OBSERVATIONAL LEARNING AND MOVEMENT REPRESENTATION

THE DEVELOPMENT OF A COGNITIVE REPRESENTATION THROUGH OBSERVATIONAL MOTOR LEARNING

By

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Abstract

Two experiments are reported that examined whether KR was necessary to develop a representation through observational motor learning. Subjects observed a learning model perform three variations of a three segment timing task and then performed two transfer tasks. The first experiment found that a cognitive representation could be formed through observational learning, even when KR was not provided during acquisition. This was determined since there were no differences in performance of the two observer groups on the transfer tests. The observers were however, better than the control group on the transfer tests. Evidence for the development of a cognitive representation was also found when auditory information was eliminated during acquisition on the second experiment. Once again there were no differences in the performance of the two observer groups. These results were discussed in reference to observational motor learning and the necessity of knowledge of results to acquire movement skills.

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Introduction

Modelling (or demonstration) has been used extensively by teachers and coaches to communicate information about motor skills. Although research has determined that modelling is an effective method to transmit information about motor skills (McCullagh, Weiss, & Ross, 1989), theoretical explanations are few and poorly supported. The purpose of the present experiment was to examine the processes that may explain how one learns motor skills through observation.

A recent review of the literature addressed various characteristics that are important to observational learning (McCullagh et al., 1989). The cognitive and motor development of the observer are important when providing demonstrations (McCullagh, Stiehl, & Weiss, 1988; Weiss & Klint, 1987). The motor skill level of the observer must also be considered, especially with regard to age (Feltz, 1982; Thomas, Pierce, & Ridsdale, 1977). Also, the observer must be motivated to learn the task (Feltz & Landers, 1977). Models have usually been experts, although the question of skill level of the model has been of interest in recent research (Adams, 1986; Martens, Burwitz, & Zuckerman, 1976; Lee & White, 1990; Pollock & Lee, submitted). Attention must also be given to the mode (visual or auditory) of the demonstration (Doody, Bird, & Ross, 1985). And finally, the benefits of knowledge of results (KR) to observational learning is an important consideration (Adams, 1986; Doody, et al., 1985; McCullagh & Caird, 1990). The present experiment is primarily concerned with how KR is linked to observational learning of motor skills.

Bandura (1986; Carroll & Bandura, 1982) and Adams (1986) discussed two views of how movement is learned through observation. Bandura (1986) suggested that observational learning involved information that is processed into a cognitive representation and governed by four subprocesses: attention, retention, production and motivation. For example, subjects must determine what is important and selectively attend to this, actively engage in a retention strategy, be able to reproduce the representation and be motivated in order to learn through observation. Carroll and Bandura (1982, 1985, 1987, 1990) suggested that motor skill demonstrations provided information that was acquired through visual observation and processed into a cognitive representation of the action. The representation served to regulate movement production, as well as to provide a standard of correctness to guide the movement. Carroll and Bandura stressed that the information provided by the model must be correct in order to develop a representation. The representation would then enable the observer to produce the appropriate movement at a later time.

The suggestion that a cognitive representation of movement is formed is common to many theories of motor learning (Adams, 1971; Keele, 1976; Schmidt, 1988). A cognitive representation has been defined as a symbolic image of the action to be performed (Gould & Roberts, 1981). A representation is constructed by transforming observed behaviour into symbolic codes. The cognitive representation has been suggested to include auditory as well as visual information acquired from observation (Doody et al., 1985). Carroll and Bandura (1986) also suggested that spatial and temporal information can be attained through observation and become a part of the representation. Thus, a "representation hypothesis" of observational motor learning would suggest that a cognitive representation is formed through observation. However, evidence that the formation of a cognitive representation explains how one learns through observation is limited.

Adams (1986) agreed that the development of a representation of a simple movement could occur through observation. However, he further suggested that the formation of a cognitive representation may also occur if the model was learning a task, by allowing the observer to join in the problem-solving processes undertaken by the model. Also, he suggested that most movements are complex and additional information, other than visual, must be available to form the representation. That additional information was KR. This information was assumed to be used to reduce the error discrepancy between the previous movement and the movement goal. Thus, Adams (1986) suggested that an observer who watches a learning model and receives the model's KR could form a cognitive representation by actively engaging in the problem-solving processes that accompany learning.

Adams' experiment included four groups of subjects: a control group of learners, a group of learning models, a group of observers who received the model's KR, and a group of observers who did not receive the model's KR. The task was to perform three movement segments that each had a distinct duration timing goal. Adams (1986) found that although observational learning occurred without KR, the best performance occurred for the observers that received the learning model's KR. The observers with and without KR performed similar early in practice, but the observers with KR performed better by the end of practice. This indicated that early in practice there was a greater influence of the cognitive representation, and later in practice those that learned to process KR were better suited to use the KR to reduce their timing error. But this study did not determine which was more important to observational learning, the ability to form a cognitive representation or the ability to process KR. A "processing hypothesis" would suggest that observational motor learning benefits are due more to the ability to process KR than the ability to form a cognitive representation. If the "representation" and "processing" hypotheses could be isolated then one could begin to determine the processes involved in observational learning. A more detailed account of these hypotheses will now be presented.

The "Representation Hypothesis" of Observational Motor Learning

There are several notable theories of information processing that discussed the formation of a cognitive representation. Adams' (1971) closed-loop theory of motor learning included two representations. The first representation was a perceptual trace that included sensory, spatial and temporal qualities of movement. This was considered to be a reference mechanism that was responsible for determining the correctness of the movement in progress. The other representation in the theory was the memory trace.

Its role was to select and initiate a movement, whereafter its completion would be determined by the perceptual trace.

Schmidt (1975) developed a schema theory in the attempt to overcome some problems with Adams' theory. Schmidt (1975) agreed that there were representations of movement, but that they were in much more abstract form. These abstract cognitive representations were called schemata. The schemata included abstractions of initial conditions, parameters of the movement (such as overall duration and force), knowledge of movement outcomes, and sensory consequences of movement. There were two schema representations. A recall schema produced a movement by determining the relations between the initial conditions, parameters and movement outcomes, then selecting the most appropriate response. A recognition schema evaluated the movement by determining the relations between the initial conditions, the parameters and the sensory consequences. Another aspect of the schema theory was the generalized motor program (GMP). The GMP is a motor program in memory for a particular class of movements. In order to execute a program for a specific movement, the parameters must be supplied from the schema.

Research investigating the schema theory and observational learning has been limited. Sensory consequences are limited to those that are externally available to the subject while watching a demonstration. For example, visual and auditory information are available while tactile and kinaesthetic information are not acquired through observation. This is a limiting factor of observational learning, but the importance of these limitations are unknown.

Adams (1971) and Schmidt (1975) both agreed that a representation of the movement was formed when learning a movement. The movement representations were based on physical practice, not observation. However, Bandura (1986) suggested that a representation could be formed through observation only. If a schemata could be formed through observation without the sensory consequences and knowledge of the movement outcome then would the schemata be weaker? If a schemata could be formed through observation, then execution of a correct movement would suggest that the schemata and the GMP were formed. If a movement was performed correctly by subjects who observe, yet do not receive KR, this may suggest that KR was not necessary to form a cognitive representation. These issues must be considered when determining the processes of observational learning.

Practice variability is also an issue of the schema theory. Schmidt (1975) stated that the more variable the practice, the better the learning. A presupposition of this experiment was that variable practice during acquisition would promote learning. Zelaznik, Shapiro and Newell (1978) examined practice variability. Subjects had auditory feedback only, and KR (no physical practice) available to learn a criterion movement on a linear slide. Results indicated that the group learning with variable practice learned better than the group with constant practice on the criterion movement, even though the variable group never heard the criterion movement. Although the purpose of this experiment differed, it provided evidence that variable practice may be beneficial to observational learning. Bird and Rikli (1983) investigated practice variability and observational learning of an angular positioning task. Subjects either observed a model that performed only one version of the task (constant practice) or four versions of the task (variable practice), or subjects performed the actual tasks with constant or variable practice. The variable physical practice group performed the best on the transfer task, as Schmidt (1975) predicted. However, the constant physical and variable observational groups performed similarly. These results suggested that, not only was variable practice a beneficial way to learn through observation but that one could possibly learn a movement without physical practice. In consideration of these results, a variable practice schedule was used in the present experiment to enhance the observational learning effects.

The development of representation has occurred for studies examining relative timing (phasing) of movement. Wulf and Schmidt (1988, 1989) provided evidence that practice on three versions of a movement with the same relative timing led to better performance on a transfer test of the same relative timing than on a transfer test of different relative timing. Presumably there has been better development of the GMP in the same-phasing (same relative timing) transfer group which allowed for better same-phasing transfer. These studies suggested that a representation for invariant timing could be learned by variability of practice using versions of the same relative timing structure. The present experiment used a similar task to determine if a timing representation could be learned through observation. A different-phasing transfer was also used to determine if a representation was formed. Essentially, a different-phasing situation would be a different representation from acquisition, therefore, all subjects should perform equally since none of them would have had experience with this task

(Schmidt, 1988).

The "Processing Hypothesis" of Observational Motor Learning

A key ingredient to motor learning is augmented feedback (Bilodeau, 1966). KR and knowledge of performance (KP) are types of augmented feedback. KR provides information about the results or outcome of previous movements. KP provides qualitative information about the movement production. Both KR and KP have been determined to be the most useful sources of information to enable one to correct their movements when learning a motor skill (Salmoni, Schmidt & Walter, 1984). One role of KR, as stated before, is that of information. During the initial stages of learning, KR was proposed to be utilized when learning a movement goal. How an observer might learn from a model's KR was the question of interest here.

Traditionally, KR has been argued to assist in the development of a cognitive representation. However, early research suggested that learning about KR may be important. Learning about KR could be a key factor during observational learning and is the basis of the "processing hypothesis". For, when one receives the model's KR during observation they not only are obtaining information about the movement outcome but they may also be learning how to process and use the KR to learn the movement.

Early studies investigating information feedback considered what was learned from the KR. These studies considered KR benefits from a processing point of view. A "processing hypothesis" stated that in addition to learning from KR, one learns how to process KR. Once the informational content of KR was understood, then the subjects were able to use it. Until then, the KR was not useful. Bilodeau (1953) had subjects attempt to learn a motor task while receiving KR. The KR however, was transformed mathematically: given either as the true score, or one of five linear transformations (all resulting in a larger KR score). Results indicated that performance was poor until the transformation was determined by the subjects. These results supported the "processing hypothesis", that learning about the nature of KR and learning why KR is useful is important.

Another study examined this concept in a different way (Denny, Allard, Hall & Rokeach, 1960). Subjects were given KR on a line drawing task in units of "glubs" instead of known units. Once the subjects determined what a glub was, they could perform the task. Once again, learning how to process KR seemed to be important.

These experiments support the contention that learning to process KR is an important factor in motor learning. Adams (1986) suggested that learning to process the model's KR was an important part of observational learning. A "processing view" of observational learning suggested that when an observer watched a model perform a sequential timing task and received the model's KR, the KR was used to learn what a millisecond is and how fast one must move to reach that millisecond goal, not necessarily to form a cognitive representation. The present experiment attempted to determine if KR was a necessary element to observational learning.

Investigations of learning without KR have found mixed results. The majority of researchers have found KR to be a learning variable (see Salmoni, et al., 1984 for a review). For example, KR is necessary to learn a task, without KR learning does not occur. Several studies, however, found that a reduction in error occurred even when KR was not given (Newell, 1976; Wrisberg & Schmidt, 1975; Zelaznik & Spring, 1976). If one was not learning from the KR then they may be learning from other sources of information. The task conditions may have provided sufficient information, without KR, to learn the task. But, as the information inherent in the task becomes less sufficient, the importance of augmented information such as KR and KP may increase. If other types of information can be used, the need for KR may not be as great. Similarly, in the case of observational learning, when there is limited information available to the observer, there may be an increased importance for KR. McCullagh, Burch, and Siegel (unpublished) found similar learning of an in-step soccer pass when an observer received self-modelled demonstrations as when they received self-modelled demonstrations and received KP, thus questioning the need for KR when descriptive knowledge of one's own performance was available. However, the learning may be explained by an increased ability to correctly parameterize the motor program by determining the parameters through observation. There is a need to separate the ability to form a cognitive representation and the need to use KR.

The "Representation" vs The "Processing" Hypotheses: Previous Research

Several researchers have attempted to separate observational learning benefits that were due to the learning of KR from those due to the formation of a representation. McCullagh and Caird (1990) examined three groups of observers: one group observed a correct model, while two groups observed learning models either receiving the model's KR or not receiving the KR. A final group physically practised and received their own KR. The task was movement timing. Observers physically practised half of their acquisition trials and watched demonstrations of the other trials. All subjects then performed retention and transfer trials. The observers of the learning models who received KR and the physical practice group performed the best. However, the observers of the correct model performed better than the observers of the learning models that did not receive KR. These results provide further evidence that a learning model and KR enhance learning. However, the physical practice trials during acquisition may account for the learning, since subjects may have formed a cognitive representation during these trials, and not necessarily during observation.

Another study examined a similar issue. McCullagh et al. (unpublished) attempted to separate the two variables of KR and the type of model used. Comparisons of a correct model group, to a correct model + self-model group, self model only (experiment 2) and no demonstration group (experiment 1) learning a soccer pass were made. Groups viewed demonstrations and intermittently performed physically (with or without KP) throughout the study. Results indicated that subjects that viewed the correct demonstrations with KP performed the best, however, the correct and self-model observers did not benefit further from the KP. These results suggested that augmented information was not necessarily the most important source of information when other sources were available. If the KR was not important, then other information may have enhanced learning.

