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HUMAN TIMING PERFORMANCE

A Dissertation Presented

by

HEATHER J. BARNES

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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Department of Psychology

HUMAN TIMING PREPARATION

A Dissertation Presented

by

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ABSTRACT

HUMAN TIMING PREPARATION

MAY 1992

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If a subject is involved in a task requiring strict temporal control and the timing demands of the task are going to change, the allocation of attention is crucial. In each experiment, subjects were required to perform a series of taps so as to produce one goal time and then tap so as to produce the same or another goal time.

Experiment 1 used a visual presentation of the stimuli. This presentation provided subjects with an implicit representation of the time intervals to be produced and an explicit representation of the serial position at which to switch from the first goal time to the second. The results indicated subjects had no problems switching from one goal time to the other at the correct serial position. However, tapping performance not only became more variable but performance virtually came to a halt when subjects changed from one goal time to another. One explanation is that subjects did not prepare for changes until the first interval following the required switch. A second is that the results were partly due to subjects trying to map the visual presentation of the stimuli to the times to be produced by tapping.

Experiments 2 and 3 used an auditory presentation of the stimuli to address these alternatives. This presentation provided subjects with an explicit representation of the time intervals to be produced and an implicit representation of the serial position at which to switch from one goal time to the other. The results of Experiment 2 indicated subjects did not always switch at the correct serial position. In Experiment 2, the sequence could not be hierarchically organized. However, the tapping sequence used Experiment 3 was hierarchically organized and subjects were instructed to use a counting strategy to aid in correct parsing of the sequence. However, the effect of switching at the wrong serial position was still present.

A model that relies on the intimate relationship of attention and timing control are presented. Further, the role of the representation of the task variables are addressed in relation to the parsing errors found in Experiments 2 and 3.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION

Timing is everything! In order to get the loudest laugh from the crowd, the comedian must give the punch line at just the right moment. In order to hit a home run in baseball, the batter must hit the ball at just the right time to maximize the forces that will carry the baseball over the fence. In order to perform a musical composition, the pianist must strike each piano key at just the right time to create the rhythm that distinguishes one composition from another. How is it that we are able to organize our actions to achieve such precise timing?

The answer to this question is efficient planning. The timing of our actions must be planned with utmost efficiency. The purpose of this research project was to examine the nature of the process which prepares the timing of actions. Specifically, what is the nature of the process which prepares the timing of sequenced finger tapping? Only a few researchers (Rosenbaum & Patashnik, 1980) have investigated the on-line preparation of timing. Thus, the project will add to the body of knowledge concerning temporal control of action. Also, the research project introduces a new paradigm with which to study timing control. This procedure is an adaptation of the movement precuing technique (Rosenbaum, 1980).

The Generalized Motor Program

In 1968 Keele described a motor program as "a set of muscle commands that are structured before a movement begins that allows the entire sequence to be carried out uninfluenced by peripheral feedback" (p. 387). Taken literally, Keele's definition is an extreme view in that it does not recognize any need for peripheral feedback. Certainly peripheral feedback plays a role in the fine tuning of an action. Thus, the generalized motor program is the accepted view of what a motor program represents. The generalized motor program is an abstract set of commands, prepared before a movement, with parameters that are specified on the basis of the task demands. Thus, a single generalized motor program can be used in a number of movement situations. This structure is analogous to a computer program. The computer program is developed from a general idea about a task to be accomplished. It consists of a list of commands with parameters (variables) that are specified with each execution. Similarly, the motor program is developed from an intention to carry out a movement. The motor program consists of a list of parameters that are specified during the response preparation stage each time a movement sequence is executed.

Underlying Parameters of the Generalized Motor Program

One concern for investigators is to identify the underlying parameters of the generalized motor program. This research suggests that timing is an underlying parameter in the motor program. Several techniques have been used to identify the parameters of the motor program. Early techniques relied on identifying invariant features of actions (Shaffer, 1980; Shapiro, 1977; Terzuolo & Viviani, 1979; 1980). Keele and his colleagues (Ivry & Keele, 1987; Keele & Ivry, 1987) investigated patients with neurological deficits. Correlational techniques with normal populations have also been used by Keele and his colleagues (Ivry & Keele, 1987; Keele & Ivry, 1987) to identify timing as an underlying parameter in the motor program.

Identifying invariant features of actions is a method used to investigate timing as an underlying parameter in the motor program (Carter & Shapiro, 1981; Shaffer, 1980; Shapiro, 1977; Terzuolo & Viviani 1979, 1980). Shapiro (1977) had subjects learn a wrist movement sequence comprised of nine movement segments. Different movement segments took a specified amount of time. The total time for the movement sequence was 1600 ms. After the subjects completed considerable practice, they were instructed to speed up the movement sequence while maintaining the pattern of movement times for each segment. The result was that the proportion of time for each segment relative to the total sequence time was the same for the learned and the speeded movement durations. In another study Shapiro (1978) used the same paradigm but also asked subjects to perform the movement sequence as quickly as possible ignoring the timing of the different segments. The striking result was that under these instructions, the proportion of time for each segment was identical to the previously described condition. Carter and Shapiro (1981) found that the phase relations of the muscles involved in these movement sequences, as measured by EMGs, was maintained as the overall duration of the movement sequence decreased. Other evidence suggesting that timing is an underlying parameter in the motor program has been found in typing, piano playing, and handwriting tasks (Terzuolo & Viviani, 1979; 1980; Shaffer, 1980).

Global timing adjustment is said to occur when the rate of a response sequence is adjusted in a uniform manner. Terzuolo and Viviani (1980) argued that rate changes occur through changes of the running speed of a central clock. Their arguments are based on findings of preserved relative timing in typing and handwriting. Investigating the interresponse intervals of successive keystrokes by professional typists, Terzuolo and Viviani (1979, 1980) found that the ratio of successive time intervals between keystrokes was independent of the speed at which the entire word was typed. Thus, changes in the speed at which the entire word is typed resembles a "stretching" of the overall duration.

Terzuolo and Viviani (1980) also used tangential velocity profiles to examine the timing patterns of handwriting. They observed that when there are changes in the size or the speed of writing, an invariant timing pattern is exhibited. Even though the overall duration of writing a letter decreases, the ratio of successive handwriting stroke durations within the letter remains constant. Similar results have been reported by Shaffer (1980) for typing and piano playing. In general, the results are taken as evidence of global timing control of movement sequences (but see Gentner 1982, 1987).

Keele and his colleagues (Ivry & Keele, 1987; Keele & Ivry, 1987) have advanced the notion that timing is an underlying parameter of the generalized motor program by investigating patients with neurological deficits. These researchers proposed a model in which various parameters of the motor program are computed in different areas of the brain, then the results of the computations are sent to the motor cortex to be integrated for movement execution. For example, suppose the motor cortex sends a signal to initiate a keypress. In turn, this signal initiates the processes determining the next response. One of these processes is determining the timing of the next response. Another process is computing the force with which to perform the movement. Once these processes are completed, the various computations are returned to the motor cortex and the next response is triggered. Keele and his colleagues (Ivry & Keele, 1987; Keele & Ivry, 1987) used two approaches in testing patients with neurological disorders to investigate the validity of a central timing mechanism: case studies and between-group comparisons. Summarizing the results from the case studies allows for examination of neurological damage that affects central timing control. Peripheral nerve damage resulted in deficits in motor implementation, Parkinson's disease (basal ganglia dysfunction) resulted in deficits in timing control, and cerebellar damage resulted in damage to both timing control and motor implementation.

Another approach used by Keele and his colleagues (Keele & Ivry, 1987; Ivry & Keele, 1987) to study patients with neurological deficits involves between-group comparisons. Keele and Ivry (1987) tested various groups of patients with neurological disorders and normal subjects using both production and perception tasks. The groups included cerebellar patients, Parkinsonians, cortical patients, peripheral neuropathy patients, sensory loss patients, and control subjects. The Parkinson's disease patients consisted of a group on their normal medication treatments and a group tested while on and off medication. Cortical patients had lesions that extended into the posterior region of the frontal lobe. Patients with peripheral nerve damage displayed impairment in hand coordination. The normal control subjects consisted of a group of college students and a group of elderly subjects above the age of 50 years.

Findings of the correlation techniques used to identify timing as an underlying parameter of the motor program indicate that the ability to regulate timing is correlated across different effectors. As Keele et. al. (1985) indicate, individuals who are good timers with one effector tend to be good timers with other effectors. This provides evidence for a central timekeeper: If each effector had to time independently, the correlation of timing regularity across effectors would not be expected. Another finding is that the ability to regulate timing in a motor production task is correlated both with the ability to regulate timing in a perceptual timing task and a speeded motor tapping task (tap as fast as possible). However, the ability to regulate timing in a speeded motor tapping task and a perceptual timing task are not correlated. The explanation for this finding can be seen in the components underlying the separate tasks. Possibly, the perceptual timing and the motor timing task are correlated because they share a common central timer. Likewise, the motor timing and the speeded motor task may be correlated because they share an underlying motor component. Since the perceptual timing task and the speeded motor task do not share either a common timekeeper or an underlying motor component, they are not correlated. Finally, the finding that timing and force are not correlated is taken as evidence that they are independently controlled. The argument for the existence of a timing mechanism used by the motor program is strengthened by the finding that motor timing regularity correlates with some tasks (duration perception and speeded motor) and not with others (force production). The results of the correlational techniques support the model proposed by Keele and his colleagues whereby timing is one of many parameters of the motor program that are specified separately and then integrated with other parameters for movement execution.

Movement Precuing Technique

Obtaining reaction times for movements has traditionally been used for investigating response preparation. One method is to obtain simple reaction times for movements which vary in complexity. When a constant movement is followed by various other movements or various types of movements, movement complexity is assumed to change. Thus, the time to respond to a stimulus in conditions where the first movement is constant is assumed to reflect the time to program the changing portions of the action. Generally, as the complexity of an action increases so does the reaction time to begin the action (Sternberg, Monsell, Knoll, & Wright, 1978). Thus, simple reaction time data provide information about how completely constructed motor programs are executed.

In order to investigate how motor programs are constructed, choice reaction time studies have been conducted. In this paradigm subjects are uncertain as to which of two or more responses will be required on each trial. The stimulus is used to tell the subject which response to perform. Thus, the reaction time is assumed to reflect the time to program the uncertain portion of the action. One limitation of using the choice reaction time paradigm deals with the possible interpretations of the results. One interpretation is that the subject has preprogrammed all of the possible motor programs which may be required. In this case the choice reaction time reflects the time to choose the correct motor program to be executed. Another interpretation is that there is a "skeleton" program with the known parameters specified and the uncertain parameters left unspecified. In this situation the choice reaction time reflects the time to specify the uncertain parameters (Klapp, 1978).

The movement precuing technique was developed to overcome the limitations of reaction time studies for investigating movement preparation (Rosenbaum, 1980). Experiments using the movement precuing technique provide the subject with partial information about one or more of the dimensions of an upcoming movement. An assumption of this technique is that the motor programming process can be decomposed into operations for specifying each parameter of the upcoming movement. Thus, providing information about specific dimensions of a movement allows the experimenter to infer that the reaction time reflects the time needed to specify the parameters which were not precued. Comparing different precue conditions allows investigators to examine the preparation time for specifying parameters for upcoming movements.

