNTER% = 1
    NUMBER.ITERATIONS.PER.TRIAL% = 1
    NUMBER.SAMPLES.PER.ITERATION% = 1200
    NUMBER.SAMPLES.PER.TRIAL% = NUMBER.ITERATIONS.PER.TRIAL% * (NUMBER.SAMPLES.PER.ITERATION% + 10)
    NUMBER.TRIALS.PER.BLOCK% = 1
    TOTAL.ITERATIONS.PER.BLOCK% = NUMBER.ITERATIONS.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    TOTAL.SAMPLES.PER.BLOCK% = NUMBER.SAMPLES.PER.TRIAL% * NUMBER.TRIALS.PER.BLOCK%
    NUMBER.BLOCKS% = 8
    TEMPLATE.FLAG% = 1
    CALL TRIAL
  NEXT BCOUNTER%
  SCREEN 0, 0, 0: WIDTH 80: CLS
END SUB

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Subroutine: PROMPT

SUB PROMPT

REM-------------------------------------------------------------
REM ---- Prompt for task characteristics
REM-------------------------------------------------------------
CLS

LOCATE 1, 1: PRINT "Experiment: ", STUDY$ 
LOCATE 2, 1: PRINT "Participant: ", PARTICIPANT$ 
LOCATE 3, 1: PRINT "Day: ", DAY%

TYPE.FEEDBACK$ = " "
LOCATE 6, 1: PRINT SPACES(79) 
LOCATE 6, 1: INPUT "Please enter feedback type (C,T,N) ==> ", TYPE.FEEDBACK$ 
TYPE.FEEDBACK$ = UCASES(TYPE.FEEDBACK$)
DO WHILE ((TYPE.FEEDBACK$ <> "C") AND (TYPE.FEEDBACK$ <> "T") AND 
(TYPE.FEEDBACK$ <> "N"))
LOCATE 7, 1: PRINT SPACES(79) 
LOCATE 7, 1: PRINT "ERROR: Feedback type invalid. Enter C - concurrent, T - terminal, 
N - None."
LOCATE 6, 1: PRINT SPACES(79) 
LOCATE 6, 1: INPUT "Please enter feedback type (C,T,N) ==> ", TYPE.FEEDBACK$ 
TYPE.FEEDBACK$ = UCASES(TYPE.FEEDBACK$)
LOOP

LOCATE 7, 1: PRINT SPACES(79) 
LOCATE 7, 1: INPUT "Please enter task type (C or D) ==> ", TYPE.TASK$ 
TYPE.TASK$ = UCASES(TYPE.TASK$)
DO WHILE ((TYPE.TASK$ <> "C") AND (TYPE.TASK$ <> "D"))
LOCATE 8, 1: PRINT SPACES(79) 
LOCATE 8, 1: PRINT "ERROR: Task type invalid. Enter C for continuous or D for discrete."
LOCATE 7, 1: PRINT SPACES(79) 
LOCATE 7, 1: INPUT "Please enter task type (C or D) ==> ", TYPE.TASK$ 
TYPE.TASK$ = UCASES(TYPE.TASK$)
LOOP

LOCATE 8, 1: PRINT SPACES(79) 
LOCATE 8, 1: INPUT "Please enter relative phase (-1,0,90,180) ==> ", RELATIVE.PHASE% 
DO WHILE ((RELATIVE.PHASE% <> -1) AND (RELATIVE.PHASE% <> 0) AND 
(RELATIVE.PHASE% <> 90) AND (RELATIVE.PHASE% <> 180))
LOCATE 9, 1: PRINT SPACES(79) 
LOCATE 9, 1: PRINT "ERROR: Relative phase invalid. Enter -1 (no relative phase), 0, 90, 
or 180."
LOCATE 8, 1: PRINT SPACES(79) 
LOCATE 8, 1: INPUT "Please enter relative phase (-1,0,90,180) ==> ", RELATIVE.PHASE% 
LOOP