McCullagh and Little (1989) also attempted to separate KR effects from the ability to form a cognitive representation through observational motor learning. A control group that physically practised and received partial KR was compared to three observer groups (auditory + visual, visual only and auditory only). None of the observers received the model's KR during acquisition, although they did have intermittent physical practice during acquisition. The auditory + visual and auditory only groups performed the with the least error of the observer groups. The results of this experiment suggested that a representation was formed since the observers did improve in performance on transfer tests. However, since the observers did not receive KR at all during acquisition, the benefits of processing KR were not discussed.

A need to further examine these issues seems apparent from the review of the current literature. The primary purpose of the present experiment was to determine if KR was necessary to develop a cognitive representation through observational learning. The experiment had models learn three variations, with the same relative timing, of a three segment timing task. Observers watched a videotape of one of the models learning the tasks. One observer received the model's KR and one observer did not receive the model's KR. There was also a control group that did not perform or observe the acquisition trials. All subjects then performed two transfer tasks, one with the same phasing requirements (with and without KR), and one with different phasing requirements (with and without KR).

Subjects that observed without receiving the model's KR were used to test the effectiveness of forming a cognitive representation, while subjects that observed with KR were used to test the effectiveness of learning to process KR. The hypothesis was that if a cognitive representation is formed through observational learning, then both groups of observers should perform equally on the same-phasing transfer and better than a control group that did not receive observation. However, if the benefit of observation was due to the increased knowledge of learning <u>how</u> to use KR, not simply the development of a representation, the observer who received the model's KR should perform better on the transfer tasks when KR was given. When KR was withheld, all groups should perform equally. These hypotheses are illustrated in Table 1.

Insert Table 1 about here

Method

Subjects

Forty-eight university undergraduates participated in the experiment. All subjects received a course credit for their participation. Subjects were randomly assigned to four groups (learning model, observers that received KR, observers that did not receive KR, and a control) equally balanced for gender. All subjects were right handed. None of the subjects had previously practised the task, and none were told the purpose of the experiment.

Apparatus and Task

The apparatus and task were identical to that used by Lee, Wulf, and Schmidt (in press). The apparatus consisted of a wooden base with four electromagnetic microswitches mounted upon it in a diamond formation. Each microswitch was 18 centimetres apart. Subjects moved their right arm from the front-centre (home) switch forward and to the left to contact the first target, then forward and to the right to the second target, then towards the body and to the right to the final target. A segment was defined as the movement required between two targets. Therefore, segment 1 was the movement between the home position and target 1, segment 2 was the movement between target 1 and target 2, segment 3 was the movement between target 2 and the final target. A cylindrical shaped magnet (1 cm X 4 cm) was used as a stylus to contact each target. Each microswitch was connected to a Lafayette Performance pack which recorded each segment's movement time (MT) to the nearest ms.

The subject's task on each trial of the experiment was to move from the home position to the three successive targets according to the specified MT goals. The MT goals for each segment of each variation of the task were printed on separate cards and mounted on the wall behind the apparatus.

Each learning model was filmed using a Sony video 8 camera. These recordings were later transferred onto VHS tape. The observers viewed their assigned model's demonstrations on a 36 cm x 30 cm coloured monitor.

Insert Table 2 about here

<u>Procedure</u>

A summary of the testing sequences is provided in Table 2. The four groups of subjects were controls, learning models, observers who received the model's KR, and observers who did not receive the model's KR. All subjects were tested individually. Subjects were told the task goal and that the model was learning three variations of a same-phasing movement task. The model on videotape performed the acquisition trials and the observers watched. One group of observers received verbal KR, in ms, after each trial about each segment and the other group did not receive KR. Observers never physically practised the acquisition task. All groups then performed the transfer tasks. Schmidt (1988) suggested that transfer test are used to determine what characteristics of performance were relatively permanently learned. The transfer tasks in this experiment had the same relative timing, but different absolute timing than any of the three variations that were practised or observed. By designing the experiment this way, the number of exposures to the acquisition task was controlled. The learning models physically performed the acquisition trials and received visual KR after each trial. They then performed the transfer tasks. The control group performed the transfer tasks without any previous practice or observation.

A summary of absolute movement times, goal proportions and overall movement times is provided by Table

3.

Insert Table 3 about here

Acquisition. The models performed three variations of the three segment movement task. The absolute movement time goals (in ms) were 150-300-225, 200-400-300, and 250-500-375. All the variations had the same phasing. The same-phasing tasks all had the same relative proportion of time allotted to each segment of the movement while the absolute movement times differed. Therefore, the proportions for the three segments relative to the total movement time was (.22-.44-.33). A total of 72 acquisition trials were divided into 12 blocks of 6 trials each. These variations were randomly ordered with the restriction that each variation was performed once in every set of three blocks. The observers watched the videotape of the model perform these tasks with the knowledge that they would later perform a similar task.

Same-Phasing Transfer. All subjects performed the same-phasing transfer task. This transfer task had the same phasing as the acquisition trials (.22-.44-.33) but longer absolute times (300-600-450: total MT = 1350 ms). Subjects performed 18 trials of this task without KR, followed by 18 trials with verbal KR.

Different-Phasing Transfer. The second transfer task had a novel phasing requirement (.33-.22-.44), although the overall MT was the same as the same-phasing transfer task (450-300-600; total MT = 1350 ms). Subjects performed 18 trials of this task without KR, followed by 18 trials with verbal KR.

Data Analysis

Absolute constant error (|CE|) and variable error (VE) were calculated from the MT data. |CE| measures the accuracy of the movement, for example how many ms were the subjects away from the criterion MT. VE measured the consistency of the movements. These dependent variables were analyzed separately.

Acquisition. A 3-way, repeated measures 3 (variation: 1/2/3) X 3 (segment: 1/2/3) X 4 (blocks: 1/2/3/4) ANOVA was used to analyze the learning models' data.

Same-Phasing and Different-Phasing Transfer. A 4 (group: control/model/observer with KR/observer without KR) X 3 (segment: 1/2/3) X 3 (block: 1/2/3) ANOVA with repeated measures on the last two factors was used to analyze each transfer test. The transfer tests with or without KR were analyzed separately.

The .05 level for statistical significance was set for all tests. Significant ANOVA tests were further analyzed using the Tukey HSD method. Complete ANOVA tables are in Appendix A.

Results

Acquisition

|CE|. As may be seen in Figure 1, the first segment of each of the three task variations were performed similarly over trial blocks. However, for segment 2, variations 1 and 3 were not different over blocks, while performance of variation 2 improved dramatically after block 1. In segment 3, variation 1 was significantly different from block 1 to block 3, while variations 2 and 3 showed improved performance between block 1 and block 2 only. Analysis of these data revealed a variation x segment x block interaction, $F(12, 132) = 3.06$, $p < .001$. Other significant effects included a variation x segment interaction, a variation x blocks interaction, a segment x blocks interaction, and main effects for segment and blocks.

Insert Figure 1 about here

VE. All variations were performed with similar error for segment 1 (V1=20 ms, V2=29 ms, V3=28 ms). However, for segments 2 and 3, variation 1 (S2=49 ms, S3=53 ms) was performed better than variation 2 (S2=78 ms, S3=78 ms), and variation 3 (S2=98 ms, S3=83 ms). The reliability of these differences was supported by a variation x segment interaction, $F(4, 44) = 3.09$, $p < .05$. Also found were main effects for segment and variation.

Same-Phasing Transfer Without KR

|CE|. The models, observers with KR and the observers without KR all performed significantly better than the control group on the third segment of this transfer test. Segments 1 and 2 however, revealed no differences between groups. The results are illustrated in Figure 2 and supported by a group x segment interaction, $F(6, 88) = 3.46$, $p < .01$. The group main effect and the segment main effect were also significant.

Insert Figure 2 about here

|VE|. No differences in error over blocks were found for the first segment of this transfer test. VE decreased from block 1 (85 ms) to block 2 (68 ms) and block 3 (79 ms) for segment 2. VE decreased for segment 3, from block 1 (87 ms) and block 2 (79 ms) and to block 3 (62 ms).

A segment x block interaction, $\underline{F}(4, 176) = 2.64$, $\underline{p} < .05$, supported these findings. Main effects for segment and blocks were also found.

Same-Phasing Transfer With KR

$|\underline{CE}|$. Group means at each segment are presented in Figure 3. The groups did not differ on segment 1 or segment 2. However, the models performed with significantly less error than all other groups on segment 3. Also, while the two observer groups did not differ, they did perform significantly better than the control group on segment 3. This group x segment interaction was significant, $\underline{F}(6, 88) = 4.85$, $\underline{p} < .001$. There were no changes in error over blocks for segment 1. However, for segment 2, block 1 (113 ms) was performed with significantly more error than blocks 2 (77 ms) and block 3 (74 ms). Segment 3 had similar results, with block 1 (161 ms) having more error than block 2 (114 ms) and block 3 (97 ms). These results were verified by a segment x block interaction, $\underline{F}(4, 176) = 3.54$, $\underline{p} < .01$. Main effects were also noted for group, segment and blocks.

Insert Figure 3 about here

VE. The performance of each group for the 3 segments is presented in Figure 4. There were no differences between the groups for segment 1. There also were no differences between the models, the observers with KR and the observers without KR for segment 2, yet all groups performed with less error than the control group. For segment 3, only the models performed with less error than the control group. These findings were supported by a group x segment interaction, $F(6, 88) = 2.32$, $p < .05$.

Insert Figure 4 about here

There were no difference in the blocks for segment 1. Segment 2 error decreased significantly from block 1 (118 ms) to block 2 (75 ms) but there was no further decrease on block 3 (79 ms). Segment 3 also had decreased in error from block 1 (111 ms) to block 2 (87 ms) but there was no further decrease for block 3 (88 ms). These results were verified by a segment x block interaction, $F(4, 176) = 2.41$, $p = .05$. Main effects were also found for segment and blocks.

Different-Phasing Transfer Without KR

$|CE|$. The were no differences in performance between the groups for segment 1 and 3. However, for segment 2 observers that did not receive KR (57 ms) performed with less error than the models (140 ms), the observers that received KR (113 ms) and the control group

(123 msec). These results were supported by a group x segment interaction, $F(6, 88) = 2.745$, $p < .05$. No other differences were found.

VE. The observers without KR (52 ms) performed with significantly less error than the models (90 ms) but were not different from the observers with KR (77 ms) and the control group (74 ms). These results were supported by a main effect for group, $F(3, 44) = 2.97$, $p < .05$. A main effect for segment ($F(2, 88) = 40.88$, $p < .001$) revealed that segment 1 (49 ms) was performed with less error than segment 2 (72 ms), which in turn, was performed with less error than segment 3 (99 ms). Block 1 (85 ms) was performed with significantly more error than block 2 (73 ms) and block 3 (62 ms), $F(2, 88) = 10.71$, $p < .001$.

Different-Phasing Transfer With KR

|CE|. Figure 5 illustrates the performance of the groups over blocks for each segment. There were no group differences for the three blocks of segment 1. For segment 2, the models and the observers without KR performed with less error than the observers with KR and the control group for the first block of trials, yet with no differences for the second block. However, for block 3, the models performed with less error than only the observers that received KR. There were no difference between the other

groups on the third block of the second segment. The third segment produced a different set of findings. For block 1, the observers without KR performed with less error than the models and the control group. There were no differences between the observers for this first block. On the second block of the third segment, the models, the observers without KR and the control group all performed with less error than the observers with KR. The final block revealed no differences between the groups except that the observers without KR performed with significantly more error than the controls. The results were verified by a group x segment x blocks interaction, $F(12, 176) = 2.19$, $p < .05$. Interactions of group x blocks, and segment x blocks and a block main effect were also significant.

Insert Figure 5 about here

VE. Segment 1 (65 ms) and segment 2 (76 ms) were performed with less error than segment 3 (92 ms), as supported by a main effect for segment, $F(2, 88) = 11.27$, $p < .001$. Block 1 (88 ms) was performed with more error than block 2 (75 ms) and block 3 (71 msec). This was supported by a main effect for blocks, $F(2, 88) = 5.23$, $p < .01$.

Discussion

The purpose of this experiment was to determine if KR was necessary to develop a representation through observational learning. Two hypotheses were suggested. According to the processing hypothesis, if KR was necessary to develop a representation through observational learning, then subjects who observed with KR should have performed better on the transfer tests that received KR. However, according to the representation hypothesis, if KR was not necessary to develop a representation, then both observer groups should perform equally on both transfer tests regardless of whether or not KR was available. The results of the transfer tests favoured the representation hypothesis. Both observer groups performed with less error on the same-phasing transfer without KR than the control group, suggesting that both groups developed a representation. These results were largest for segment 3. Similar results were found when KR was given on the same-phasing transfer test. Again, there were no differences between the observers, and both were better than the control group. These results are supportive of the representation but not the processing hypothesis.

In order for observational learning effects to occur the model must demonstrate the task proficiently (McCullagh et al., 1989). However, Adams (1986) suggested that observing a learning model may be more beneficial than observing a correct model, since observation of a learning model not only allowed for the formation of a cognitive representation, but also enabled participation in problem-solving activities that enhanced the cognitive representation of the movement. The models in this experiment were attempting to learn three variations of a same-phasing task. Analyses of the acquisition results revealed the models did improve over blocks. This supported the experimental presupposition that the models were indeed learning the task. However, the first segment of all variations of the task was performed with the least error and with no improvement over blocks. Segment 2 and segment 3 decreased in error over blocks. The large decrease in error from block 1 to block 2 on variation 2 may be explained as an ordering effect since all models performed variation 2 for the first block of trials on the acquisition phase.