Several predictions can be made concerning reaction times under different movement precuing conditions. If specification of movement dimensions occur serially, reaction times should be additive as more dimensions need to be specified. Further, if reaction times are shortened for a particular precued dimension, x, only when a specific other dimension, y, is precued simultaneously, one can infer that there is a strict serial order in which the specification of movement dimensions must occur. In other words, y must be specified before x.

Another condition used in the movement precuing technique is an invalid movement precue condition. Here the precued dimension does not occur in the subsequent movement. The reaction time is usually lengthened compared to valid precue conditions. The lengthened reaction time suggests reprogramming of the correct dimension.

Rosenbaum (1980) originally used the movement precuing technique to investigate the preparation of an aimed hand movement. The three movement dimensions identified by

Rosenbaum were arm, direction, and extent (distance). The dimension of arm required specification of either the left or the right hand. The dimension of direction required specification of moving either toward or away from the body. The dimension of extent required specification of either a short movement distance or a long movement distance. Rosenbaum concluded that these movement dimensions are programmed independently. Further, he concluded that the time needed to specify each parameter is a function of the movement dimension being specified. Rosenbaum also concluded that while the order of specification is not fixed, specification of movement dimensions occurs serially.

Specification of the Timing Parameter

Only a few investigators (Rosenbaum & Patashnik, 1980) have studied the preparation of the timing parameter in the motor program. Rosenbaum and Patashnik (1980) examined the process of "setting" the timing parameter. In their experiments subjects pressed the left index finger followed by the right index finger to produce a target intertap interval. Subjects were required to minimize the time to begin the two-tap sequence. The subjects received feedback concerning the accuracy of the intertap interval in the form of a vertical line presented at the end of each trial. The length of the feedback line indicated the difference between the time of the actual intertap interval and the target interval. The direction of the feedback line indicated the direction of the timing error. The degree of accuracy required by the subjects varied. The "stringent" condition required greater accuracy compared to the "relaxed" condition. In the "stringent" condition small timing errors resulted in long feedback lines. In the "relaxed" condition small timing errors resulted in relatively short feedback lines. Earlier research (Wing, 1980) showed that as the interresponse interval increases, the variance of the interresponse time also increases. In the Rosenbaum and Patashnik experiment the variance of the intertap time was also found to increase as the interval increased. However, in the "stringent" condition, the variance increased at a lower rate than in the "relaxed" condition. Examining the reaction time data, Rosenbaum and Patashnik found that the reaction times in the "stringent" condition were longer than in the "relaxed" condition. Rosenbaum and Patashnik proposed that when it is time for a response to occur, a pulse is executed to trigger the response. The first pulse triggers the first response and the second pulse triggers the second response. An internal clock meters out the delay between the pulses. The reaction time to begin an interresponse time interval reflects the processes involved with setting the clock. The time needed to "set the clock" (or identify the trigger pulses) before the movement is inversely related to the variability of the selected pulses.

The Rosenbaum and Patashnik study is one method used to investigate the specification of the timing parameter in the motor program. A problem with the investigation of preparation of the underlying parameters of the motor program is that there is the artificial pressure of reaction time. The way a person plans a movement under the pressures associated with reaction time experiments may not be comparable to the way he or she plans a movement with no reaction time pressures. The paradigm used in this research project was designed to investigate the process of planning the timing of sequenced finger tapping without the pressures of reaction time.

CHAPTER 2

EXPERIMENT 1

The technique used in Experiment 1 required subjects to tap so as to produce one interresponse time and then to tap so as to produce the same or another interresponse time. Figure 1 illustrates the presentation of a trial in Experiment 1. The details of the procedure will be explained later. For now, it suffices to say that the lines representing the goal tapping times were presented to the subject on a computer screen. The line labelled (A), in Figure 1, represents the first goal tapping time. The line labelled (B) represents the second goal tapping time. As the subject tapped, the interresponse interval (IRI) was measured and the corresponding interresponse time was graphed on the computer screen (as a "*") in relation to the goal tapping time.

This procedure makes it possible to observe effects of anticipated timing changes in tapping performance. If a subject is engaged in a task involving strict temporal control and the timing demands of the task are going to change, there are several possibilities for specifying the timing parameter for the later portion of the task. One possibility is that, because the subject has information about the second goal tapping time before the task begins, he/she can use this information to prepare for the second goal time before any tapping takes place. A second possibility is that the subject holds the temporal information in memory and prepares the timing parameter during tapping at the first goal time. A third possibility is that the subject holds the temporal information in memory and prepares the timing parameter once tapping at the first goal time is completed. In the first two approaches, the subject uses information about the second goal tapping time before or during production of the intervals at the first goal time. In the last approach, the subject waits until the last possible moment to specify the timing parameter even though the information was available in advance. A final possibility is that the subject uses some combination of these approaches.

The primary aim of Experiment 1 was to investigate these alternatives. If the subject uses the advance timing information before tapping begins, this should be reflected in increased initiation times for conditions in which the first and the second goal times differ compared to the initiation times of conditions in which the first and second goal times are equal. If the subject acts on the advance timing information during tapping at the first goal time, this should increase the task demands which are typically reflected in the mean, standard deviation, and/or the coefficient of variation (sd/mean) of the IRIs. Thus, acting on the advance timing information during tapping at the first goal time should result in increases in mean, standard deviation, and/or the coefficient of variation at the first goal time. Finally, if the subject acts on the advance timing information once tapping at the first goal time is completed, this should also increase the task demands. However, the increased task demands should be reflected once tapping at the first goal time is completed. Thus, changes in performance should be expected in the last IRI at the first goal time and/or the first IRI at the second goal time.

By varying the number of taps at the first goal tapping time, we can examine how the "clock setting" process is affected by varying levels of task demand. If there are only a few number of taps at the first goal tapping time, there is not much time provided for the subject to act on the advance timing information. On the other hand, if there are a large number of taps at the first goal time, this gives the subject more time to act on the advance information.

Method

Subjects

Four right handed volunteers from the University of Massachusetts at Worcester served as subjects. Three subjects were female; one was male. The ages ranged from 28 to 35 years. Subjects were not paid for their participation. Each subject read and signed an informed consent form.

Apparatus

The subject sat in a private testing room facing a Zenith 386 computer. Tapping responses were made by pressing the "0" key on the computer keyboard number pad. The experiment was controlled by a Turbo Basic computer program.

Procedure

The task involved performing manual responses (right index finger tapping) at different tapping rates. Three goal intervals, I^*, were used: 150, 200, and 400 ms. In a trial, the subject was required to tap so as to produce one of the goal intervals, I_1^*, and then tap so as to produce the same or another goal interval, I_2^*. The conditions were formed by crossing I_1^* and I_2^* in all possible ways. The I_1^* x I_2^* conditions were 150 x 150, 150 x 200, 150 x 400, 200 x 150, 200 x 200, 200 x 400, 400 x 150, 400 x 200, 400 x 400 ms. The numerical values of I_1^* and I_2^* were not revealed to subjects. Instead, the values were referred to as the "fast", "medium", and "slow" times. The subject either produced $n_1 = 4$ or $n_1 = 12$ intervals at I_1^*, tapping 5 or 13 times, respectively. Then the subject immediately produced $n_2 = 15$ intervals at I_2^*, tapping 15 times. Figure 2 gives an example of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^*. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject is labelled according to its serial position within I_1^*, (A), or I_2^*, (B). The first tap produced by the subject marked the beginning of the interval A(1). The fifth tap produced by the subject (when n_1 equalled 4) marked the end of interval A(4) as well as the beginning of the first interval at I_2^*, interval B(1). In this example, the final tap produced by the subject marked the end of interval B(4).

I_1^* and I_2^* were presented to the subject as horizontal lines on the computer screen (see Figure 1). The "fast" time was always represented on line number six of the computer screen (approximately 5 cm from the top of the screen), the "medium" time was always represented on line number 12 of the computer screen (approximately 10 cm from the top of the screen), and the "slow" time was always represented on line number 18 of the computer screen (approximately 15 cm from the top of the screen). The line representing I_1^* is labeled "A" in Figure 1 and the line representing I_2^* is labeled "B". The hash marks represent the number of taps which the subject was to perform. Thus, if n_1 equalled 4 (as in Figure 1), four hash marks appeared on the line representing I_1^*. Likewise, if n_1 equalled 12, 12 hash marks appeared on the line representing I_1^*. Overlaying the last hash mark before the required switch to I_2^* was a vertical line extending the entire length of the screen. The purpose of the long vertical line was to ensure that the subject knew he/she should switch to I_2^*. Fifteen hash marks always appeared on the line representing I_2^*.

As the subject tapped, the interval, I, between each tap was measured to the nearest millisecond. Immediately after the registration of each I, an asterisk was presented on the computer screen. The height, Y(I), of the asterisk was based on the following formula:

$$Y(I) = L + (((I - I^*) / I^*) * 100) / 10 \tag{1}$$

where Y(I) was the line number corresponding to the line on the computer screen on which the "*" was graphed, L was the goal vertical position, I was the observed interresponse time, and I^* was the goal tapping interval. Based on this formula, intervals shorter than I^* appeared as a "*" above the goal tapping line, intervals longer than I^* appeared as a "*" below the goal tapping line, and intervals within ± 10% of the goal tapping time appeared as a "*" on the line representing the goal tapping time (see Figure 1).

The subject began tapping when he/she was ready. There was no reaction time pressure. At the end of each trial, the screen remained visible so the subject could inspect his/her performance (see Figure 1). On the right side of the screen, the subject also received feedback in the form of the percentage of taps in which the "*" fell on the goal tapping lines for that trial and for all previous trials in that block. Thus, as seen in Figure 1, which illustrates feedback after three trials, on the first trial 20% of the asterisks fell on the goal tapping lines, on the second trial 40% of the asterisks fell on the goal tapping lines, and on the third trial (the trial for which the "*" are displayed) 13% of the asterisks fell onthe goal tapping lines. When the subject was ready, he/she pressed the "ENTER" key to clear the screen and begin the next trial.

Each subject performed each condition 24 times. Within a block of trials, a subject was presented one repetition of each I_1^* x I_2^* x n_1 condition where I_1^* remained constant throughout a set of trials and I_2^* and n_1 were randomized. For example, in a block of trials, a subject was presented every combination of I_2^* and n_1 at I_1^* equalled 150 ms, followed by every combination of I_2^* and n_1 at I_1^* equalled 200 ms, followed by every combination of I_2^* and n_1 at I_1^* equalled 400 ms. Note that this is only an example. The order of presentation of I_1^*s was randomized.

The first session consisted of a guided introduction to the procedure, one practice trial, and 12 blocks of experimental trials. The first session lasted 1 hour. The length of the remaining sessions was left to the subject's discretion (in order to accommodate schedules). The subject could either choose to participate in 30 minute sessions in which 12 blocks of experimental trials were performed, or in 1 hour sessions in which 24 blocks of experimental trials were performed. Regardless of session length, all sessions were held on consecutive days.

Results

Overview

Four dependent measures were analyzed: mean initiation time, and for each produced interval, mean IRI, log standard deviation (log(sd)) (Myers & Well, 1991; Winer, 1971), and coefficient of variation (CV) (sd/mean). Mean initiation time was defined as the interval beginning with the presentation of the stimuli and ending with the first button press produced by the subject. Each subject began tapping when he/she was ready. Eventhough there was no reaction time pressure, the time subjects took to initiate a trial might yield interesting results regarding the preparation of timing sequences. The IRI was defined as the time between each response produced by the subject. The mean, log(sd), and CV of each IRI were calculated for each serial position for each condition for each subject. In the analyses to be discussed, the factor Block was used to examine learning effects. Block 1 represents the first 8 times subjects completed a particular condition, Block 2 represents the second 8 times subjects completed a particular condition, and Block 3 represents the final 8 times subjects completed a condition.