LOCATE 9, 1: PRINT SPACES(79) 
LOCATE 9, 1: INPUT "Please enter number of blocks ==> ", NUMBER.BLOCKS%
LOCATE 10, 1: PRINT SPACE$(79)
LOCATE 10, 1: PRINT "Please enter number of trials ==> ",
NUMBER.TRIALS.PER.BLOCK%

LOCATE 11, 1: PRINT SPACE$(79)
LOCATE 11, 1: PRINT "Please enter number of samples ==> ",
NUMBER.SAMPLES.PER.TRIAL%

END SUB
Subroutine: STIMULUS1

SUB STIMULUS1
WINDOW (400, 400)-(900, 900)
I! = 0
FOR I = 1 TO 359
    IF I! <= 180 THEN X! = I!
    IF I! > 180 THEN X! = 360 - I!
    J! = I! + RELATIVE.PHASE%
    IF J! <= 180 THEN Y! = J!
    IF J! > 180 AND J! <= 360 THEN Y! = 360 - J!
    IF J > 360 THEN Y! = J! - 360
    X! = (X! / 180) * 180 * 1.4 + 400 + ((500 - 180 * 1.4) / 2)
    Y! = (Y! / 180) * 180 * 1.4 + 400 + ((500 - 180 * 1.4) / 2)
    PSET (X!, Y!), DEFAULT.TEMPLATE.COLOR% * TEMPLATE.FLAG%
NEXT I
END SUB
Subroutine: STIMULUS2

SUB STIMULUS2

REM WINDOW (-200, -200)-(380, 380)
WINDOW (400, 400)-(900, 900)

I! = 0

FOR I = 1 TO 359

IF I! <= 180 THEN X! = I!
IF I! > 180 THEN X! = 360 - I!

J! = I! + RELATIVE.PHASE%
IF J! <= 180 THEN Y! = J!
IF J! > 180 AND J! <= 360 THEN Y! = 360 - J!
IF J! > 360 THEN Y! = J! - 360

X! = (X! / 180) * FEEDBACK.DIAMETER% * 1.4 + 400 + ((500 - FEEDBACK.DIAMETER% * 1.4) / 2)
Y! = (Y! / 180) * FEEDBACK.DIAMETER% * 1.4 + 400 + ((500 - FEEDBACK.DIAMETER% * 1.4) / 2)
PSET (X!, Y!), DEFAULT.TEMPLATE.COLOR% * TEMPLATE.FLAG%

NEXT I

END SUB
Subroutine: TRIA L

SUB TRIAL

SCREEN 7

CALL STIMULUS2

WINDOW (400, 400)-(900, 900): SLEEP (2): CLS

REM -------------------------------
REM ----- Turn off LED's
REM -------------------------------

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = 0; D%(1) = 0; D%(2) = 0; D%(3) = 0; D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)

IF DASG.FLAG% <> 0 THEN CALL ABORT

FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1
REM -------------------------------
REM ----- Turn on LED
REM -------------------------------

DASG.MODE% = 13: DASG.FLAG% = 0
D%(0) = LED%(I%); D%(1) = 0: D%(2) = 0; D%(3) = 0; D%(4) = 0
NOTE.INDEX% = LED%(I%)
SOUND 1046.5, DURATION!(NOTE.INDEX%)

REM -------------------------------
REM ----- Collect data from CHANNEL 1
REM -------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0; D%(1) = 0; D%(2) = 0; D%(3) = 0; D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL1% = D%(0)

REM -------------------------------
REM ----- Collect data from CHANNEL 2
REM -------------------------------

DASG.MODE% = 3: DASG.FLAG% = 0
D%(0) = 0; D%(1) = 0; D%(2) = 0; D%(3) = 0; D%(4) = 0
CALL BASDASG(DASG.MODE%, VARPTR(D%(0)), DASG.FLAG%)
IF DASG.FLAG% <> 0 THEN CALL ABORT
CHANNEL2% = D%(0)

REM -------------------------------
REM ----- Plot displacement data (Concurrent)
REM -------------------------------

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PSET (-CHANNEL1%, -CHANNEL2%), DEFAULT.FEEDBACK.COLOR% *
CONCURRENT.FEEDBACK.FLAG%