The representation hypothesis of observational motor learning stated that a cognitive representation of a movement could be formed in the absence of KR. Many theories of learning considered that there was a cognitive representation of movement (Adams, 1971; Bandura, 1986;

Schmidt, 1975), although they disagreed on the role of KR. In this experiment a representation of the task appeared to have been formed by both the models and the observers. During the same-phasing transfer without KR, these groups all performed with less |CE| than the control group (especially, on segment 3). These results supported Carroll and Bandura's proposal that a cognitive representation of an action could be acquired through observation only, without KR (Carroll & Bandura, 1982, 1985, 1987, 1990).

The majority of studies investigating observational learning had subjects alternate periods of observation and physical practice during acquisition (eg., Martens et al., 1976; McCullagh et al., 1989). One limitation to this method is that the development of the representation may have occurred during the physical practice trials and not necessarily during the observation. Perhaps, observation could be used as a type of information feedback, which is then used to correct behaviour during the next physical practice trial. Since in the present experiment the transfer tests were performed without any previous physical practice by the observers or control group, the results provided further evidence that the performance differences were due <u>only</u> to observation effects.

Other explanations are proposed for the lack of differences between the observers. The first consideration questions the complexity and characteristics of KR. The processing hypothesis stated that, in addition to learning the informational content of KR, subjects must also learn to use and process the KR. Studies investigating this idea determined that complex KR was only useful after the nature of KR was determined (Bilodeau, 1953; Denny et al., 1960). The present experiment gave KR in ms units. Perhaps this KR was too simple and all subjects were able to process it, even if they only received it on the KR transfer phase. An alternate explanation may be that KR is only useful during physical practice. The models improved their performance when they received KR on the same-phasing transfer tests, however, the observers that received KR during acquisition did not improve. Perhaps the observers could not learn to process and utilize the KR without actual practice. All the research investigating KR and observational learning have had physical practice during the acquisition phase. The physical practice may have enabled the subjects to process and utilize the KR (Adams, 1986; McCullagh & Caird, 1990; McCullagh & Little, 1989; McCullagh et al., unpublished).

A final suggestion for the lack of difference between the observers on the same-phasing transfer test may be that other sources of augmented information feedback available to the observers may have reduced the reliance on KR. McCullagh et al. (unpublished) found that KR was not necessary when other forms of feedback, such as self-modelling information, were present. During this experiment, all subjects received visual as well as auditory information on all acquisition trials. The auditory systems are well suited for the perception and retention of temporal information (O'Connor & Hermelin, 1978). Since this experiment was concerned with timing, the auditory information may have been more useful to the observers than the KR.

Several studies have investigated audition and observational learning and have found audition to be an important factor in producing observational learning effects (Doody et al., 1985; McCullagh & Little, 1989; Zelaznik & Spring, 1976). Doody et al. (1985) compared observers that received visual, auditory, or visual plus auditory feedback to a control group on a sequential timing task. The observers in the auditory and visual plus auditory groups performed with the least error. These results suggested that audition may be a useful source of information when learning a timing task. Therefore, the presence of auditory information, the tapping of the magnet on the microswitches, during this experiment may have reduced the KR effects. The sound of the tapping may have provided another source of timing information. This was examined further in Experiment 2.

The VE results were consistent with the literature. The observers that did not receive KR performed with less VE than the model. This may be explained by transfer appropriate processing (Bransford, Franks, Morris & Stein, 1979; Lee, 1988). For example, the models learned with KR and may have had a more difficult time adjusting to the no KR situation (Lee, 1988). The observers, especially those that did not receive KR, adapted well to this transfer condition. Once again, segment 1 was performed with the least error and performance became more consistent over blocks (cf. Salmoni et al., 1984).

The presence of KR during the different-phasing transfer created inconsistent results. All subjects performed similarly on segment 1, consistent with the earlier transfer tests. But, on segment 2, the models and observers that did not receive KR performed with less error than the observers who received KR and the control group on block 2. However, for block 3, the models were better only than the observers with KR, suggesting that the observers that received KR were negatively affected by acquisition. The results differed again for segment 3. The models, observers without KR and the control group performed better than the observers with KR on block 2. Yet on block 3, the observer that did not receive KR performed with more error than the control group. The results of the different-phasing transfer suggested that this transfer test was indeed more difficult than the same-phasing transfer. The observers that received KR had more difficulty on this transfer task than even the control group on some occasions. Perhaps these results were due to the order by which the transfer tests were conducted. The same-phasing transfer always preceded the different-phasing transfer. The representation for the same-phasing transfer, as well as the same-phasing acquisition trials, may have interfered with this transfer test, therefore producing inconsistent results.

Overall, the first experiment provided evidence that a cognitive representation of a sequential timing task could be learned through observational learning both with or without KR. These results were not consistent with previous research. The KR provided in this experiment may not have been necessary for the subjects to form a representation of the movement. The presence of auditory information may have provided enough information for both groups of observers to form a representation. The effects of auditory feedback were examined in Experiment 2.

Experiment 2

In the first experiment there were no differences between the observers on the same-phasing transfer test. Several explanations were considered. The purpose of this experiment was to investigate one of these explanations: that the presence of auditory information affected the observers' ability to form a representation or process KR.

The auditory systems are well suited for the perception and retention of temporal information (O'Connor & Hermelin, 1978), indicating that audition may be important when learning a timing task. Several studies have also examined the implications of audition and observational learning.

An early study by Zelaznik and Spring (1976) attempted to determine if recognition memory could be developed in the absence of movement. Although not examining the observational learning and audition issue directly, the study did use an observation design. Observers listened to a subject produce a specific MT on a linear slide task, and received their KR. They then performed the actual task on a no-KR test. Results indicated that the observers performed better than the models on the first few trials of practice, after having heard only auditory information plus KR.

More recently, Doody et al. (1985) designed an experiment to examine the importance of audition to observational learning. Three groups (auditory + visual, auditory only, visual only) observed models perform a sequential timing task with a single timing goal. Subjects observed a model and intermittently performed physical practice trials during acquisition. Results revealed that subjects in the auditory + visual as well as the auditory only groups, performed best on the acquisition and no KR transfer test. These results also support the concept that auditory information was important to observation. Once again, the observation trials were confounded with physical practice trials making is hard to separate how the representation was developed.

Finally, McCullagh and Little (1989) examined the modality of presentation of the task and a correct model. The design was similar to Doody et al. (1985). Three groups of observers (auditory + visual, visual only, auditory only) were compared to a group that received partial KR and physically practised an equal number of trials as the observers on a sequential timing task. The difference in this study was that the number of acquisition trials were controlled and none of the observer groups received KR.

Results indicated that the physical practice group performed with the least error. However, the observers who received auditory and visual feedback, and those that received auditory only performed with less error than the subjects that observed visually only. The importance of auditory information, even without KR, seems to be well supported.

In Experiment 1, the presence of auditory information may have been more useful than KR or decreased the KR effects. Since a timing task was utilized the auditory information available during acquisition may have provided enough information to learn the task and the additional KR was not processed. The purpose of this experiment was to determine if the absence of auditory information affected the formation of a cognitive representation of a timing task. If the auditory information was eliminated, would KR then be necessary to develop a cognitive representation of the movement through observation.

The same hypotheses tested in Experiment 1 were examined. If there was evidence that a cognitive representation was formed, then all observer groups would perform equally on the same-phasing transfer task. However, if observation effects occurred due to the increased ability to process KR, then the observers who received KR would perform better on the transfer tests when they received KR. Once again the different-phasing transfer test should have poor performance by all subjects since it was a different movement class and a different GMP.

Method

Subjects

Twenty-four university undergraduates participated in the experiment. All subjects received a course credit for their participation. Subjects were randomly assigned to two groups (observers with KR and observers without KR) equally balanced for gender. None of the subjects had previously practised the task, and none were told the purpose of the experiment.

The videotapes of the twelve models used for this experiment were the same that were used in experiment 1.

Apparatus and Task

The apparatus and task were the same as used in Experiment 1. The one difference was that the monitor's sound was turned off, therefore there was no auditory information about the tapping of the stylus given to the subjects during the acquisition phase.

Procedure

The procedures for this experiment were the same as used in Experiment 1. All acquisition and transfer trials were the same.

Data Analysis

The transfer data for this experiment were combined with the observer transfer data from Experiment 1 with the purpose of assessing the effect of auditory information in combination with the availability of KR during observation. Separate 2 (modality: auditory + visual/ vision only) X 2 (feedback: observer with KR/ observer without KR) X 3 (segment: 1/2/3) X 3 (blocks: 1/2/3) ANOVA with repeated measures on the last two factors were used to analyze all the transfer data.

Results

Same-Phasing Transfer Without KR

|CE|. Segment 1 (58 ms) was performed with less error than segment 2 (179 ms) and segment 3 (161 ms). These results were supported by a main effect for segment, $F(2, 88) = 21.9$, $p < .001$. No other significant differences were noted.

VE. The means for the four groups over blocks are presented in Figure 6. For subjects that observed with KR in either modality, there were no differences over blocks. However, for subjects that did not receive KR, there were no differences between modality of presentation for block 1. But, for block 2 and 3 subjects that received vision plus audition performed with less error than those subjects that received vision only. These results were verified by a modality x feedback x block interaction, $F(2, 88) = 4.58$, $p < .05$.

Insert Figure 6 about here

Figure 7 illustrates the performance of the observers over blocks for each segment without regard to modality. Observation with or without KR resulted in similar performance over blocks for segments 1 and 2. However, for segment 3, the observers that received KR performed with more error than the observers that did not receive KR, on blocks 1 and 2, but not on block 3. These results were supported by a feedback x segment x block interaction, $F(4, 176) = 2.68$, $p < .05$. Also significant was the segment x block interaction and segment and blocks main effects.

Insert Figure 7 about here

Same-Phasing Transfer With KR

$|CE|$. There was no difference in error over blocks for segment 1. For segment 2, block 1 (119 ms) had greater error than block 2 (81 ms) and block 3 (71 ms). Segment 3 revealed differences between all of the blocks, B1 = 160 ms, B2 = 120 ms, B3 = 89 ms. Analysis of these data revealed a segment x block interaction, $F(4, 176) = 4.62$, $p = .001$. Main effects for segment and block were also found.

VE. Segment 1 (39 ms) was performed with less error than segment 2 (89 ms) and segment 3 (97 ms). This was verified by a segment main effect, $F(2, 88) = 84.59$, $p < .001$. Also, there was a decrease in error from block 1 (86 ms) to block 2 (69 ms), but no further reduction to block 3 (70 ms), as indicated by a blocks main effect, $F(2, 88) = 5.56$, $p < .01$.

Different-Phasing Transfer Without KR

|CE|. There were no differences due to modality of presentation for segment 1 and segment 3. However, for segment 2, the subjects that received auditory plus visual information (85 ms) had less error than the subjects that received vision only (153 ms). These results were verified by a modality x segment interaction, $F(2, 88) = 4.04$, $p < .05$. Again, there were no differences in segment 1 and segment 3 over the blocks. However, for segment 2, block 1 (141 ms) had more error than block 2 (112 ms) and block 3 (100 ms). This was supported by a segment x block interaction, $F(4, 176) = 3.92$, $p < .01$. Segment and block

main effects were also significant.

VE. Figure 8 illustrates the performance of the observers over blocks at each segment averaged over the modality of presentation. The observers with KR and the observers without KR were not different over blocks for segment 1. No differences were found for segment 2, on blocks 1 and block 2, yet for block 3 the observers that received KR performed with significantly more error than the observers that did not receive KR. And for segment 3, the observers that received KR performed with more error than the observers that did not receive KR for block 1 as well as for block 2. These results were verified by a feedback x segment x blocks interaction, $F(4, 176) = 3.64$, $p < .01$. The segment x block interaction and the segment and blocks main effects were also significant.

Insert Figure 8 about here

Different-Phasing Transfer With KR

|CE|. As seen in Figure 9, there were no differences over blocks for the observers who received KR, as a function of the modality of presentation. However, for the observers that did not receive KR, audition plus vision performed with less error on block 1 than those that had

vision only. There were no differences on block 2 or block 3. These results were verified with a modality x feedback x block interaction, $F(2, 88) = 3.96$, $p < .05$.

Insert Figure 9 about here

Performance of the two modality groups, over blocks on each segment is presented in Figure 10. Modality of presentation did not affect performance throughout blocks for segment 1. On segment 2, subjects that received audition plus vision performed with less error than those that received vision only on block 1. They did not differ on the other blocks. For segment 3, while the subjects did not differ on block 1 and 2, the subjects that received audition plus vision performed with more error than those that received vision only on block 3. These results were supported by a modality x segment x block interaction, $F(4, 176) = 3.22$, $p < .05$.

Insert Figure 10 about here

The effects of KR during observation as revealed on the segments of the 3 different-phasing transfer blocks with KR is shown in Figure 11. The observers did not differ over blocks for segment 1. However, for segment 2 the observers that did not receive KR performed with less error than the observer that received KR on block 1 and did not differ on the final two blocks. But on segment 3, the first and third block did not differ, while the observers that did not receive KR performed with less error than the observers that received KR on block 2 . Further analysis of these results revealed a feedback x segment x block interaction, $F(4, 176) = 4.45$, $p < .01$.

Insert Figure 11 about here

A segment x block interaction, as well as main effects for segment and blocks were also found.

VE. The observers that received KR (87 ms) performed this transfer task with more error than the observers that did not receive KR (73 ms). This was supported by a main effect for feedback, $F(1, 44) = 4.00$, $p < .05$. Segment 1 (67 ms) had less error than segment 2 (82 ms) and segment 3 (89 ms) and was verified by a main effect for segment, $F(2, 88) = 7.89$, $p < .001$. Block 1 (90 ms) had greater error than block 2 (75 ms) and block 3 (74 ms), and was supported by a main effect for block, $F(2, 88) = 6.31$, $p < .01$.