Thus, in each analysis the smallest cell was comprised of a mean, log(sd), or CV based on eight scores within each serial position. In order to make comparable contrasts among conditions, responses included in the analyses were restricted to those within an absolute distance, $|D|$ of 4 taps from the switch. Thus, $|D|$ equal 1 included the last response at I_1^* and the first response at I_2^*, $|D|$ equal 2 included the second to last response at I_1^* and the second response at I_2^*, and so forth. The signed distance of the tap, $\pm D$ (e.g., +1 or -2) identified the response as either a "preswitch tap" (minus distances) or a "postswitch tap" (positive distances). Because of the complexity of the design, alpha was set at $p < .01$ for each analysis.

Mean Initiation Time

The initiation times were analyzed using a block (1, 2, 3) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) analysis of variance (ANOVA). One interaction was significant: I_2^* x n_1, $F(2, 6) = 9.52$, $p < .01$. As seen in Figure 3, mean initiation times decreased as I_2^* increased. This effect was greatest when n_1 was 12. No other main effects and interactions were significant, $p > .90$. The summary table for this analysis is provided in Appendix A.1.

Mean Interresponse Interval

Mean IRIs were analyzed with an ANOVA that evaluated the effects of block (1, 2, 3) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) x $|D|$ (1, 2, 3, 4) x $\pm D$ (preswitch, postswitch). Several effects and interactions were significant. Block was not significant and did not interact with any other variables. Thus, for further analyses the data were collapsed over block. The summary table for this analysis is provided in Appendix A.2.

In order to examine changes in performance that might reflect timing preparation of I_2^*, it was necessary to use those trials which represented each subject's best performance. Best performance was defined as trials in which nonboundary intervals fell within ±35% of the I^*. Nonboundary intervals included IRIs which did not surround the required switch. Thus, the first, second, and third intervals at I_1^*, A(1), A(2), A(3), and the second, third and fourth intervals at I_2^*, B(2), B(3), and B(4) comprised the nonboundary intervals of each I^*. Recognizing the previous finding in the literature that the variance of an IRI increases with the mean of the interval, a percentage of I^* as opposed to a constant value was used to trim the data. Thirty-five percent of each I^* was chosen as the criterion with which to trim the data in order to maintain a reasonable tradeoff of accuracy required by the subject and the number of untrimmed trials. Using a percentage lower than 35% (increased accuracy required by the subject) resulted in more than 50% of the data being trimmed. Using a percentage higher than 35% (decreased accuracy required by the subject) resulted in an unsatisfactory accuracy requirement on the part of the subject. Table 1 provides the actual values used to trim the data for each I^*.

The trimming procedure was to discard a trial if the produced IRI at any nonboundary interval fell outside the ±35% range. Thus, if one IRI fell outside the range, the entire trial was discarded. Trimming the data with this procedure left unequal cell sizes for each condition for each subject. The actual number of untrimmed observations for each cell for each subject is provided in Appendix A.3.

Using the mean IRIs calculated from the data trimmed for best trials, an ANOVA was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) x $|D|$ (1, 2, 3) x $\pm D$ (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.4.

The highest-order significant interactions were two three way interactions: I_1^* x $|D|$ x $\pm D$, $F(6, 18) = 5.00$, $p < .003$ and I_2^* x $|D|$ x $\pm D$, $F(6, 18) = 13.68$, $p < .0001$. Figure 4 illustrates the I_1^* x $|D|$ x $\pm D$ interaction. The left panel illustrates the mean IRIs at each serial position before the required switch, the vertical line shows the location of the required switch, and the right panel illustrates the mean IRIs at each serial position after the required switch. There are several results to note in this three-way interaction. The first is that mean IRIs approximated the respective I_1^*s of 150, 200 and 400 ms. The mean IRIs produced when I_1^* equalled 150, 200, and 400 ms were 152, 198, and 386 ms, respectively. The second result to note is that as the +D increased, mean IRIs converged toward the overall mean (of the I^*s) of 250 ms. Given that the data are collapsed over I_2^*, convergence is expected. The final result to note in this interaction is the increased mean IRI at the first interval after the required switch, interval B(1).

Figure 5 illustrates the I_2^* x |D| x ±D interaction. Again, the left panel illustrates the mean IRIs at each serial position before the required switch, the vertical line shows the location of the required switch, and the right panel illustrates the mean IRIs at each serial position after the required switch. There are several results to note in this interaction. The first is that mean IRIs before the required switch converged toward the overall mean of 250 ms. Given that the data are collapsed over I_1^*, convergence is expected. The second result to note is that mean IRIs approximated the respective I_2^*s of 150, 200 and 400 ms. The mean IRIs produced when I_2^* equalled 150 , 200, and 400 ms were 192, 242, and 404 ms, respectively. The final result to note is the increased mean IRIs at the first interval after the required switch, interval B(1).

Whereas the above results concerned the three-way interactions, several lower-order interactions and main effects were significant. The significant interaction of n_1 x |D|, $F(3, 6) = 26.27$, $p < .0001$ is shown in Figure 6. It appears that the increase in mean IRI at interval B(1) was due to those trials where n_1 equalled 4. Three additional two-way interactions were significant : I_1^* x ±D, $F(2, 6) = 435.50$, $p < .0001$; I_2^* x ±D, $F(2, 6) = 416.96$, $p < .0001$; and I_2^* x |D|, $F(6, 18) = 13.46$, $p < .0001$.

Two main effects were significant: I_1^*, $F(2,6) = 873.85$, $p < .0001$ and I_2^*, $F(2, 6) = 2233.57$, $p < .0001$. No other effects or interactions were significant, $p > .04$.

In sum, several noteworthy results emerged from the mean IRI data. First, mean IRIs approximated the respective I_1^*s and I_2^*s of 150, 200, and 400 ms. Second, mean IRIs at interval B(1) were elevated. Third, the increased mean IRIs at interval B(1) were due to those trials in which n_1 equalled 4.

Log Standard Deviation

Log(sd) was studied with an ANOVA that evaluated the effects of block (1, 2, 3) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis is provided in Appendix A.5.

The factor of block was involved in a five way interaction with I_1^*, I_2^*, n_1, and |D|, F(24,72) = 2.19, $p < .005$. There were several patterns in this interaction that emerged as block increased from 1 to 3. First, when I_1^* and I_2^* differed, log(sd)s were higher than conditions in which I_1^* and I_2^* were equal. This difference was greatest just prior to and immediately following the required switch. The second emergent pattern was that when I_1^* and I_2^* differed, log(sd)s were higher just prior to and immediately following the required switch than at those intervals 2 and 3 taps away from the required switch, the nonboundary intervals. Also, the patterns were less variable when n_1 was 12 than when it was 4.

In order to examine changes in tapping performance that might reflect timing preparation of I_2^*, log(sd)s were calculated for the data trimmed for best trials. This was data in which IRIs produced in nonboundary intervals fell within ±35% of the I^*s. An analysis was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n1 (4, 12) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis is provided in Appendix A.6.

The highest-order significant interaction was the three-way interaction of I_1^* x I_2^* x |D|, F(12, 36) = 3.46, $p < .001$. Figure 7 illustrates this interaction. In each graph I_1^* is constant. For example, the first graph shows the 150 x 150, 150 x 200, and 150 x 400 ms conditions. There are two results to note in this interaction. The first is the dramatic increase in mean log(sd)s when |D| equalled 1. The second noteworthy result is that when |D| equalled 1, the log(sd)s were higher when I_1^* and I_2^* differed than when I_1^* and I_2^* were equal.

Whereas the above results concerned the three-way interaction, several lower-order interactions and main effects were significant. One two-way interaction was significant: |D| x ±D, F(3, 9) = 9.93, $p < .003$. Figure 8 illustrates this interaction. Note the increasedvalue of mean log(sd) at the first interval after the required switch, interval B(1).

The main effect of ±D was significant, F(1, 3) = 38.11, $p < .008$. No other main effects or interactions were significant, $p < .02$.

In sum, there are several noteworthy results that emerged from the log(sd) data trimmed for best trials at nonboundary intervals. The first is the increased value of mean log(sd) when $|D|$ equalled 1. The second is that at $|D| = 1$, log(sd)s were higher when I_1^* and I_2^* differed than when I_1^* and I_2^* were equal. The third important result is the general increase in mean log(sd) at interval B(1).

Coefficient of Variation

The coefficient of variation (CV) data were analyzed using an ANOVA that evaluated the effects of block (1, 2, 3) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) x $|D|$ (1, 2, 3, 4) x $\pm D$ (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis appears in Appendix A.7.

The highest-order significant interaction was the five-way interaction of block, I_1^*, I_2^*, n_1, and $|D|$, $F(24,72) = 2.10$, $p < .008$. The main result of this interaction was the emerging pattern of increased CVs at $|D|$ equalled 1. When I_1^* and I_2^* differed, CVs were higher than when I_1^* and I_2^* were equal. This difference was largest at $|D| = 1$. Also, when I_1^* and I_2^* differed, CVs were higher at $|D| = 1$ than at $|D| = 2$. As block increased from 1 to 3, these patterns became more evident. Also, the pattern of slowing was less variable when the number of preswitch taps was 12 than when it was 4.

In order to examine changes in tapping performance that might reflect timing preparation of I_2^*, CVs were calculated for the data trimmed for best trials. These data included trials in which IRI produced at nonboundary intervals fell within ±35% of the I^*s. An ANOVA was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x n_1 (4, 12) x $|D|$ (1, 2, 3) x $\pm D$ (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis is provided in Appendix A.8.

The highest-order significant interaction was the four-way interaction of I_2^*, n_1, $|D|$, and $\pm D$, $F(6, 18)$, $p < .007$. Figure 9 illustrates this interaction. In each graph I_2^* is constant. The left panels illustrate the mean CVs at each serial position before the required switch, the vertical lines show the location of the required switch, and the right panels illustrate the mean CVs at each serial position after the required switch. The result to note is the increase in mean CVs at the first interval after the required switch, interval B(1).

The two-way interaction, |D| x ±D, was significant, $F(3, 9) = 13.09$, $p < .001$. The pattern of this interaction has been discussed in the context of the higher-order interaction. No other effects or interactions were significant, $p > .03$.

Discussion

Experiment 1 was designed to investigate the processes underlying the preparation of the timing of sequenced finger tapping. The question was how the "clock setting" process is affected by the simultaneous performance of a task requiring strict temporal control. Mean initiation times suggested that there were two effects taking place. First, it took longer to prepare 12 responses than it did to prepare 4 responses. This result is consistent with the length effects found in reaction time experiments reported by Sternberg, Monsell, Knoll, & Wright, 1978. Second, initiation times were shortest when I_1^* was the longest (400 ms) and when n_1 was the greatest (12 taps). This result suggested that the system is capable of simultaneously preparing for an action and executing an action. Of course, when the system is simultaneously involved in preparation and execution, the task demands are greater than when the system is involved in only preparation or execution. It appears that in Experiment 1 the system took advantage of this capability of simultaneously preparing and executing an action when I_1^* was the longest (400 ms) and when n_1 was the greatest (12 taps). The question arises, when did subjects act on the advance timing information?