REM -------------------------------------------------------------
REM ----- Transfer data to an array
REM -------------------------------------------------------------

ODD% = I% MOD 2
SAMPLE.INDEX% = INT(I% / 2)

IF ODD% = 0 THEN
  SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 0) = LED%(I%)
  SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1) = CHANNEL1%
  SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2) = CHANNEL2%
END IF

NEXT I%

WINDOW (400, 400)-(900, 900): SLEEP (SLEEP.SECONDS%): CLS

FOR I% = 0 TO NUMBER.SAMPLES.PER.TRIAL% - 1

  SAMPLE.INDEX% = INT(I% / 2)

  CHANNEL1% = SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 1)
  CHANNEL2% = SAMPLE%(TRIAL.COUNTER%, SAMPLE.INDEX%, 2)

  PSET (-CHANNEL1%, -CHANNEL2%), DEFAULT.FEEDBACK.COLOR% *
  TERMINAL.FEEDBACK.FLAG%

NEXT I%

SLEEP (SLEEP.SECONDS%): CLS

END SUB
Data Preparation Programs Written in REXX

Data was prepared for analysis via a series of computer programs written in REXX. Programs CAFTAF02, CAFTAF03, and PLRN01 from Experiment 1 were used without modification.
### Table H.1 ANOVA Table for RMSE in Acquisition

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ANOVA Summary Table for Absolute Delta of Relative Phase

Table H.5 ANOVA Table for Delta of Relative Phase in Acquisition

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Table H.6 ANOVA Table for Delta of Relative Phase in Retention

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ANOVA Summary Table for SD of Relative Phase

Table H.7 ANOVA Table for SD of Relative Phase in Acquisition

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Table H.8 ANOVA Table for SD of Relative Phase in Retention

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ANOVA Summary Table for Range of Motion 1

Table H.9 ANOVA Table for Range of Motion 1 in Acquisition

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Table H.10 ANOVA Table for Range of Motion 1 in Retention

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<td>Total</td>
<td>431</td>
<td>557621.01</td>
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</tbody>
</table>
### ANOVA Summary Table for Range of Motion 2

#### Table H.11 ANOVA Table for Range of Motion 2 in Acquisition

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>47</td>
<td>932425.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>3</td>
<td>3368.85</td>
<td>1122.95</td>
<td>0.05</td>
<td>0.9836</td>
</tr>
<tr>
<td>Residual between</td>
<td>44</td>
<td>929056.25</td>
<td>21114.9</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>336</td>
<td>488516.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>7</td>
<td>77578.28</td>
<td>11082.6</td>
<td>9.19</td>
<td>0.0001</td>
</tr>
<tr>
<td>Block*Feedback</td>
<td>21</td>
<td>39424.71</td>
<td>1877.37</td>
<td>1.56</td>
<td>0.1513</td>
</tr>
<tr>
<td>Residual within</td>
<td>308</td>
<td>371513.12</td>
<td>1206.21</td>
<td>1</td>
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<tr>
<td>Total</td>
<td>383</td>
<td>1420941.21</td>
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</table>

#### Table H.12 ANOVA Table for Range of Motion 2 in Retention

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<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>47</td>
<td>1485952.89</td>
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</tr>
<tr>
<td>Feedback</td>
<td>3</td>
<td>56238.66</td>
<td>18746.2</td>
<td>0.58</td>
<td>0.6332</td>
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<tr>
<td>Residual between</td>
<td>44</td>
<td>1429714.23</td>
<td>32493.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>384</td>
<td>196831.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>8</td>
<td>20734.02</td>
<td>2546.75</td>
<td>5.31</td>
<td>0.0003</td>
</tr>
<tr>
<td>Block*Feedback</td>
<td>24</td>
<td>7170.07</td>
<td>298.75</td>
<td>0.62</td>
<td>0.8304</td>
</tr>
<tr>
<td>Residual within</td>
<td>352</td>
<td>168927.69</td>
<td>479.91</td>
<td>1</td>
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</tr>
<tr>
<td>Total</td>
<td>431</td>
<td>1682784.67</td>
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</table>
Summary of Significant Findings for Experiment 2