Discussion

The purpose of this experiment was to determine if KR during observation was necessary to develop a representation in the absence of auditory information. The same hypotheses that were tested in Experiment 1 were assessed. If a cognitive representation was formed in the absence of KR then the representation hypothesis would be supported. If the ability to process KR was more important when learning a movement then evidence of the processing hypothesis would be found. Experiment 1 supported the representation hypothesis since there was no evidence that KR enhanced observational learning. It was proposed that the presence of auditory information may have overshadowed the effects of observing with KR. This experiment eliminated the auditory information during observation, in attempt to increase the importance of the KR. However, the results indicated that, once again, the observers that received KR during acquisition did not differ from the observers that did not receive KR. There was also limited support that the presence of auditory information enhanced the observational learning.

The representation hypothesis was further supported when the subjects received KR on the same-phasing transfer test. All subjects performed equally well, regardless of the modality of presentation or type of feedback given during observation. These findings indicated that cognitive representations had been formed. Also, the additional feedback (KR) given during the transfer phase did not appear to enhance the performance of the observers who received KR during the acquisition phase, suggesting that the ability to process KR was not learned during acquisition. The results of this experiment are not consistent with the processing hypothesis, although they are, consistent with Experiment 1.

Previous researchers suggested that auditory feedback was useful when learning a timing task (Doody et al., 1985; McCullagh & Little, 1989; Zelaznik & Spring, 1976). All of these studies found that observing a timing task when auditory information was available was more beneficial than observing with vision only. In the present study the observers that observed without KR, and received auditory information had less VE than the observers who received KR and auditory information (on the same-phasing transfer without KR). These results indicated that the auditory feedback was more useful to the observers that did not receive KR and did not affect those that learned with KR. Even without auditory information, the observers that received KR did not seem to use the KR available to them to improve performance any more than the observers that did not receive KR. It may be that the auditory information was more useful than the KR, but when KR was given the auditory information was ignored. Bandura (1986) stated that the correct information must be selectively attended to in order to form a correct representation. Perhaps the auditory information was attended to more when the KR was not available. However, when KR was available, it may have been attended to even though it was not as useful as the auditory information.

The presence of auditory information also appeared to aid subjects when KR was not available on the different-phasing transfer test. The subjects that observed with auditory + visual information performed with less $|CE|$ on segment 2 than the group that observed with vision only. Also, when there was KR on the different-phasing transfer test the auditory + visual group performed better than those that observed with vision only. Once again the presence of auditory information seemed to have a limited affect on performance, but not in the way expected. In this experiment it seems that auditory information was more important than the KR.

These experiments attempted to eliminate the confound of physical practice during the observation trials of acquisition that occurred in the previous experiments

(Doody et al., 1985; McCullagh & Caird, 1990). Actual physical practice during acquisition trials may have influenced the formation of a cognitive representation since a representation of a movement is also formed through physical practice (Adams, 1971; Schmidt, 1988). If this was the case, then in earlier studies the formation of the representation may have been due to the physical practice and not necessarily to the observation trials. The present experiment confirmed that some learning did occur through observation only.

The elimination of physical practice from acquisition may have also influenced the KR effects. KR has been found to be an important aspect of learning but it may be that actual physical practice was necessary for KR to be useful. All subjects had the equal physical practice trials on the transfer tests. Only the models had physical practice during acquisition. It may be that KR given to the observers during the transfer trials was not useful since they had not learned to utilize it during acquisition. The presence of KR also was not useful to the subjects on the different-phasing transfer test. On both transfer tests (different-phasing with KR and without KR) the observers who observed without KR performed better than those that received KR. These results are inconsistent with the literature (eg., Doody et al., 1985; McCullagh & Caird, 1990; McCullagh & Little, 1989).

Overall, this experiment provided limited support for the contention that the lack of observer difference was due to the presence of auditory information. Auditory information had a small effect on the observers who did not receive KR and on the different phasing transfer. However, eliminating the auditory information did not enhance the KR effects, as was expected.

General Discussion

Two experiments were conducted to determine what was learned through observational learning. Specifically, could a representation be formed in the absence of KR, and (in Experiment 2) could this representation be formed in the absence of KR and auditory information? Both experiments revealed similar results, yet they did not conform to results of earlier research. Several suggestions are proposed to account for this discrepancy.

Bandura (1986) and Carroll and Bandura (1982, 1985, 1987, 1990) proposed that observational learning occurred when an observer watched a model perform a movement. An abstract cognitive representation was formed of this movement and could later be used to perform the movement. This cognitive representation could be formed from the information available from vision, and KR was not needed for the observer to form the representation. The results of the present experiment supported these ideas. Observers who did not receive KR during acquisition performed as well on the transfer tests as the observers who received the model's KR. In Experiment 1, during the same-phasing transfer without KR both observers performed as well as the models suggesting that all subjects had formed representations of the movement. These results not only suggested observational learning could occur without KR, but that it allowed for similar representations as subjects that physically practised the task.

Theories of learning, however, indicated that KR was one of the most important processes for learning to occur (Adams, 1971; Schmidt, 1988). KR given throughout physical practice allows for rapid improvement of skills (Schmidt, 1991). The understanding of the KR given and the ability to process it are important aspects of learning (Bilodeau, 1953; Denny et al., 1960). Studies investigating KR and observational learning have found that observing and receiving the model's KR enhanced learning more than observation without KR (Doody et al., 1985; McCullagh & Little, 1989). These studies, however, had physical practice trials and observation trials interspersed throughout acquisition. The present experiments attempted to determine which was more important to observational learning: the ability to form a cognitive representation or the ability to process KR. The findings supported the representation view. Transfer was not enhanced by observing with KR. In fact, on some occasions the observers that received KR performed worse than those that did not receive KR.

It is possible however, that a representation of relative timing may be learned with little or no KR at all. Wulf and Schmidt (1989) had subjects learn three versions of a task of the same relative timing. One group was given 100% KR on all of the versions, while another group was given 100% KR on version 1 and 3 and 0% KR on version 2. Retention tests revealed that subjects that learned with 0% KR performed version 2 with less error than those that learned with 100% KR. Therefore, under some circumstances, this study suggested that KR may not be necessary to learn the movement.

Several suggestions for the differences found in the present experiments were suggested. The first suggestion was investigated in Experiment 2. The presence of auditory information during all of the observation trials may have decreased the reliance on KR. If all subjects used the auditory information to learn the timing of the movement then the KR may not have been used or processed. The second experiment eliminated the auditory information that had been available during acquisition of Experiment 1 to test this idea. The results did not support the hypothesis. Both observers performed similarly on all transfer tests showing no advantages of receiving KR during acquisition.

An alternate proposal for the failure of the processing hypothesis was that the lack of physical practice during the acquisition phase did not allow for processing of KR. As mentioned earlier, studies examining observational learning and KR have had physical practice interspersed with the observation trials (Doody et al., 1985; McCullagh & Caird, 1990; McCullagh et al., 1989). KR has been found to be an essential part of learning but one may need to physically practice in order to benefit from the information obtained from the KR. Perhaps KR effects occur only if one has the chance to utilize the KR with the movement to be performed. If this was the case, then all observers had equal ability to use the KR since they all received the same amount of physical practice trials. An investigation comparing observers that receive KR with or with out physical practice during acquisition may determine if physical practice effects the information obtained by KR.

A third possibility for the absence of KR effects on observation could be due to the complexity of the KR. Schmidt (1991) stated that there were four functions of KR. These were motivation, reinforcement, dependency and information. The function stressed in this experiment was information. The KR given in this experiment was the actual MT for each segment of the task performed by the subject. KR was given after each trial in ms. Perhaps this type of KR was too simple to enhance the performance of those observers that received KR. Perhaps all the observers understood what a ms was and they had the ability to process it even if they only received it on the transfer tests. If the same task was used but the KR given was transformed maybe the KR would be useful only the observers that received it during acquisition.

A final possibility to explain the lack of KR effects during observation could be that a novel transfer test was used in these experiments. Most studies have investigated observational learning effects by examining the performance of the same task that was practised during acquisition (Doody et al., 1985; McCullagh et al., unpublished; McCullagh & Little, 1989). In these experiments, none of the subjects, even the models, had actually physically practised the transfer tasks. Perhaps one needs to receive KR on the actual task to be performed in order to benefit from it. If a retention test of one of the variations was given, perhaps the KR effects would have occurred.

Despite the lack of KR effects the observers did learn the task. Even though the observers had not actually physically practised this task they performed similarly to the models and better than the control group on several transfer tests. Therefore, observational learning did provide an opportunity for the formation of a cognitive representation.

The present experiments results were interesting. Although they were not consistent with the current literature the second experiment did replicate the first. Observational learning was found to be a useful method to transmit information. Subjects who observed a model, and did not physically practice the skill, in some situations, performed as well as the models on the transfer tests. Although KR was stated to be a powerful component of learning, the present experiment did not find this to be true for transfer following observation. Perhaps KR cannot be used without physical practice. But, more than likely the KR given was utilized by all subjects and it was not complex enough to create KR effects. Observation alone was found to be a powerful method to promote learning, although future research should not underestimate the importance of KR. Auditory information should also not be misjudged when performing timing tasks for it was also found to be an important source of information during these experiments.

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Table 1. Summary of the Hypotheses of the Same-Phasing and Different-Phasing Transfer.

Performance on Same-Phasing Transfer

Representation Hypothesis		Processing Hypothesis	
Transfer without KR	Transfer with KR	Transfer without KR	Transfer with KR
KR = noKR > Con	KR =noKR =Con	KR =noKR = Con	KR >noKR = Con

Performance on Different-Phasing Transfer

Representation Hypothesis		Processing Hypothesis	
Transfer without KR	Transfer with KR	Transfer without KR	Transfer with KR
KR = noKR = Con	KR =noKR =Con	KR =noKR = Con	KR >noKR = Con

Table 2. Summary of the Testing Sequence for All Groups

1.[1]	Acquisition	72 Trials
2.	Same-Phasing Transfer (without KR)	18 Trials
3.	Same-Phasing Transfer (with KR)	18 Trials
4.	Different-Phasing Transfer (without KR)	18 Trials
5.	Different-Phasing Transfer (with KR)	18 Trials

[1] Only the learning models performed these trials. The observers watched videotapes of the models.

Table 3. Summary of the Details of Experimental Design: Absolute Movement Time and Overall Movement Times (in parenthesis)

Acquisition (Same-Phasing .22-.44-.33)

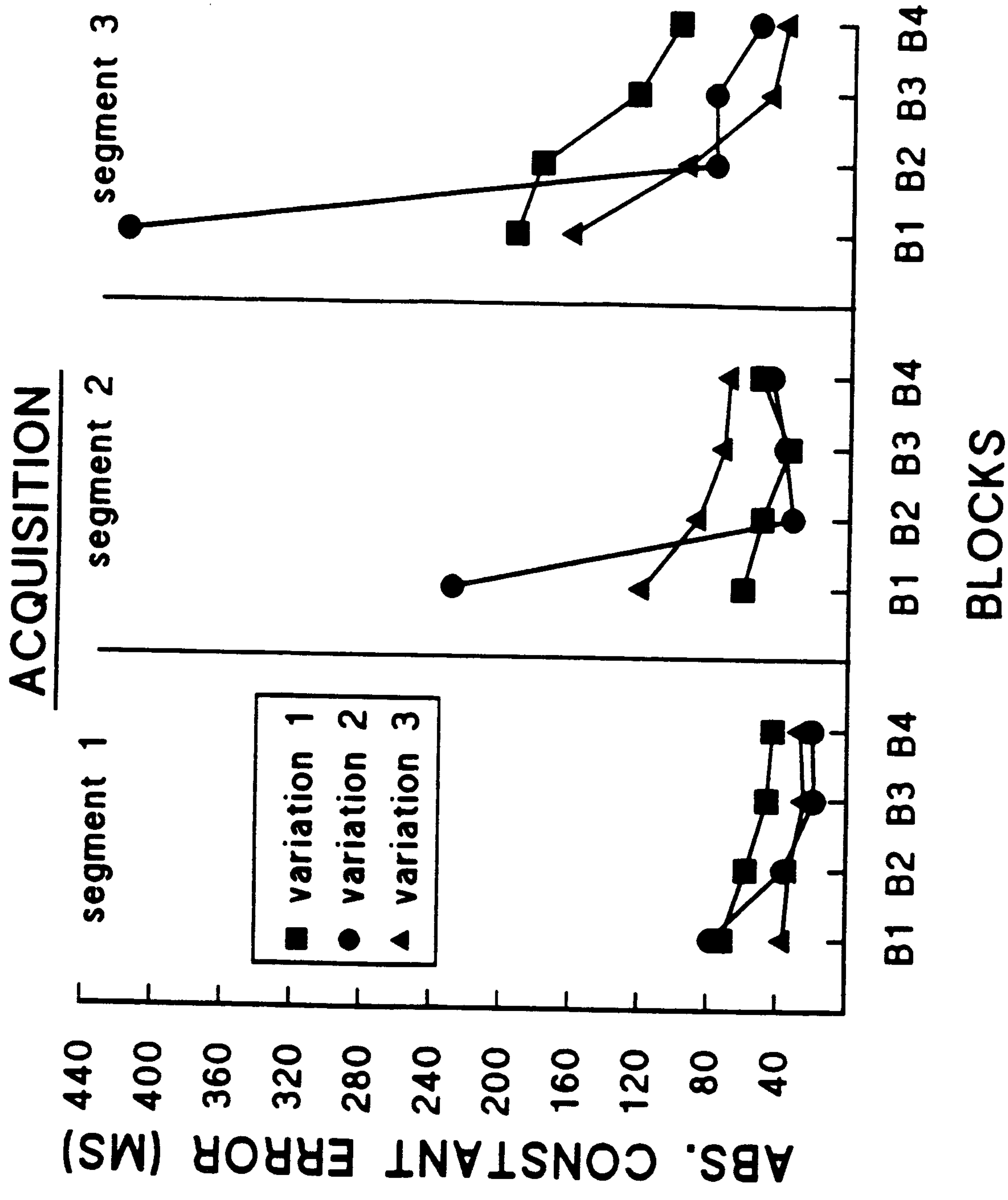
1. 150-300-225 (675 msec)
2. 200-400-300 (900 msec)
3. 250-500-375 (1125 msec)