Changes in task demands are reflected through changes in performance. Thus, changes in tapping performance might reflect the preparation of I_2^*. There was a dramatic increase in the mean IRI at the first interval following the required switch, interval B(1). This increase in mean IRI was accompanied by similar increases in log(sd) and CV. What was the cause of this effect? A possible hypothesis is that a constant amount of time is needed to switch from I_1^* to I_2^*. According to this <u>constant preparation-time</u> model, if the switching time exceeds I_2^* and the switch from I_1^* to I_2^* does not begin until tapping at I_1^* is completed, this results in the mean IRI at B(1) being longer than I_2^*.

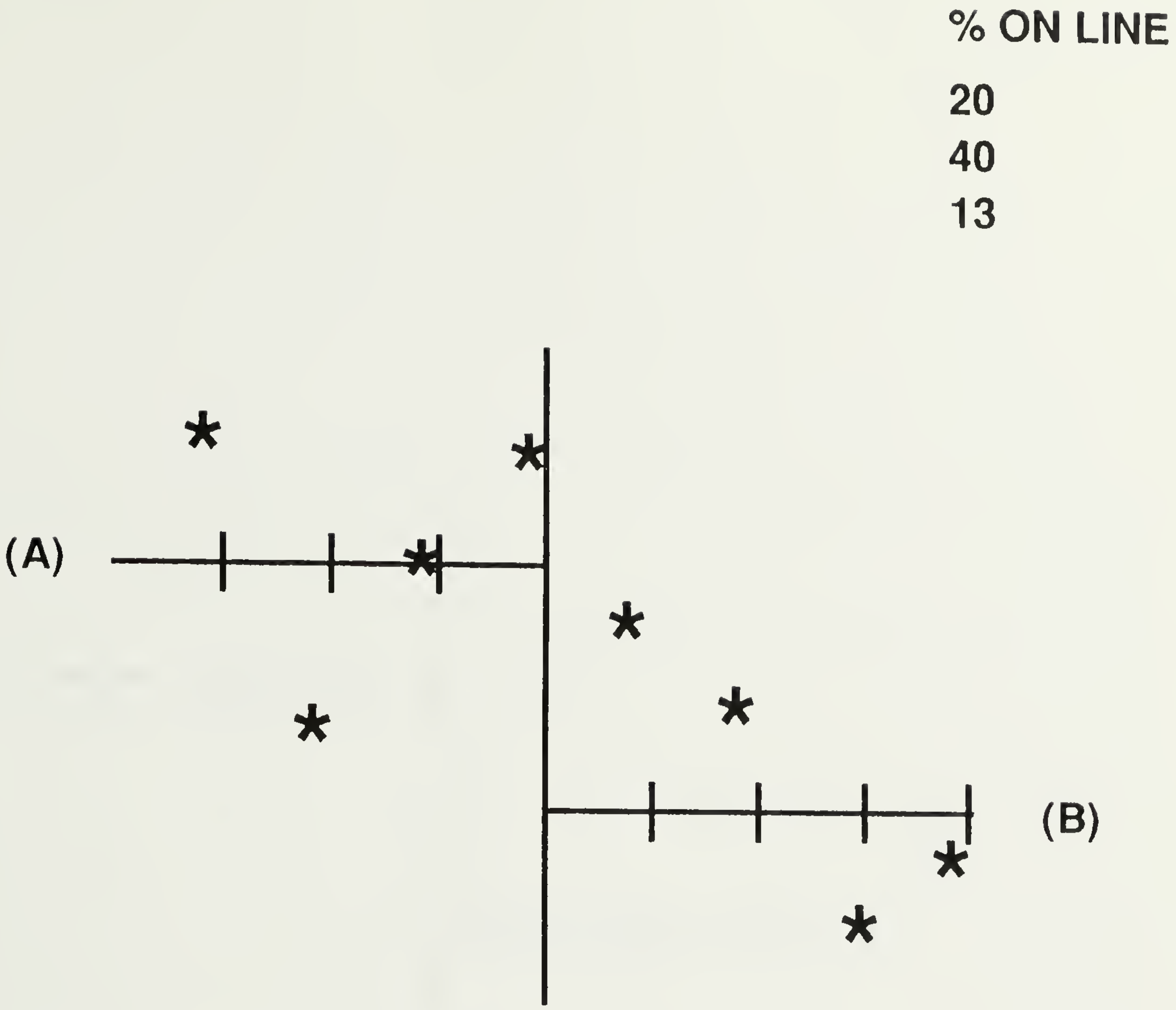

Figure 1. Example of presentation of first and second goal tapping times in Experiment 1. (A) represents the first goal tapping time. (B) represents the second goal tapping time. As the subject taps, interresponse intervals were measured and the corresponding interresponse times were graphed (*) on the screen at a distance from the line proportional to the goal tapping time. Interresponse time is represented on the ordinate. Sample number is represented on the abscissa. The subject also received feedback in the form of the percentage of taps in which the "*" fell on the goal tapping lines. See text for an explanation.

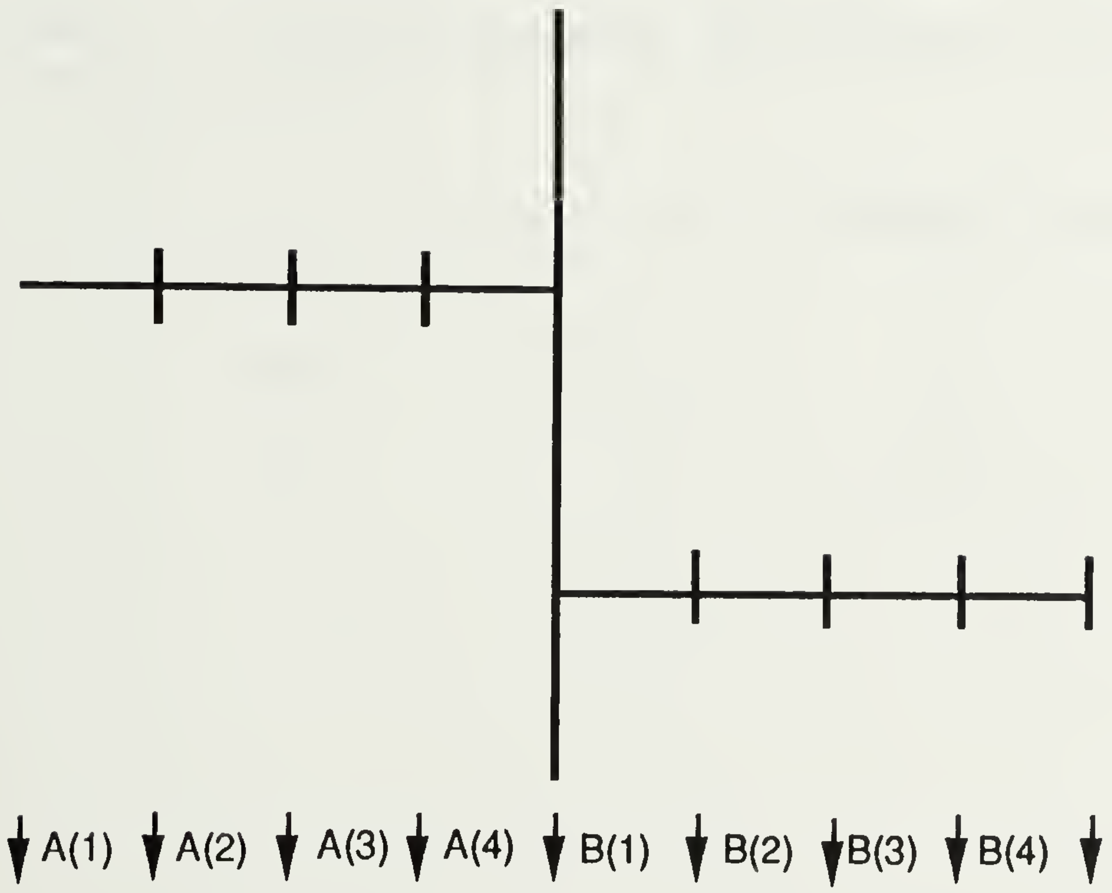

Figure 2. Example of the presentation of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^*. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject Is labelled according to its serial position within I_1^* (A) or I_2^* (B).

Table 1. The actual values (in ms) used to trim the data for each I^* using 35% trimming criterion for Experiment 1.

I^*	LOWER LIMIT	UPPER LIMIT
150	97	203
200	130	270
400	260	540

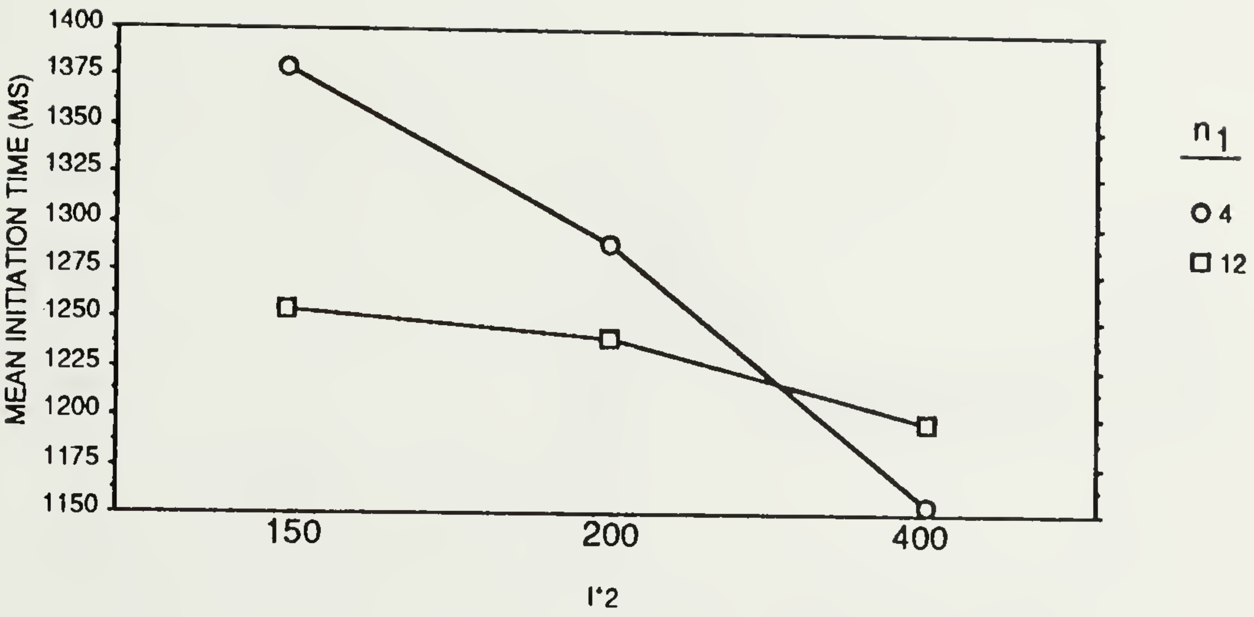

Figure 3. Mean initiation time as a function of I_2^* and n_1 for Experiment 1.