Table H.13 Summary of Significant Findings in Acquisition

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>VARIABLE</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEEDBACK</td>
<td>RMSE</td>
<td>F(3.44) = 3.58</td>
<td>0.0212</td>
</tr>
<tr>
<td>BLOCK</td>
<td>RMSE</td>
<td>F(7,308) = 24.16</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK X FEEDBACK</td>
<td>RMSE</td>
<td>F(21,308) = 5.58</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK</td>
<td>SD of RMSE</td>
<td>F(7,308) = 35.74</td>
<td>0.0001</td>
</tr>
<tr>
<td>FEEDBACK</td>
<td>IDelta of RPI</td>
<td>F(3,44) = 3.74</td>
<td>0.0177</td>
</tr>
<tr>
<td>BLOCK</td>
<td>IDelta of RPI</td>
<td>F(7,308) = 21.30</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK X FEEDBACK</td>
<td>IDelta of RPI</td>
<td>F(21,308) = 5.44</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK</td>
<td>SD of RP</td>
<td>F(7,308) = 40.39</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK</td>
<td>RANGE OF MOTION 1</td>
<td>F(7,308) = 9.10</td>
<td>0.0001</td>
</tr>
<tr>
<td>BLOCK X FEEDBACK</td>
<td>RANGE OF MOTION 1</td>
<td>F(21,308) = 2.36</td>
<td>0.0337</td>
</tr>
<tr>
<td>BLOCK</td>
<td>RANGE OF MOTION 2</td>
<td>F(7,308) = 9.19</td>
<td>0.0001</td>
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</tbody>
</table>

Table H.14 Summary of Significant Findings in Retention

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>VARIABLE</th>
<th>F</th>
<th>PR&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEEDBACK</td>
<td>RMSE</td>
<td>F(3,44) = 3.05</td>
<td>0.0385</td>
</tr>
<tr>
<td>BLOCK</td>
<td>RMSE</td>
<td>F(8,352) = 3.61</td>
<td>0.0071</td>
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<td>BLOCK</td>
<td>SD of RMSE</td>
<td>F(8,352) = 2.29</td>
<td>0.0381</td>
</tr>
<tr>
<td>FEEDBACK</td>
<td>IDelta of RPI</td>
<td>F(3,44) = 3.34</td>
<td>0.0277</td>
</tr>
<tr>
<td>BLOCK</td>
<td>IDelta of RPI</td>
<td>F(8,352) = 3.51</td>
<td>0.0091</td>
</tr>
<tr>
<td>BLOCK</td>
<td>SD of RP</td>
<td>F(8,352) = 2.72</td>
<td>0.0362</td>
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<tr>
<td>BLOCK</td>
<td>RANGE OF MOTION 1</td>
<td>F(8,352) = 4.30</td>
<td>0.0084</td>
</tr>
<tr>
<td>BLOCK</td>
<td>RANGE OF MOTION 2</td>
<td>F(8,352) = 5.31</td>
<td>0.0003</td>
</tr>
</tbody>
</table>
APPENDIX I. SELECTED TRIALS FOR EXPERIMENT 2

Concurrent Group

Figure I.1 Selected Trials for Experiment 2 Concurrent Participant ALB

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Figure I.2 Selected Trials for Experiment 2 Concurrent Participant BCC
Figure I.3 Selected Trials for Experiment 2 Concurrent Participant CJM

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Figure I.4 Selected Trials for Experiment 2 Concurrent Participant JCG
Figure I.5 Selected Trials for Experiment 2 Concurrent Participant JLD
Figure I.6 Selected Trials for Experiment 2 Concurrent Participant JMB
Figure I.7 Selected Trials for Experiment 2 Concurrent Participant KPL
Figure I.8 Selected Trials for Experiment 2 Concurrent Participant MLF
Figure 1.9 Selected Trials for Experiment 2 Concurrent Participant RAR
Figure I.10 Selected Trials for Experiment 2 Concurrent Participant RMV
Figure I.11 Selected Trials for Experiment 2 Concurrent Participant SAW
Figure I.12 Selected Trials for Experiment 2 Concurrent Participant WMP
Control Group