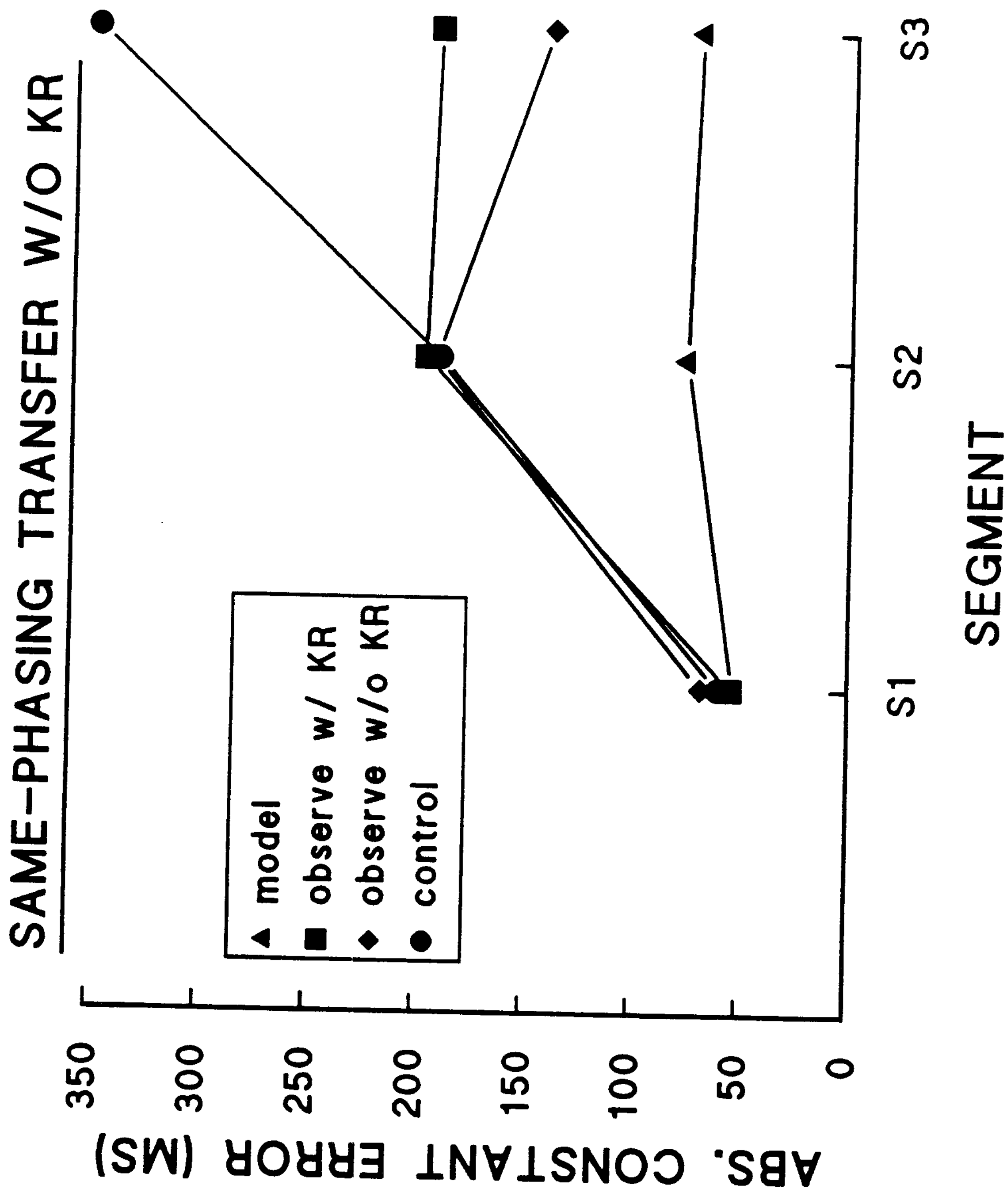
Transfer 1 (Same-Phasing .22-.44-.33)

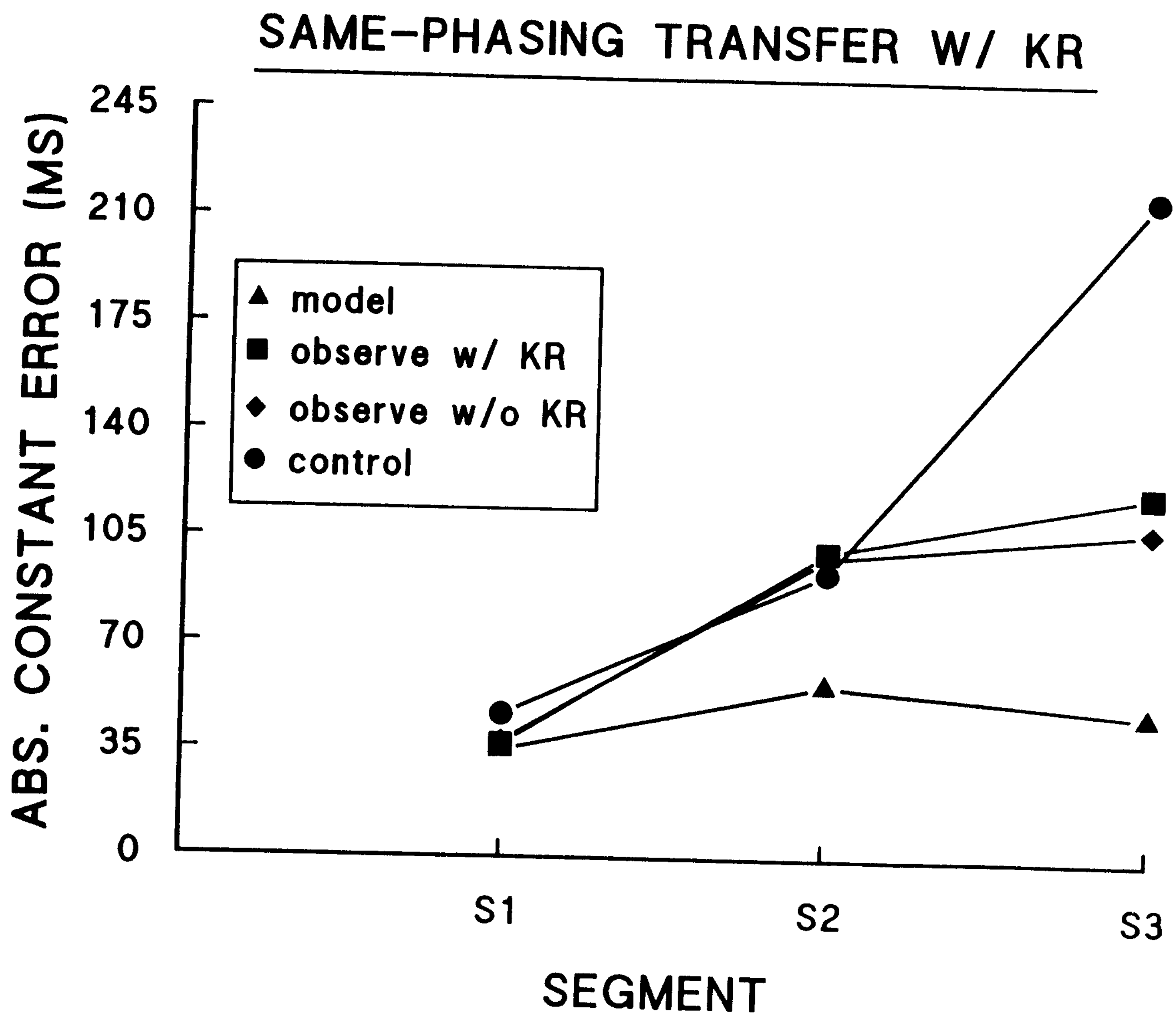
300-600-450 (1350 msec)

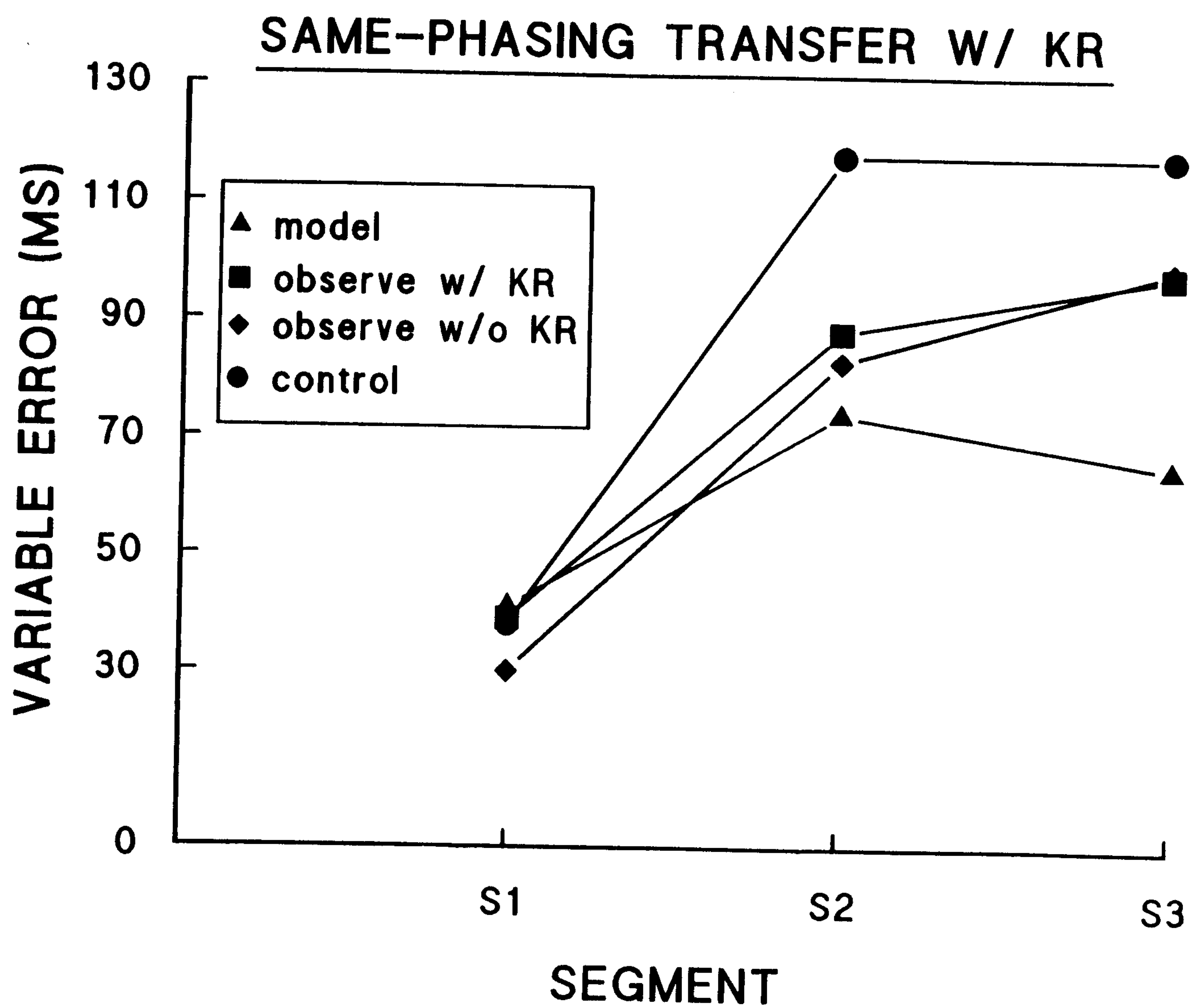
Transfer 2 (Different-Phasing .33-.22-.44)