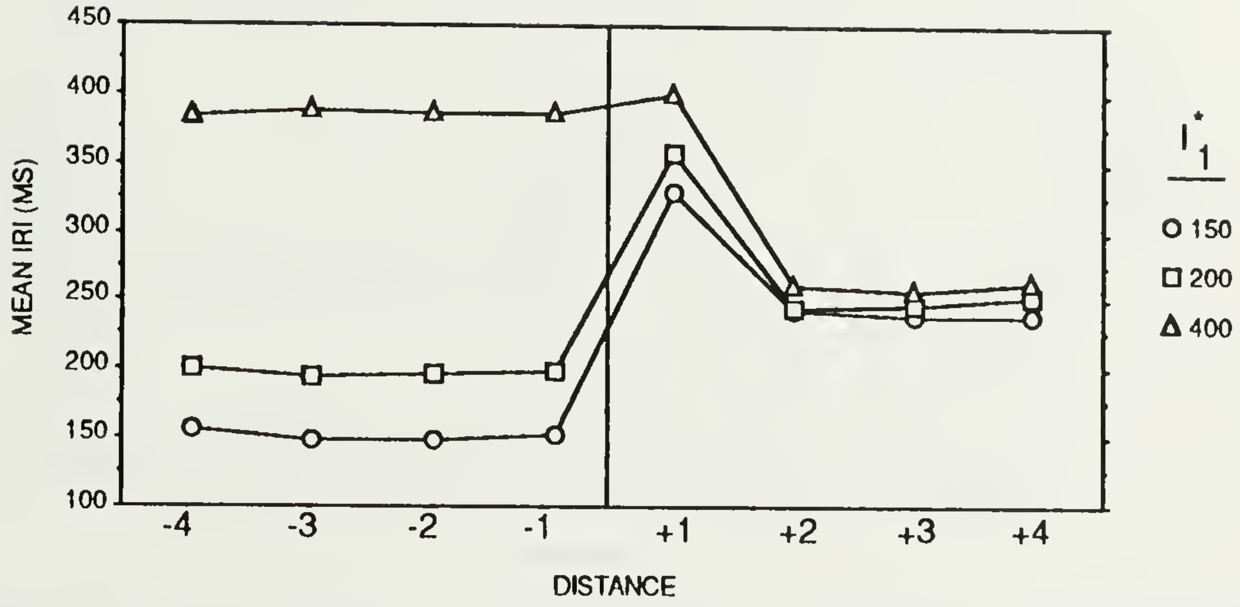

Figure 4. Mean IRI of data trimmed for best trials as a function of I_1^*, |D|, and ±D for Experiment 1.

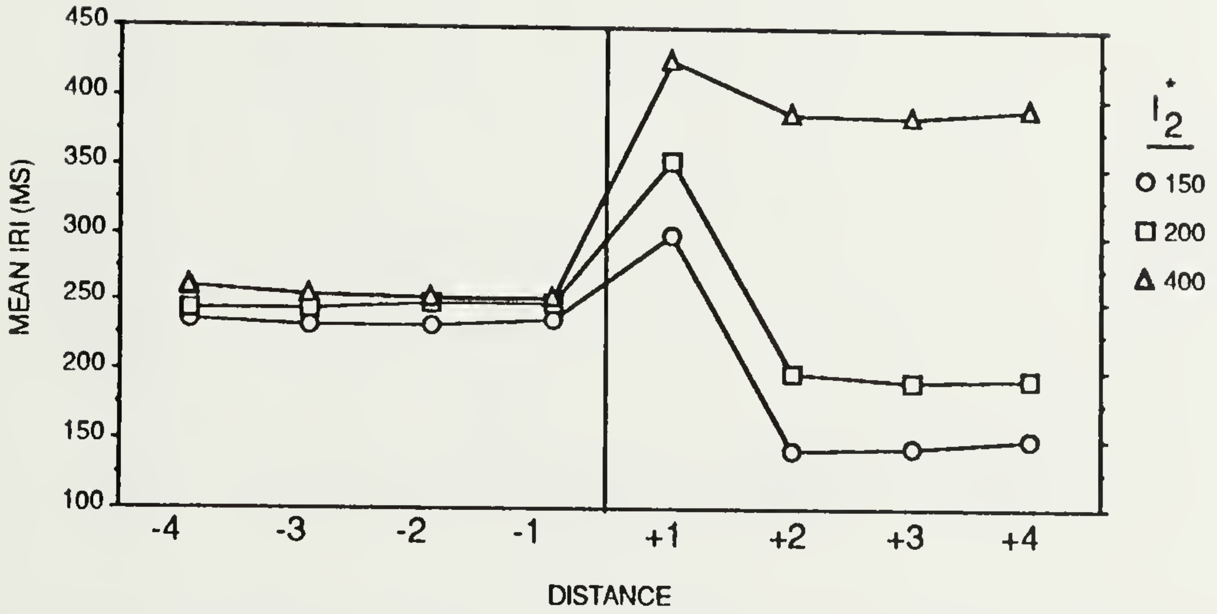

Figure 5. Mean IRI of data trimmed for best trials as a function of I_2^*, |D|, and ±D for Experiment 1.

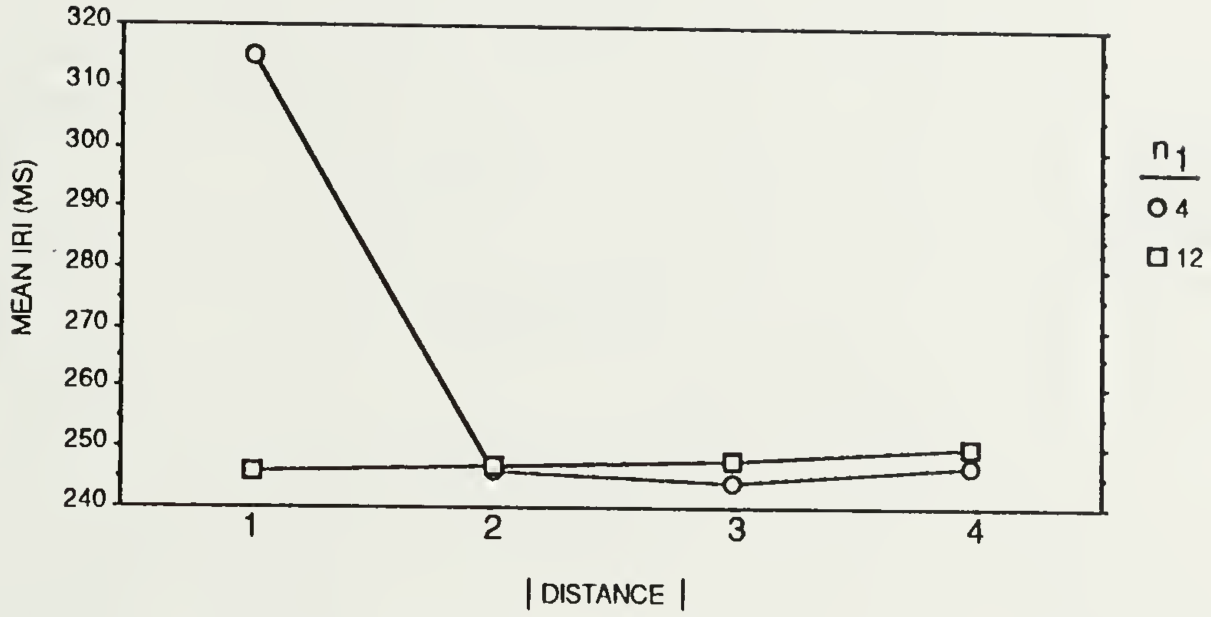

Figure 6. Mean IRI of data trimmed for best trials as a function of n_1 and |D| for Experiment 1.

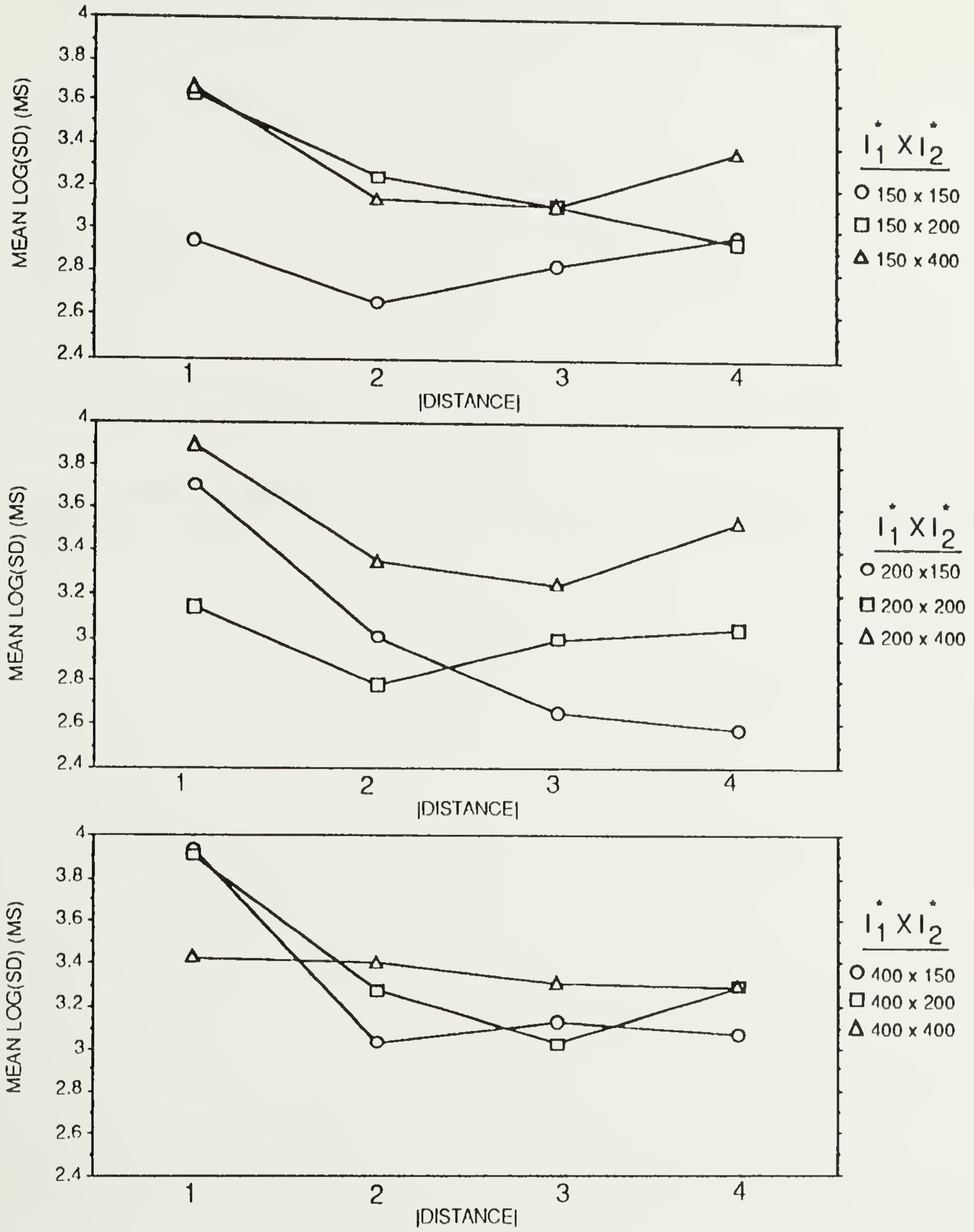

Figure 7. Mean Log(SD) from data trimmed for best trials as a function of I_1^*, I_2^*, and |D| for Experiment 1.