Figure I.13 Selected Trials for Experiment 2 Control Participant BLT

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Figure I.14 Selected Trials for Experiment 2 Control Participant BRK
Figure I.15 Selected Trials for Experiment 2 Control Participant CHB
Figure I.16 Selected Trials for Experiment 2 Control Participant CMM
Figure I.17 Selected Trials for Experiment 2 Control Participant CTM
Figure I.18 Selected Trials for Experiment 2 Control Participant EEC
Figure I.19 Selected Trials for Experiment 2 Control Participant FDD
Figure I.20 Selected Trials for Experiment 2 Control Participant JAB
Figure I.21 Selected Trials for Experiment 2 Control Participant JAG
Figure I.22 Selected Trials for Experiment 2 Control Participant JLG
Figure I.23 Selected Trials for Experiment 2 Control Participant KJO
Figure 1.24 Selected Trials for Experiment 2 Control Participant SDL
Terminal Group

Figure I.25 Selected Trials for Experiment 2 Terminal Participant ALP
Figure I.26 Selected Trials for Experiment 2 Terminal Participant AVV
Figure I.27 Selected Trials for Experiment 2 Terminal Participant AMF
Figure I.28 Selected Trials for Experiment 2 Terminal Participant BAG

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Figure I.29 Selected Trials for Experiment 2 Terminal Participant DLS
Figure I.30 Selected Trials for Experiment 2 Terminal Participant GAK
Figure I.31 Selected Trials for Experiment 2 Terminal Participant GLH
Figure I.32 Selected Trials for Experiment 2 Terminal Participant JGM
Figure I.33 Selected Trials for Experiment 2 Terminal Participant LCH
Figure I.34 Selected Trials for Experiment 2 Terminal Participant MVB
Figure I.35 Selected Trials for Experiment 2 Terminal Participant RMR
Figure 1.36 Selected Trials for Experiment 2 Terminal Participant SAV
Transition Group

Figure I.37 Selected Trials for Experiment 2 Transition Participant BJB

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Figure I.38 Selected Trials for Experiment 2 Transition Participant BTW
Figure I.39 Selected Trials for Experiment 2 Transition Participant CAO
Figure I.40 Selected Trials for Experiment 2 Transition Participant CJB
Figure I.41 Selected Trials for Experiment 2 Transition Participant CLN
Figure I.42 Selected Trials for Experiment 2 Transition Participant EMG
Figure I.43 Selected Trials for Experiment 2 Transition Participant JAL

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Figure I.44 Selected Trials for Experiment 2 Transition Participant KAF
Figure I.45 Selected Trials for Experiment 2 Transition Participant RJS
Figure I.46 Selected Trials for Experiment 2 Transition Participant RNG
Figure I.47 Selected Trials for Experiment 2 Transition Participant WEB
Figure I.48 Selected Trials for Experiment 2 Transition Participant WMW
VITA

Cynthia Marie Hadden was born on January 28th, 1960, in Opelousas, Louisiana. She spent her childhood with her family in Port Barre, Louisiana, where she attended elementary and high school at Port Barre High. In 1977, Cynthia elected to skip her senior year of high school and accept early admission to Louisiana State University at Eunice. In 1979, she graduated from Louisiana State University at Eunice with an associate of science degree in biological sciences. Cynthia transferred to Louisiana State University in Baton Rouge, Louisiana, where she received a bachelor of science degree in biochemistry in 1981. She earned a master of science degree in Systems Science from Louisiana State University in 1985. Cynthia has been employed full-time at Louisiana State University since November 11, 1982. She has been serving as Director of Administrative Information Systems since August, 1990. She is currently a doctoral candidate and will receive her degree of Doctor of Philosophy in August, 1998.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Cynthia Marie Hadden

Major Field: Kinesiology

Title of Dissertation: Concurrent vs. Terminal Augmented Feedback in the Learning of a Discrete Bimanual Coordination Task

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 14, 1998

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