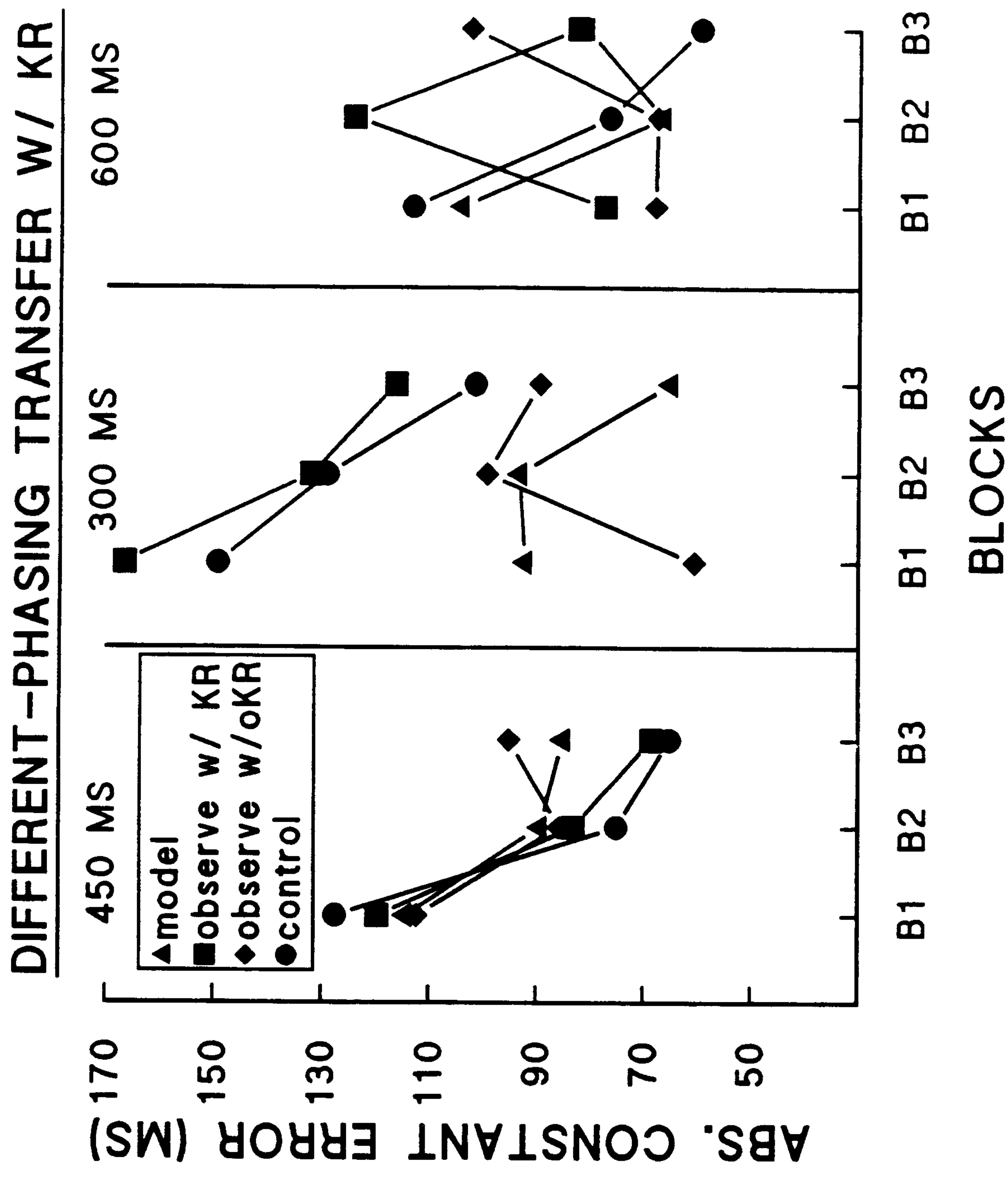
450-300-600 (1350 msec)

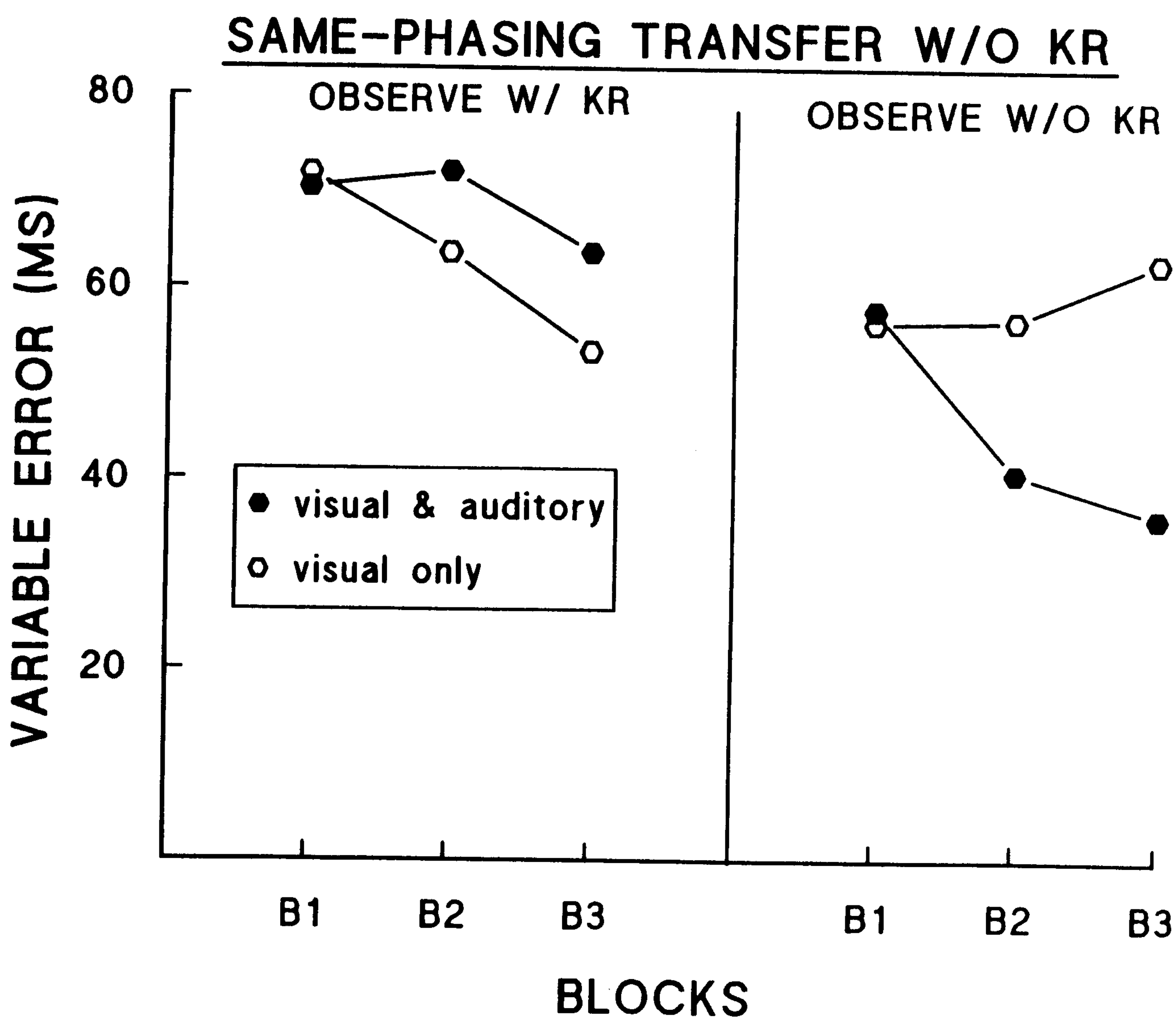

ACQUISITION
segment 1
segment 2
segment 3
variation 1
variation 2
variation 3
ABS. CONSTANT ERROR (MS)
440
400
360
320
280
240
200
160
120
80
40
B1 B2 B3 B4
B1 B2 B3 B4
B1 B2 B3 B4
BLOCKS

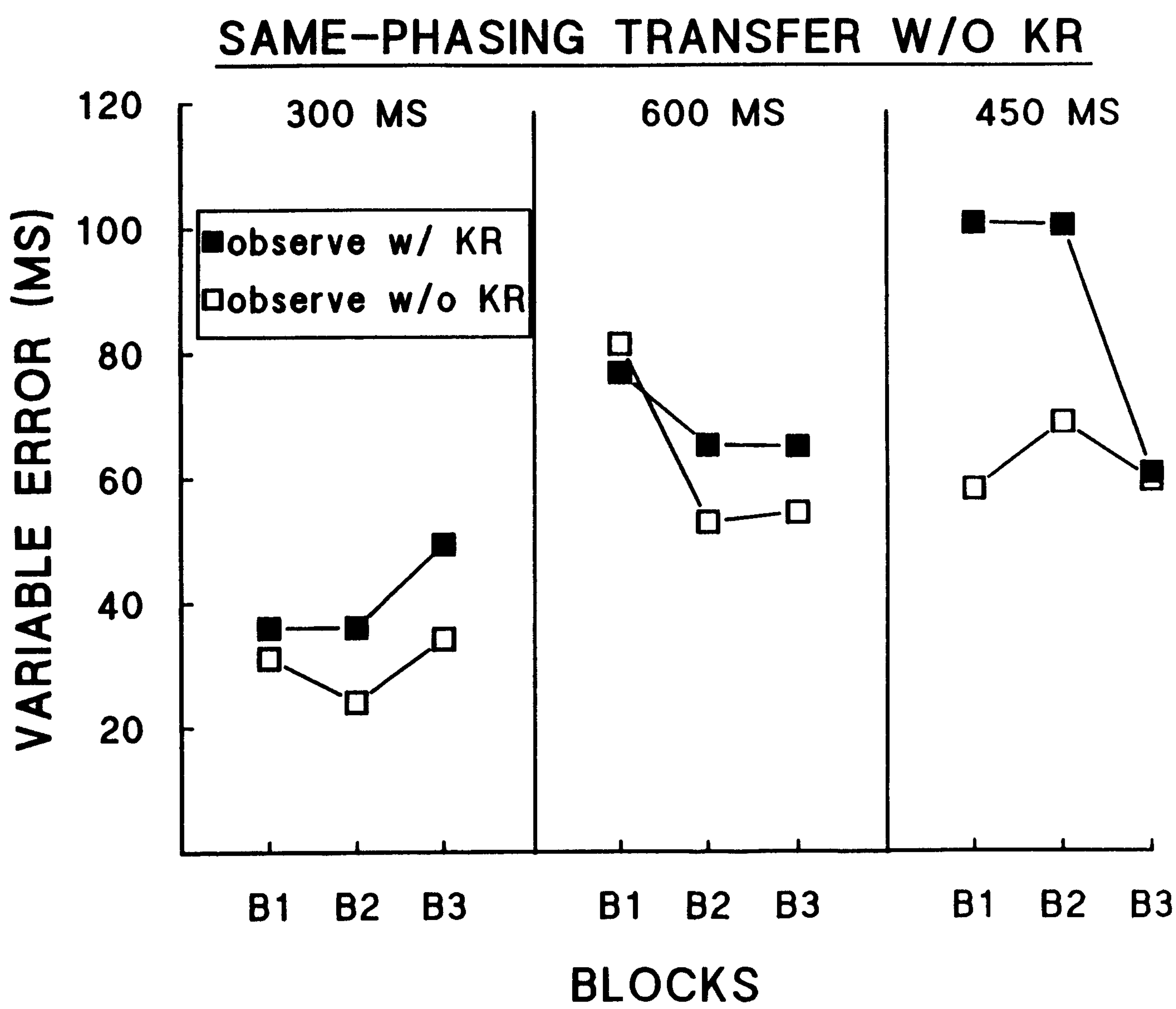

SAME-PHASING TRANSFER W/O KR
model
observe w/ KR
observe w/o KR
control
ABS. CONSTANT ERROR (MS)
350
300
250
200
150
100
50
0
S1
S2
S3
SEGMENT

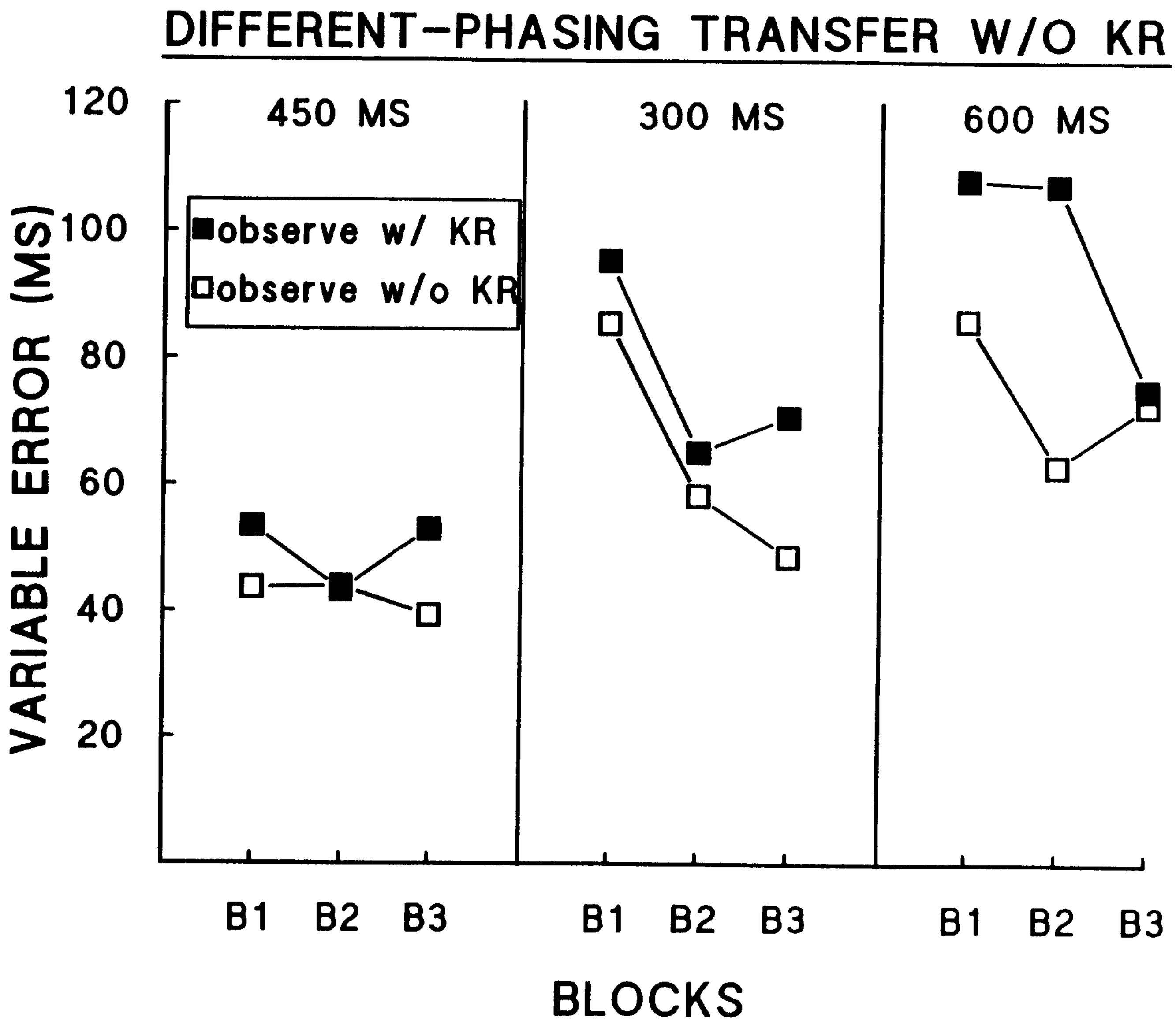

SAME-PHASING TRANSFER W/ KR
ABS. CONSTANT ERROR (MS)
245
210
175
140
105
70
35
0
model
observe w/ KR
observe w/o KR
control
S1
S2
S3
SEGMENT