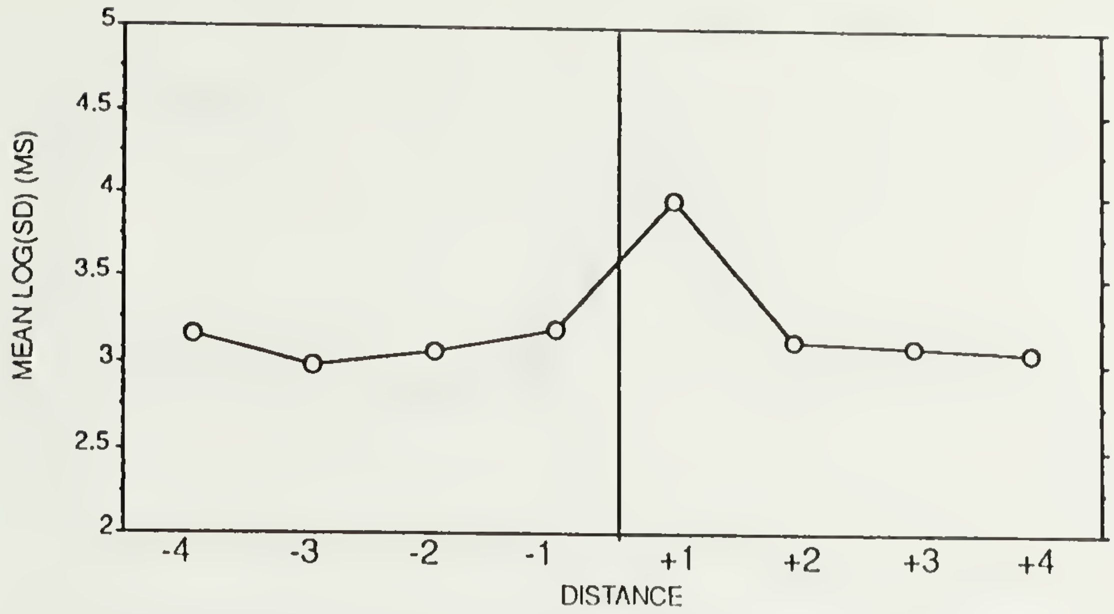

Figure 8. Mean Log(SD) of data trimmed for best trials as a function of |D| and ±D for Experiment 1.

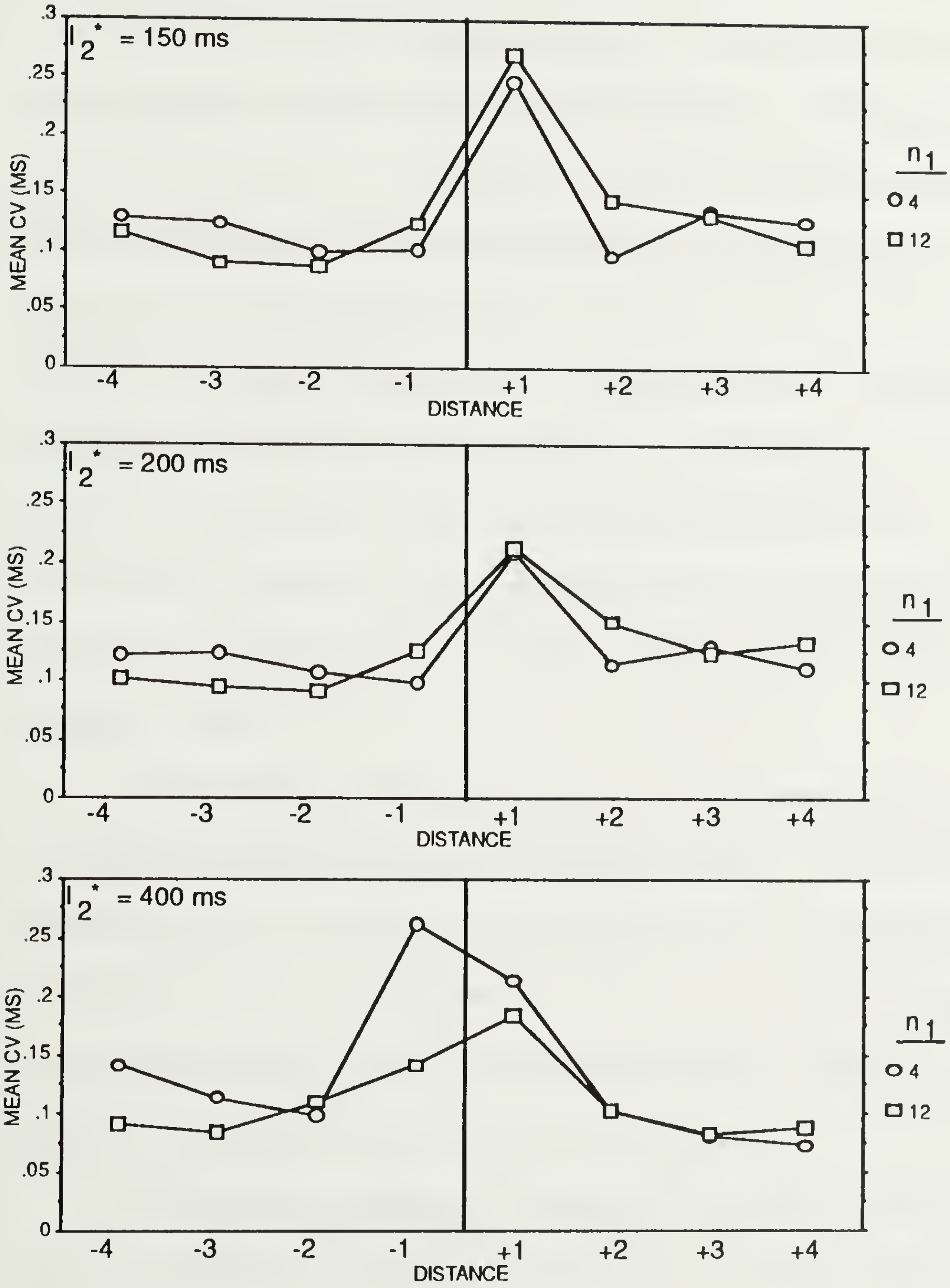

Figure 9. Mean CV of data trimmed for best trials as a function of I_2^*, n_1, |D|, and ±D in Experiment 1.

CHAPTER 3

EXPERIMENT 2

If a subject is engaged in a task involving strict temporal control and the timing demands of the task are going to change, there are several possibilities for specifying the timing parameter for the later portion of the task. The findings of Experiment 1 suggested two alternatives. First, it may be that subjects acted on advance timing information at the "last moment." That is, subjects may have used advance information to prepare for changes in the timing demands of the task at the first interval following the required switch. The key evidence for this alternative is that tapping performance not only become more variable when task demands increased, but tapping performance virtually came to a halt when subjects changed from I_1^* to I_2^*. A second explanation for the findings of Experiment 1 is that the results were partly an artifact of a strategy or memory search where the subjects tried to map the visual presentation of the stimuli to the times to be produced by tapping.

To test the latter hypothesis, instead of using visual presentation of the stimuli, the stimuli for Experiment 2 were presented in an auditory fashion. Thus, if the changes in tapping performance seen in Experiment 1 were brought about by increased task demands, from simultaneous preparation and execution of a task, the results should be replicated. However, if the results were merely artifactual, induced by the indirect mapping of visual stimuli to time intervals to be produced, the results should not be replicated.

A second issue addressed in Experiment 2 concerned a characteristic of the timing process. Specifically, are there reliable effects in the data that can be explained by context dependencies of I_1^* and I_2^* combinations? The way a response is produced depends on its relationship to earlier and later responses (Jordan & Rosenbaum, 1989). In Experiment 1, subjects produced IRIs that approximated I^*s. However, there was some variation depending on whether the IRIs occurred before the required switch or after the required switch. For example, when I_1^* equalled 150, 200, and 400 ms, the mean I_1s produced were 152, 198, and 386 ms, respectively. When I_2^* equalled 150 , 200, and 400 ms, the mean I_2s produced were 147 , 196 , and 387 ms, respectively. (The means of I_2^* do not include B(1) because the mean IRI at interval B(1) was systematically elevated.) Possibly, some of the variation in the produced IRIs can be accounted for by context dependencies of specific I_1^* and I_2^* combinations.

Method

Subjects

Five right handed volunteers from the University of Massachusetts at Worcester served as subjects. Four subjects were female; one was male. The mean age was 33.80 years; the standard deviation was 3.71 years. Subjects were not paid for their participation. Each subject read and signed an informed consent form.

Apparatus

The subject sat in a private testing room facing a Zenith 386 computer. Tapping responses were made by pressing the "0" key on the computer keyboard number pad. The experiment was controlled by a Turbo Basic computer program.

Procedure

The task and procedure were similar to those used in Experiment 1. The major differences were associated with the presentation of the stimuli and the number of preswitch and postswitch taps.

The I^*s were presented to the subject as tones generated by the computer. On a given trial, eight tones were generated. The first four tones represented I_1^* immediately followed by the second four tones which represented I_2^*. Figure 10 illustrates an example of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^*. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject is labelled according to its serial position within I_1^*, (A), or I_2^*, (B). As seen in Figure 10, this created three IRIs at I_1^*, labelled as A(1), A(2), and A(3), and four IRIs at I_2^*, labelled as B(1), B(2), B(3), and B(4). The first tone marked the beginning of the first Interval at I_1^*, A(1). The fourth tone marked the end of the I_1^* while at the same time marking the beginning of the first interval at I_2^*, B(1).

Once the presentation of tones ended, the subject began tapping when he/she was ready. There was no reaction time pressure. The subject was supposed to tap 4 times at I_1^* (preswitch taps) and an additional 4 taps at I_2^* (postswitch taps). As the subject tapped, the IRI was measured to the nearest millisecond. After the subject completed 8 taps, the interresponse times were graphed on the computer screen using the same formula as in Experiment 1. In Experiment 1 the asterisks were graphed after each tap, allowing the subject to receive immediate feedback after each response. In Experiment 2 the asterisks were graphed when the subject completed the trial. As in Experiment 1, the subject also received feedback in the form of the percentage of taps in which the asterisks fell on the lines representing I_1^* and I_2^* for that trial and for all previous trials in that block. Thus, the content of the feedback provided in Experiment 2 was exactly like that provided in Experiment 1. When the subject was ready, he/she pressed a button to clear the screen and begin the next trial.

The three I^*s were the same as those used in Experiment 1: 150, 200, and 400 ms. Each subject participated in 40 repetitions of each I_1^* x I_2^* condition. Trials were presented in blocks of 18 trials. Within a block of trials, I_1^* was constant and I_2^* was randomized such that there were two repetitions of each I_2^*. The order of presentation of the sets of I_1^* was randomized within a block of trials. The first session consisted of a guided introduction to the procedure, one practice trial, and 12 blocks of experimental trials. The first session lasted 1 hour. The length of the remaining sessions was left to the subject's discretion (in order to accommodate schedules). The subject could choose to participate in 30 minute sessions or 1 hour sessions. Experimental sessions were performed on consecutive days.

Results

Overview

Four dependent measures were analyzed: mean initiation time, and for each produced interval, mean IRI, log(sd), and CV. Mean initiation time was defined as the interval between the end of the final tone presented by the computer and the first button response produced by the subject. Each subject began tapping when he/she was ready. Eventhough there was no reaction time pressure, the time subjects took to initiate a trial might yield interesting results regarding the preparation of timing sequences, mean initiation times were analyzed. The IRI was defined as the time between each response produced by the subject. The mean, log(sd), and CV of each IRI were calculated for each serial position for each condition for each subject. In the analyses to be discussed, the factor block was used to examine learning effects. As in Experiment 1, block 1 represents the first 8 times subjects completed a particular condition, blocks 2, 3, and 4 represent the second, third, and fourth 8 times subjects completed a particular condition, and block 5 represents the final 8 times a subject completed a particular condition. In order to make comparable contrasts among conditions, responses included in the analyses were restricted to those within a distance of three taps from the switch. As in Experiment 1, |D| equalled 1 included the last response at I_1^* and the first response at I_2^*. The necessity for this restriction arose from the fact that subjects produced three intervals at I_1^* and four intervals at I_2^* (see Figure 10). Because of the complexity of the design, alpha was set at $p < .01$ for each analysis.

Each dependent measure was analyzed to evaluate the primary and secondary issues addressed in Experiment 2. The following is a preview of the series of analyses conducted to evaluate each issue. The details of each analysis will be provided later.

The first series of analyses addressed the primary issue of changes in tapping performance which might reflect preparation for changes in the timing demands of the task. To begin the series, an overall ANOVA was conducted on all data points for each subject (no trimming). Because these data were later trimmed and reanalyzed, these results are not discussed in detail. In order to take a closer look at changes in tapping performance which might reflect preparation for changes in the timing demands of the task, the data were trimmed such that the remaining trials represented each subject's best trials at the nonboundary intervals. An ANOVA and contrast tests were conducted on these data to investigate changes in tapping performance. These results are discussed in detail. The results of these analyses suggested that the subjects did not always switch from I_1^* to I_2^* at the correct serial position. In order to look more closely at this possibility, the trimmed data were trimmed once again. The data were trimmed a second time such that the remaining trials represented each subject's best trials at nonboundary intervals as well as best trials at the required switch. An ANOVA and contrast tests were conducted on these data to investigate switching effects. These data are discussed in detail .

The second series of analyses addressed the issue of context effects. Contrast tests were conducted on the data trimmed for best trials in order to investigate the possibility of context dependencies of specific I_1^* and I_2^* combinations.

Mean Initiation Time

Even though there was no reaction time pressure, the time subjects took to initiate a trial might reveal how they prepared the sequences. Thus, the initiation times were analyzed using a block (1, 2, 3, 4, 5) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) analysis of variance. The main effect of block was significant, $F(4, 16)=9.97$, $p < .003$. Mean initiation time decreased from 1407 to 636 ms as Block increased from 1 to 5. No other main effects and interactions were significant, $p > .07$. The summary table for this analysis appears in Appendix A.9.

Mean Interresponse Interval

Analyses Pertaining to Timing Preparation. Mean IRIs were analyzed using an ANOVA that evaluated the effects of block (1, 2, 3, 4, 5) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x |D| (1, 2, 3) x ±D (preswitch, postswitch). Block was not significant and did not interact with any other variables. Thus, for further analyses the data were collapsed over block. Several effects and interactions were significant. The summary table for this analysis appears in Appendix A.10.

To examine changes in tapping performance which might reflect timing preparation, it was necessary to use those trials which represented each subject's best performance. As in Experiment 1, best performance was defined as trials in which nonboundary intervals fell within ±35% of the I^*s. Nonboundary intervals of a trial included IRIs which did not surround the required switch.

The trimming procedure was the same as that used in Experiment 1. Trimming the data with this procedure left unequal cell sizes for each condition for each subject. The number of untrimmed observations for each cell for each subject is provided in Appendix A.11.

Using the mean IRIs calculated from the data trimmed for best trials at nonboundary intervals, an ANOVA was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x |D| (1, 2, 3) x ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis appears in Appendix A.12.

The highest-order significant interaction was the four-way interaction of I_1^*, I_2^*, |D|, and ±D, $F(8, 32) = 7.85$, $p < .0001$. Figure 11 illustrates the interaction. In each of the three graphs I_1^* is constant. The left panels illustrate the mean IRIs at each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels illustrate the mean IRIs at each serial position at I_2^*. For example, the 150 x 200 ms condition is illustrated in the top graph represented by squares. The left panel shows the mean IRIs at each serial position before the required switch (I_1^* equals 150 ms) and the right panel shows the mean IRIs at each serial position after the required switch (I_2^* equals 200 ms). There are two results to note in this four-way interaction. The first is that mean IRIs approximated the I^*s. The mean I_1s produced when I_1^* equalled 150, 200, and 400 ms were 143, 193, and 334 ms, respectively. The mean I_2s produced when I_2^* equalled 150, 200, and 400 ms were 136, 190, and 353 ms, respectively. (The means of I_2^* do not include B(1) because subjects did not always switch from I_1^* to I_2^* at the correct serial position. This finding will be discussed in detail.) The second result to note is the pattern of mean IRIs at the first interval after the required switch, interval B(1). When I_1^* and I_2^*

differed, mean IRIs at B(1) either approximated I_1^* or approximated a point halfway between I_1^* and I_2^* .

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The patterns of these effects and interactions are captured in the four-way interaction. Therefore, these results are not discussed in detail. Several three-way interactions were significant : $I_1^* \times I_2^* \times \pm D$, $F(4,16) = 6.18$, $p < .003$; $I_1^* \times |D| \times \pm D$, $F(4, 16) = 70.45$, $p < .0001$; and $I_2^* \times |D| \times \pm D$, $F(4, 16) = 20.02$, $p < .0001$. Several two-way interactions were significant: $I_1^* \times I_2^*$, $F(4, 16) = 5.27$, $p < .007$; $I_1^* \times \pm D$, $F(2, 8) = 196.47$, $p < .0001$; $I_2^* \times \pm D$, $F(2, 8) = 212.25$, $p < .0001$; $I_1^* \times |D|$, $F(4,16) = 82.00$, $p < .0001$; $I_2^* \times |D|$, $F(4, 16) = 21.35$, $p < .0001$; and $|D| \times \pm D$, $F(2, 8) = 113.07$, $p < .0001$. Three main effects were significant : I_1^*, $F(2,8) = 162.86$, $p < .0001$; I_2^*, $F(2,8) = 196.28$, $p < .000$; and $|D|$, $F(2, 8)=21.35$, $p < .0001$. No other effects or interactions were significant, $p > .03$.

To examine more closely the effects in the data trimmed for best trials, contrast tests were conducted on the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. The question of interest was whether there were changes in tapping performance at I_1^* that might reflect timing preparation of I_2^*. The specific contrast compared two differences. Figure 12 provides an example. The first difference in question served as the control. It is labelled "A" in Figure 12. This was the difference in the mean IRI at A(3) versus the mean nonboundary intervals at I_1^* when I_1^* and I_2^* were equal. Theoretically, there should be no differences in these intervals since there are no changes in the timing demands of the task. The second difference in question served as the comparison. It is labelled "B" in Figure 12. This was the difference in the mean IRI at A(3) versus the mean nonboundary intervals at I_1^* when I_1^* and I_2^* differed. Theoretically, if subjects prepare for changes in the timing demands during tapping at I_1^*, changes in tapping performance might reflect this added process. Thus, one might expect that the interval just prior to the required switch would be elevated compared to the nonboundary intervals. To ensure that any changes in performance reflect processes associated with changes in the timing demands of the task, the two differences just described, the control difference and the comparison difference, were subjected to contrast tests. If the control difference and the comparison difference are similar (e.g. the slope of A equals the slope of B), we can conclude that there were no changes in performance that related to timing preparation. If the control difference and the comparison difference yield different patterns (e.g. the slope of A is greater than the slope of B), we can conclude that the differences reflect timing preparation for I_2^*.

Contrasts were conducted twice for each I_1^* (150, 200, and 400 ms) condition shown in Figure 11. For example, for conditions in which I_1^* equalled 150 ms, the first contrast tested the 150 x 150 ms condition versus the 150 x 200 ms condition. The second contrast tested the 150 x 150 ms condition versus the 150 x 400 ms condition. This procedure was repeated on the data in each left panel in Figure 11. No significant results were found, $p>.25$. Thus, there were no changes in tapping performance at I_1^* related to timing preparation of I_2^*.

Nonetheless, there appeared to be changes at interval B(1) related to timing preparation. Figure 13 illustrates the same four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. In each graph I_2^* is constant. The question of interest was whether there were changes in tapping performance at interval B(1) that reflect timing preparation. Again, the specific contrast compared two differences, the control difference and the comparison difference. The control difference was the difference in the mean IRI at interval B(1) versus the mean nonboundary intervals at I_2^* when I_1^* and I_2^* were equal. The comparison difference was the difference in the mean IRI at interval B(1) versus the mean nonboundary intervals at I_2^* when I_1^* and I_2^* differed. To ensure that any changes in performance might reflect processes associated with changes in the timing demands of the task, the two differences were subjected to contrast tests which compared the pattern of the differences. Contrast tests were conducted twice for each I_2^* (150, 200, and 400 ms) shown in Figure 13. For example, for $I_2^* = 150$ ms, the first contrast tested the 150 x 150 ms condition versus the 200 x 150 ms condition, and the second contrast tested the 150 x 150 ms condition versus the 400 x 150 ms condition. This procedure was repeated for the data in each right panel in Figure 13. Three significant differences were found. Table 2 provides a summary of the results. Each contrast test that resulted in a significant difference was one in which I_2^* was less than I_1^*.

The pattern of IRIs at interval B(1) suggests an artifact. In some conditions, mean IRIs approximated a point halfway between I_1^* and I_2^* indicating that subjects did not always switch from I_1^* to I_2^* at the correct serial position. Assuming a two state model in which subjects either tried to produce I_1^* or I_2^*, the mean IRI at interval B(1) may have reflected the weighted average of the trials in which subjects were in one state or the other. Figure 14 shows a representative scatter plot for a condition in which I_1^* and I_2^* differed. The bimodal distribution at interval B(1) shows that in some trials B(1) approximated I_1^* and in other trials B(1) approximated I_2^*. This scatter plot and the others like it provide support for the two state model just described.

The effects at interval B(1) seem to be due to two sources: mixture (switching at the wrong serial position) and changes in the timing demands of the task. Can the effects at interval B(1) be separated to examine the effects due to mixture and the effects due to timing preparation? Several approaches were used. One was to use an ANOVA analogy which partitioned the observed variance into the variance due to mixture and the variance due to switching. This approach called for estimating the variance due to mixture and then subtracting this value from the observed variance, leaving the variance due to switching. The variance due to mixture was estimated using the following formula:

$$\mathrm{Var(mixture)} = p(\mathrm{Var}(I_1)) + (1-p)(\mathrm{Var}(I_2)) + p(1-p)(\mathrm{Mean}(I_1)-\mathrm{Mean}(I_2))^2 \qquad (2)$$

where p is the estimated proportion of trials that the subject tried to produce the I_1^* at B(1) (switching at the WRONG serial position), I_1 represents the nonboundary intervals at I_1^* and I_2 represents the nonboundary intervals at I_2^*. Statistics calculated for I_1 were taken over the first and second intervals at I_1^*, A(1) and A(2), respectively. Statistics calculated for I_2 were taken over the second, third, and fourth intervals at I_2^*, B(2), B(3), and B(4) respectively. The rationale for averaging over A(1) and A(2) and B(2), B(3), B(4), respectively, was that these represented the best estimates of stability for I_1^*s and I_2^*s.