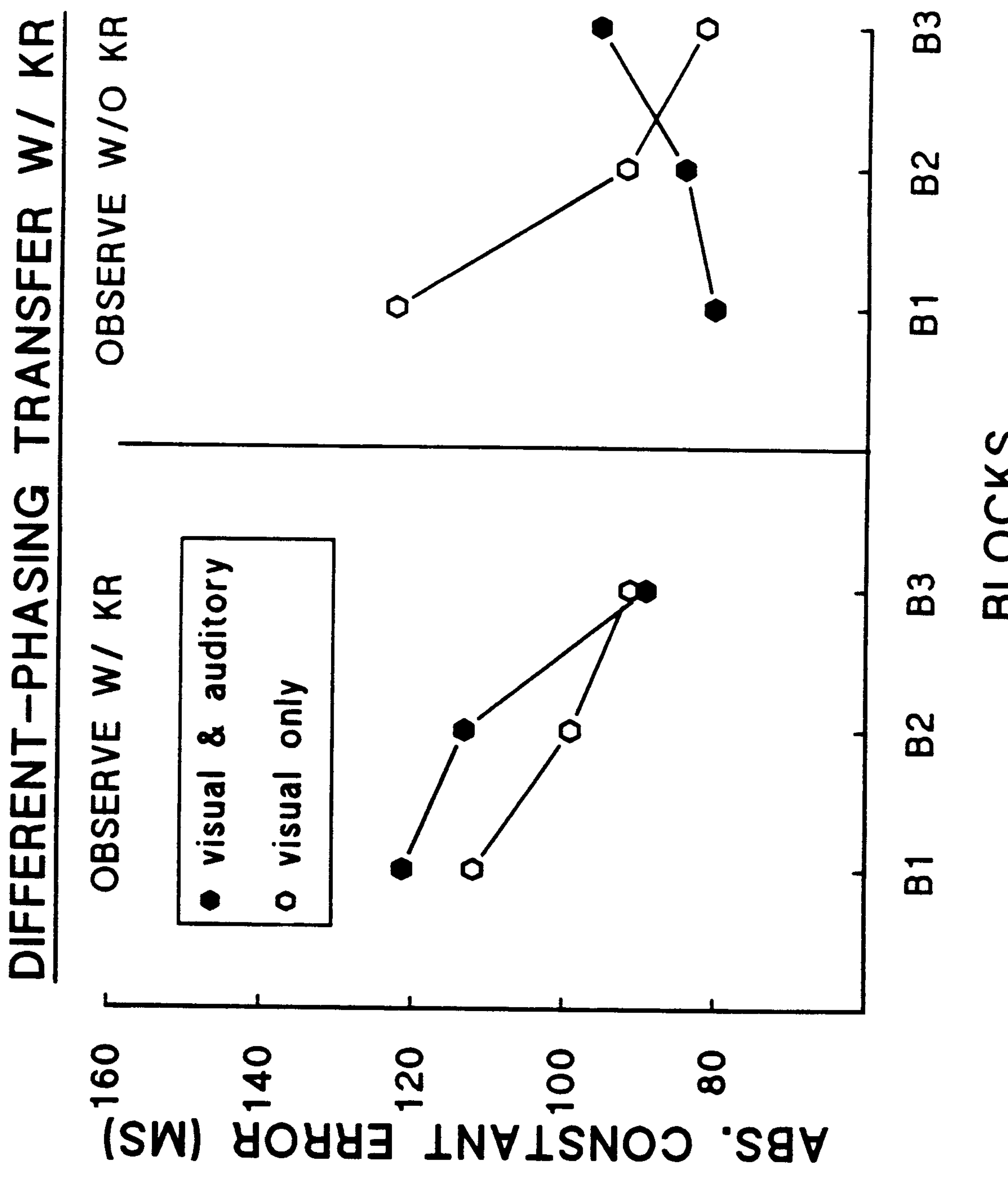

SAME-PHASING TRANSFER W/ KR
VARIABLE ERROR (MS)
130
110
90
70
50
30
0
model
observe w/ KR
observe w/o KR
control
S1
S2
S3
SEGMENT

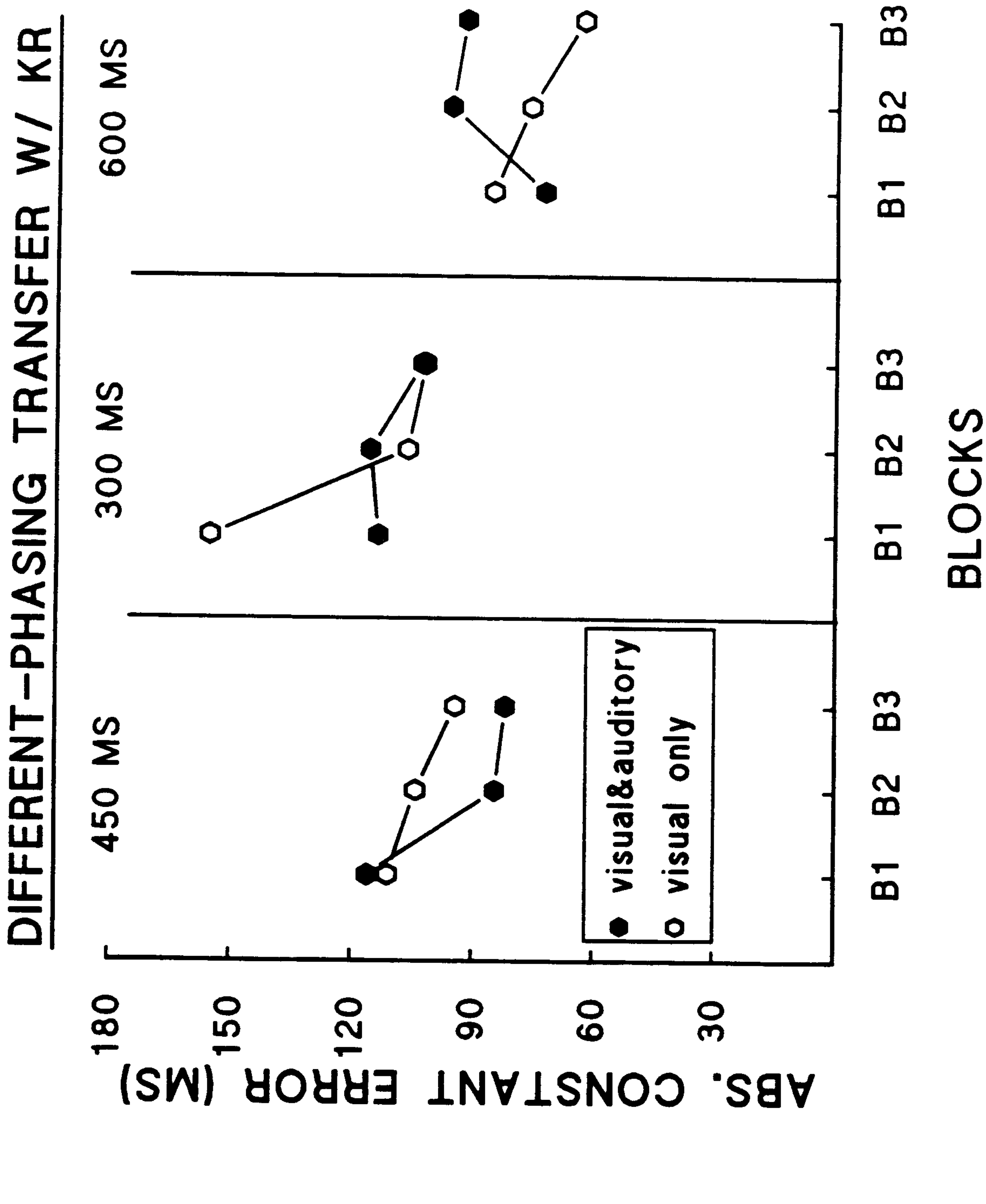

DIFFERENT-PHASING TRANSFER W/ KR
450 MS
300 MS
600 MS
model
observe w/ KR
observe w/oKR
control
ABS. CONSTANT ERROR (MS)
170
150
130
110
90
70
50
B1 B2 B3
B1 B2 B3
B1 B2 B3
BLOCKS

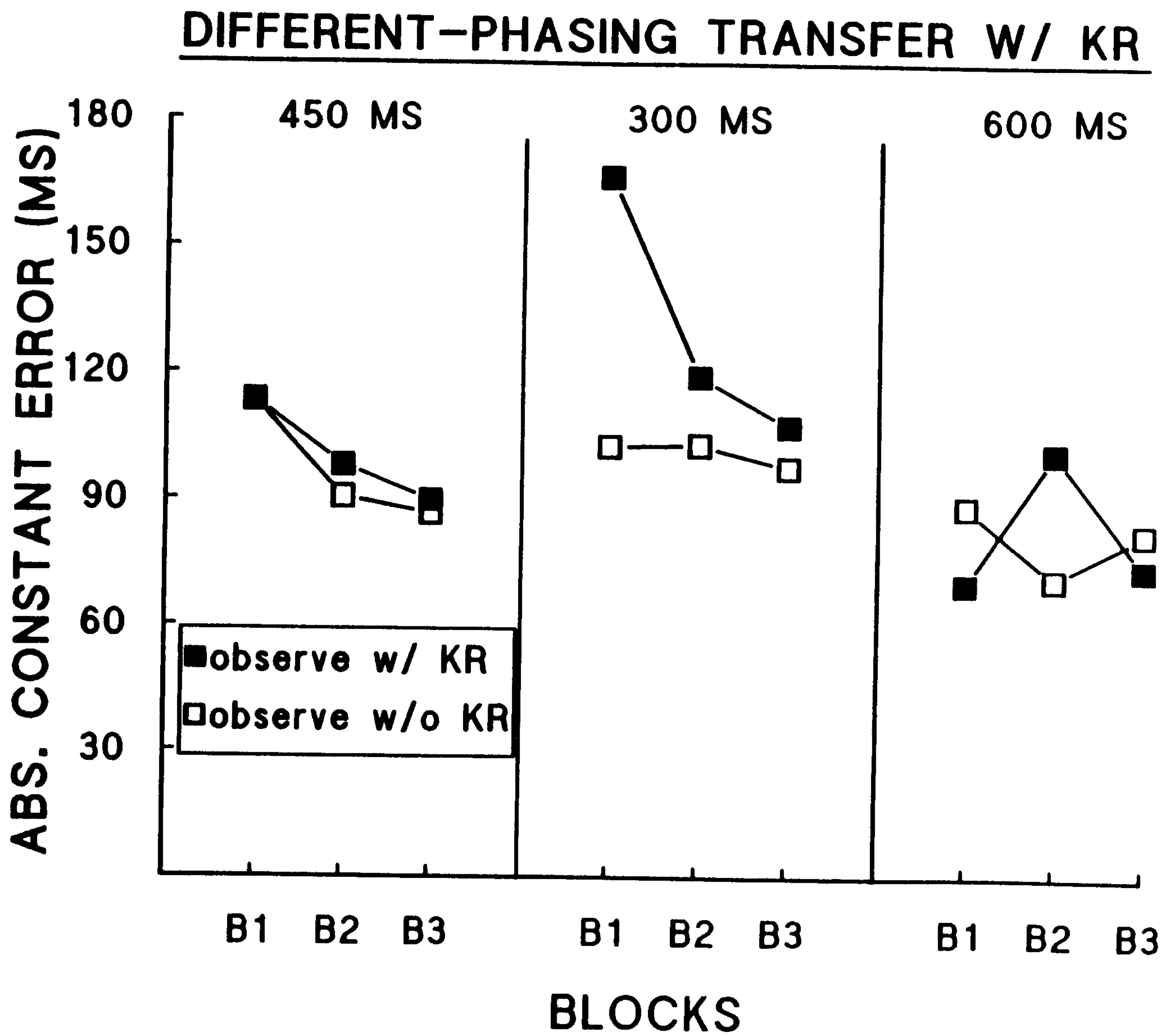

SAME-PHASING TRANSFER W/O KR
OBSERVE W/ KR
OBSERVE W/O KR
VARIABLE ERROR (MS)
80
60
40
20
visual & auditory
visual only
B1
B2
B3
B1
B2
B3
BLOCKS


SAME-PHASING TRANSFER W/O KR
300 MS
600 MS
450 MS
observe w/ KR
observe w/o KR
VARIABLE ERROR (MS)
120
100
80
60
40
20
B1 B2 B3
B1 B2 B3
B1 B2 B3
BLOCKS


DIFFERENT-PHASING TRANSFER W/O KR
VARIABLE ERROR (MS)
120
100
80
60
40
20
450 MS
300 MS
600 MS
observe w/ KR
observe w/o KR
B1
B2
B3
BLOCKS


DIFFERENT-PHASING TRANSFER W/ KR
OBSERVE W/ KR
OBSERVE W/O KR
visual & auditory
visual only
ABS. CONSTANT ERROR (MS)
160
140
120
100
80
B1
B2
B3
B1
B2
B3
BLOCKS


DIFFERENT-PHASING TRANSFER W/ KR
450 MS
300 MS
600 MS
ABS. CONSTANT ERROR (MS)
180
150
120
90
60
30
visual&auditory
visual only
B1 B2 B3
B1 B2 B3
B1 B2 B3
BLOCKS


DIFFERENT-PHASING TRANSFER W/ KR
450 MS
300 MS
600 MS
180
150
120
90
60
30
ABS. CONSTANT ERROR (MS)
observe w/ KR
observe w/o KR
B1 B2 B3
B1 B2 B3
B1 B2 B3
BLOCKS

APPENDIX A

ANOVA Tables

TABLE 4

Acquisition |CE|

Source	SS	df	F
Blocks/Subjects	819091.044	11	
Variation	51607.469	2	2.083
Error	272554.832	22	
Segment	597264.867	2	14.594 *
Error	450181.584	22	
Var x Seg	158411.490	4	7.572 *
Error	230119.396	44	
Block	735156.532	3	4.821 *
Error	1677480.420	33	
Var X Blk	444646.940	6	4.933 *
Error	991443.993	66	
Seg x Blk	299327.873	6	4.155 *
Error	792441.016	66	
Var x Seg x Blk	176067.826	12	3.060 *
Error	632847.899	132	
Total	8328642.660	431	

TABLE 5

Acquisition VE

Source	SS	df	F
Blocks/Subjects	125411.941	11	
Variation	64913.129	2	7.741 *
Error	92242.817	22	
Segment	215698.920	2	18.477 *
Error	128412.027	22	
Var x Seg	20513.704	4	3.092 *
Error	72990.014	44	
Block	81291.563	3	2.716
Error	329213.133	33	
Var x Blk	51027.889	6	1.898
Error	295664.159	66	
Seg x Blk	24436.209	6	.911
Error	295059.503	66	
Var x Seg x Blk	23971.111	12	1.099
Error	239975.182	132	
Total	2060821.270	431	

TABLE 6

Same-Phasing Transfer W/O KR |CE| (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	975480.733	3	2.722 *
Error	5256913.930	44	
Within Blocks/Subjects			
Segment	1362554.340	2	15.463 *
Grp x Seg	913667.291	6	3.456 *
Error	3877252.610	88	
Block	5946.243	2	.398
Grp x Blk	50910.000	6	1.136
Error	657131.330	88	
Seg x Blk	6571.037	4	.617
Grp x Seg x Blk	24234.993	12	.759
Error	468474.379	176	
Total	13599136.900	431	

TABLE 7

Same-Phasing Transfer W/O KR VE (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	57812.175	3	2.054
Error	412730.101	44	
Within Blocks/Subjects			
Segment	156651.673	2	38.161 *
Grp x Seg	23383.400	6	1.899
Error	180622.261	88	
Block	23828.284	2	8.320 *
Grp x Blk	4854.289	6	.565
Error	126014.760	88	
Seg x Blk	11095.382	4	2.641 *
Grp x Seg x Blk	13785.155	12	1.094
Error	1845882.126	176	
Total	1195659.610	431	

TABLE 8

Same-Phasing Transfer W/ KR |CE| (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	289747.615	3	4.649 *
Error	914142.832	44	
Within Blocks/Subjects			
Segment	515336.223	2	25.290 *
Grp x Seg	296649.500	6	4.853 *
Error	896605.836	88	
Block	116105.378	2	17.344 *
Grp x Blk	31523.008	6	1.57
Error	294555.838	88	
Seg x Blk	37299.109	4	3.540 *
Grp x Seg x Blk	44610.336	12	1.411
Error	2634.085	176	
Total	3900174.670	431	

TABLE 9

Same-Phasing Transfer W/ KR VE (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	53136.166	3	2.292
Error	339966.795	44	
Within Blocks/Subjects			
Segment	301532.309	2	54.003 *
Grp x Seg	38771.153	6	2.315 *
Error	245680.984	88	
Block	49053.976	2	4.330 *
Grp x Blk	30366.598	6	.893
Error	498509.205	88	
Seg x Blk	22091.374	4	2.411 *
Grp x Seg x Blk	39958.164	12	1.454
Error	403180.013	176	
Total	2022246.740	431	

TABLE 10

Different-Phasing Transfer W/O KR |CE| (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	134221.424	3	2.627
Error	749277.643	44	
Within Blocks/Subjetcs			
Segment	81911.420	2	2.809
Grp x Seg	240089.007	6	2.745 *
Error	1282829.800	88	
Block	5756.725	2	1.057
Grp x Blk	16171.644	6	.989
Error	239743.864	88	
Seg x Blk	16427.355	4	1.708
Grp x Seg x Blk	39984.214	12	1.386
Error	423194.853	176	
Total	3229607.950	431	

TABLE 11

Different-Phasing Transfer W/O KR VE (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	81068.711	3	2.966 *
Error	400823.211	44	
Within Blocks/Subjects			
Segment	183303.724	2	40.883 *
Grp x Seg	10496.017	6	.780
Error	197281.148	88	
Block	37377.598	2	10.711 *
Grp x Blk	8242.586	6	.787
Error	153544.703	88	
Seg x Blk	9438.637	4	2.223
Grp x Seg x Blk	8866.956	12	.696
Error	186798.186	176	
Total	1277241.480	431	

TABLE 12

Different-Phasing Transfer W/ KR |CE| (Expt. 1)

Source	SS	df	F
Between Blocks/Subjects			
Group	32751.283	3	.739
Error	650195.016	44	
Within Blocks/Subjects			
Segment	37765.787	2	2.283
Grp x Seg	63180.286	6	1.273
Error	727993.712	88	
Block	43949.095	2	10.490 *
Grp x Blk	50314.756	6	4.003 *
Error	184347.930	88	
Seg x Blk	20007.239	4	3.535 *
Grp x Seg x Blk	37257.797	12	2.194 *
Error	249064.505	176	
Total	2096827.410	431	

TABLE 13

Different-Phasing Transfer W/ KR VE (Expt. 1)

Source	SS	df	F
Between Blocks/ Subjects			
Group	26996.340	3	1.399
Error	283114.544	44	
Within Blocks/Subjects			
Segment	55279.170	2	11.271 *
Grp x Seg	15784.458	6	1.073
Error	215790.815	88	
Block	18886.392	2	5.233 *
Grp x Blk	20040.513	6	1.851
Error	158807.539	88	
Seg x Blk	6237.747	4	1.442
Grp x Seg x Blk	13511.125	12	1.041
Error	190308.683	176	
Total	1004757.330	431	

TABLE 14

Same-Phasing Transfer W/O KR |CE| (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	27664.017	1	.428
Feedback	10870.122	1	.168
Mod x Feed	65884.761	1	1.020
Error	2841547.150	44	
Within Blocks/Subjects			
Segment	1228584.480	2	21.900 *
Mod x Seg	12260.824	2	.219
Feed x Seg	918.691	2	.016
Mod x Feed x Seg	68089.526	2	1.214
Error	2468439.610	88	
Block	11023.201	2	.078
Mod x Blk	16387.242	2	1.052
Feed x Blk	14955.442	2	.960
Mod x Feed x Blk	9561.571	2	.614
Error	685214.989	88	
Seg x Blk	3210.926	4	.275
Mod x Seg x Blk	10929.188	4	.937
Feed x Seg x Blk	2727.771	4	.234
Mod x Feed x Seg x Blk	14062.148	4	1.205
Error	513381.500	176	
Total	8005713.160	431	

TABLE 15

Same-Phasing Transfer W/O KR VE (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	1744.036	1	.232
Feedback	21561.814	1	2.871
Mod x Feed	10325.335	1	1.375
Error	330433.110	44	
Within Blocks/Subjects			
Segment	123106.796	2	45.154 *
Mod x Seg	231.019	2	.085
Feed x Seg	6906.352	2	2.533
Mod x Feed x Seg	3190.540	2	1.170
Error	119959.777	88	
Block	7447.783	2	4.563 *
Mod x Blk	1191.060	2	.073
Feed x Blk	1855.560	2	1.137
Mod x Feed x Blk	7469.096	2	4.576 *
Error	71815.833	88	
Seg x Blk	24291.091	4	5.471 *
Mod x Seg x Blk	1413.427	4	.318
Feed x Seg x Blk	11901.065	4	2.681 *
Mod x Feed x Seg x Blk	1023.140	4	.230
Error	195348.613	176	
Total	941214.962	431	

TABLE 16

Same-Phasing Transfer W/ KR |CE| (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	296.678	1	.019
Feedback	574.085	1	.036
Mod x Feed	4206.257	1	.264
Error	701846.053	44	
Within Blocks/Subjects			
Segment	551843.204	2	29.969 *
Mod x Seg	23005.029	2	1.249
Feed x Seg	84.344	2	.005
Mod x Feed x Seg	2832.647	2	.154
Error	810208.113	88	
Block	131894.506	2	16.680 *
Mod x Blk	11344.197	2	1.435
Feed x Blk	5891.542	2	.745
Mod x Feed x Blk	764.032	2	.097
Error	347915.057	88	
Seg x Blk	53422.781	4	4.622 *
Mod x Seg x Blk	3001.600	4	.260
Feed x Seg x Blk	4866.114	4	.421
Mod x Feed x Seg x Blk	20578.893	4	1.780
Error	508572.609	176	
Total	3183147.740	431	

TABLE 17

Same-Phasing Transfer W/ KR VE (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	1955.000	1	.478
Feedback	2236.778	1	.547
Mod x Feed	32.783	1	.008
Error	179962.656	44	
Within Blocks/Subjects			
Segment	283893.460	2	84.587 *
Mod x Seg	3797.913	2	1.132
Feed x Seg	2131.912	2	.635
Mod x Feed x Seg	1769.900	2	.527
Error	147675.039	88	
Block	25779.017	2	5.555 *
Mod x Blk	1698.576	2	.366
Feed x Blk	342.242	2	.074
Mod x Feed x Blk	3555.347	2	.766
Error	204183.038	88	
Seg x Blk	7714.819	4	1.487
Mod x Seg x Blk	6568.945	4	.284
Feed x Seg x Blk	832.420	4	.160
Mod x Feed x Seg x Blk	2047.909	4	.395
Error	228315.681	176	
Total	1104493.440	431	

TABLE 18

Different-Phasing Transfer W/O KR |CE| (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	28942.816	1	1.131
Feedback	11203.711	1	.438
Mod x Feed	32102.256	1	.268
Error	1125827.850	44	
Within Blocks/Subjects			
Segment	142094.528	2	3.821 *
Mod x Seg	150032.071	2	4.035 *
Feed x Seg	5017.453	2	.135
Mod x Feed x Seg	44559.800	2	1.198
Error	1636141.710	88	
Block	22522.081	2	5.269 *
Mod x Blk	4864.131	2	1.138
Feed x Blk	332.461	2	.078
Mod x Feed x Blk	2059.793	2	.482
Error	188072.434	88	
Seg x Blk	25416.504	4	3.919 *
Mod x Seg x Blk	10734.809	4	1.655
Feed x Seg x Blk	5320.790	4	.820
Mod x Feed x Seg x Blk	7361.651	4	1.135
Error	285357.338	176	
Total	3727964.190	431	

TABLE 19

Different-Phasing Transfer W/O KR VE (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	4504.687	1	.623
Feedback	22721.502	1	3.140
Mod x Feed	11193.521	1	1.547
Error	318395.322	44	
Within Blocks/Subjects			
Segment	113958.763	2	30.334 *
Mod x Seg	9285.181	2	2.472
Feed x Seg	4397.181	2	1.170
Mod x Feed x Seg	1497.346	2	.399
Error	165299.925	88	
Block	28736.539	2	12.304 *
Mod x Blk	342.793	2	.147
Feed x Blk	334.479	2	.143
Mod x Feed x Blk	239.926	2	.103
Error	102765.370	88	
Seg x Blk	13275.655	4	3.665 *
Mod x Seg x Blk	1830.484	4	.505
Feed x Seg x Blk	13174.769	4	3.637 *
Mod x Feed x Seg x Blk	4018.356	4	1.109
Error	159385.631	176	
Total	975357.478	431	

TABLE 20

Different-Phasing Transfer W/ KR |CE| (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	657.906	1	.044
Feedback	14409.773	1	.965
Mod x Feed	9813.620	1	.657
Error	657171.323	44	
Within Blocks/Subjects			
Segment	87956.139	2	4.961 *
Mod x Seg	11492.786	2	.648
Feed x Seg	18388.204	2	1.037
Mod x Feed x Seg	24781.944	2	1.398
Error	780143.155	88	
Block	27776.556	2	5.316 *
Mod x Blk	10647.422	2	2.038
Feed x Blk	5576.203	2	1.067
Mod x Feed x Blk	20691.059	2	3.960 *
Error	229889.652	88	
Seg x Blk	17123.458	4	2.433 *
Mod x Seg x Blk	22643.950	4	3.217 *
Feed x Seg x Blk	31292.253	4	4.445 *
Mod x Feed x Seg x Blk	4692.154	4	.667
Error	309726.616	176	
Total	2284873.880	431	

TABLE 21

Different-Phasing Transfer W/ KR VE (Expt. 2)

Source	SS	df	F
Between Blocks/Subjects			
Modality	6.751	1	.001
Feedback	21140.012	1	3.997 *
Mod x Feed	4144.083	1	.783
Error	232741.071	44	
Within Blocks/Subjects			
Segment	35577.348	2	7.890 *
Mod x Seg	5551.542	2	1.231
Feed x Seg	1996.643	2	.443
Mod x Feed x Seg	4609.761	2	1.022
Error	198414.039	88	
Block	22520.016	2	6.305 *
Mod x Blk	1208.679	2	.338
Feed x Blk	10827.835	2	3.032
Mod x Feed x Blk	9054.596	2	2.535
Error	157155.539	88	
Seg x Blk	5277.803	4	1.100
Mod x Seg x Blk	7297.528	4	1.521
Feed x Seg x Blk	5538.010	4	1.154
Mod x Feed x Seg x Blk	5697.643	4	1.187
Error	211123.015	176	
Total	939881.915	431	