The results of this modelling approach were problematic: In some cases the variance due to mixture was greater than the observed variance. Thus, after subtraction, the variance due to switching was a negative variance, which of course is undefined. This problem arose from the fact that one or more terms in the equation for the variance due to mixture were estimatedincorrectly due to estimation error. The result was an unsatisfactory approach for separating the effects due to mixture and the effects due to switching. (I prefer this explanation to one that says the underlying mixture model is incorrect.)

Another approach to partitioning the effects due to mixture and the effects due to switching was to trim the data. The data were originally trimmed for best trials based on the assumption that nonboundary intervals, A(1-2) and B(2-4), represented the most stable production of I_1^* and I_2^*, respectively. The same rationale was used in the present context to trim the data at the interval B(1). The data were trimmed so that trials were discarded if the IRI at interval B(1) was ±35% of the I_1^*. The discarded trials represented the subject's best trials in trying to produce I_1^* at interval B(1). The remaining trials represented those trials in which the subject tried to produce I_2^* at interval B(1). Appendix A.13 provides the remaining number of observations for each subject for each condition following this trimming procedure.

Figure 15 illustrates the mean IRIs trimmed for best trials at nonboundary intervals and for best trials at interval B(1). The question of interest was whether there were changes in tapping performance at the I_1^* as the required switch approached. Contrary to what was originally planned, contrasts were not conducted on the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$ due to missing data. The pattern of results does not indicate changes in tapping performance at I_1^* as the required switch approaches except for the dramatic anticipatory context effects when I_1^* equalled 400 ms. These anticipatory effects will be discussed shortly. For now, the discussion is addressing the primary issue of changes in tapping performance that might reflect timing preparation.

Figure 16 illustrates the same four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. In this graph, the data are grouped by I_2^*. The question of interest was whether there were changes in performance at interval B(1) that might reflect timing preparation. Due to missing data, planned contrast tests were not conducted. Assuming the trimming method discarded trials in which the mixture effect existed, the remaining trials represent those trials in which the subject was trying to produce I_2^* at interval B(1). In each of the right panels, subjects were trying to produce the same I_2^*. Within each panel there are two conditions in which the timing demands of the task changed which can be compared to the one condition in which the timing demands of the task did not change. Note the slopes of the lines representing three conditions; 200 x 150, 400 x 150, and 400 x 200. In these conditions the slopes of the comparison difference were greater than the slopes of their respective control differences. However, planned contrast tests were not conducted to validate these differences.

Summarizing the findings from the mean IRI data from Experiment 2 that relate to the primary issue of changes in tapping performance that might reflect timing preparation, there were no changes in tapping performance at I_1^* that appear to reflect timing preparation for I_2^*. However, there were two effects seen in the interval immediately following the required switch, at interval B(1). The first was that of mixture. The effect due to mixture stemmed from the fact that subjects did not always switch at the correct serial position. Based on the contrast tests conducted on the mean IRI data trimmed for best trials at nonboundary intervals, the effect of mixture was seen in conditions where I_2^* was less than I_1^*. The second effect seen at interval B(1) was due to changes in the timing demands of the task. Trimming the data for the best trials at the required switch left those trials in which subjects tried to produce I_2^* at interval B(1). Due to the problems of the small number of observations and missing data, planned contrast tests were not conducted on these data. However, the pattern of results suggested that an effect due to changes in the timing demands of the task occurred in three conditions: 200 x 150, 400 x 150, and 400 x 200. Note that these are the conditions in which I_2^* was less than I_1^*.

Analyses Pertaining to Context Effects. The second series of analyses addressed the issue of context effects of specific I_1^* and I_2^* combinations. Contrast tests were conducted on the data trimmed for best trials at nonboundary intervals to test for context dependencies. The specific contrast compared the nonboundary intervals of those conditions in which I_1^*s were equal but the I_2^*s differed. For example, in the top graph of Figure 11, each line in the left panel represents the mean IRI produced by subjects when I_1^* equalled 150 ms. However, each time

150 ms was produced in a different context. In the 150 x 150 ms condition, subjects tried to produce 150 ms when I_2^* equalled 150 ms. In the 150 x 200 ms condition, subjects tried to produce 150 ms when I_2^* equalled 200 ms. In the 150 x 400 ms condition, subjects tried to produce 150 ms when I_2^* equalled 400 ms. Theoretically, whenever I_1^* was 150 ms the mean IRIs should be equal. Contrast tests conducted on the data trimmed for best trials at nonboundary intervals yielded one significant difference, $F(1, 4) = 77.50$, $MS = 47.38$, $p < .009$. The mean of the nonboundary IRIs were higher when 400 was followed by 200 ms than when 400 was followed by 150 ms. No other contrast tests yielded significant differences, $p > .02$.

Similar contrast tests were conducted on the same data grouped by I_2^*. These data are shown in Figure 13. The contrast tests compared pairs of conditions at the nonboundary intervals, B(2), B(3), and B(4), where the I_2^*s were equal and the I_1^*s differed. No significant effects were found, $p > .02$.

Summary of Mean IRI Analyses. The main question addressed in Experiment 2 was, When do subjects use advance information, presented in an auditory fashion, to specify the timing parameter of the motor program? There were no changes in the tapping performance at I_1^* that appeared to reflect timing preparation. However, there were effects at interval B(1). The effect due to mixture (switching at the wrong serial position) was seen in those conditions in which I_2^* was less than I_1^*. Another effect seen at interval B(1) was the effect due to changes in the timing demands of the task. This effect presented itself in the data trimmed for the best trials at the required switch. While formal contrast tests could not be conducted, the pattern of results for three conditions suggested changes in performance at interval B(1) that might reflect timing preparation: 200 x 150, 400 x 150 and 400 x 200. This set of conditions was the set where I_2^* was less than I_1^*. Again, formal contrast tests could not be conducted to validate these differences due to instability in the data. Thus, no further conclusions will be drawn based on these data.

Experiment 2 also addressed the secondary issues of context effects. Context effects arise when performance of one I^* is influenced by the specific combination of another I^*. Context effects were seen when I_1^* equalled 400 ms. Mean IRI were higher when I_1^* equalled 400 ms in the 400 x 200 ms condition compared to the 400 x 150 ms condition. No other context effects were significant, however.

Log Standard Deviation

Analyses Pertaining to Timing Preparation. Log(sd) was studied with an ANOVA that evaluated the effects of block (1, 2, 3, 4, 5) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x $|D|$ (1, 2, 3) x $\pm D$ (preswitch, postswitch). Block was not significant and did not interact with any other variables. Thus, the data were collapsed over block for all further analyses. Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.14.

In order to examine changes in the variability of tapping performance that might reflect timing preparation, log(sd)s were calculated for the data trimmed for best trials. The relevant data were IRIs produced in nonboundary intervals that fell within ±35% of the I^*s. An ANOVA was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x $|D|$ (1, 2, 3) x $\pm D$ (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis is provided in Appendix A.15.

The highest-order significant interaction was the four-way interaction of I_1^* x I_2^* x $|D|$ x $\pm D$, $F(8, 32) = 9.88$, $p < .0001$. Figure 17 illustrates the interaction. In each of the three graphs I_1^* is constant. The left panels illustrate log(sd)s at each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels illustrate the log(sd)s at each serial position at I_2^*. The result to note is the dramatic increase in mean log(sd) at the first interval after the required switch, interval B(1).

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The patterns of these effects and interactions were captured in the four-way interaction. Therefore, these results are not discussed in detail. Several three-way interactions were significant : I_1^* x I_2^* x $|D|$, $F(8, 32) = 10.10$, $p < .0001$; I_1^* x I_2^* x $\pm D$, $F(4, 16) = 19.56$, $p < .0001$; and I_2^* x $|D|$ x $\pm D$, $F(4, 16) = 4.41$, $p < .01$. Several two-way interactions were significant: I_1^* x I_2^*, $F(4, 16) = 6.62$, $p < .002$; I_1^* x $|D|$, $F(4,16) = 82.00$, p <

.0001; I_2^* x ±D, $F(2, 8) = 8.41$, $p < .01$; and |D| x ±D, $F(2, 8) = 28.78$, $p < .0002$. Three main effects were significant: I_2^*, $F(2,8) = 13.27$, $p < .003$; |D|, $F(2, 8) = 24.15$, $p < .0004$; and ±D, $F(1, 4) = 52.60$, $p < .001$. No other effects or interactions were significant, $p > .03$.

Contrast tests were conducted on log(sd) for the four-way interaction of I_1^* x I_2^* x |D| x ±D. The interaction is shown in Figure 17. The specific question was whethr there were changes in the variability of tapping performance at I_1^* that might reflect timing preparation of I_2^*. The contrast tests were the same as those used for the mean IRI data. The contrast compared two differences. The first difference served as the control. This was the difference in the mean log(sd) at A(3) versus the mean log(sd) of nonboundary intervals at I_1^* when I_1^* and I_2^* were equal. The second difference served as the comparison. This was the difference in the mean log(sd) at A(3) versus the mean log(sd) of nonboundary intervals at I_1^* when I_1^* and I_2^* differed. ITo ensure that any changes in performance might reflect processes associated with changes in the timing demands of the task, the two differences just described, the control difference and the comparison difference, were subjected to contrast tests. Contrasts were conducted twice for each I_1^* (150, 200, and 400 ms) condition. For example, for conditions in which $I_1^* = 150$ ms, the first contrast tested the 150 x 150 ms condition versus the 150 x 200 ms condition and the second contrast tested the 150 x 150 ms condition versus the 150 x 400 ms condition. This procedure was repeated on the data in each left panel in Figure 17. The result was that no significant differences were found, $p>.50$.

Although there were no changes in log(sd) at A(3) that reflected timing preparation of I_2^*, a similar question was asked for the tapping performance at interval B(1). Figure 18 illustrates the same four-way interaction of I_1^*, I_2^*, |D|, and ±D. In each graph I_2^* is constant. The question of interest was whether there were changes in tapping performance at interval B(1) that might reflect timing preparation. Again, the specific contrast compared two differences, the control difference and the comparison difference. The control difference was the difference in the log(sd) at interval B(1) versus the log(sd) of nonboundary intervals at I_2^* when I_1^* and I_2^* were the same. The comparison difference was the difference in the log(sd) at interval B(1) versus the log(sd) of nonboundary intervals at I_2^* when I_1^* and I_2^* differed. In order to ensure that any changes in performance might reflect processes associated with changes in the timing demands of the task, the two differences were subjected to contrast tests. Contrasts were conducted twice for each I_2^* (150, 200, and 400 ms). For example, for I_2^* equals 150 ms conditions, the first contrast tested was the 150 x 150 ms condition versus the 200 x 510 ms condition. The second contrast tested the 150 x 150 ms condition versus the 400 x 150 ms condition. This procedure was repeated on the data in each right panel in Figure 18. One significant difference was found, $F(1, 4) = 15.42$, $MS = 64.31$, $p < .01$. The slope of the comparison difference was greater than the slope of the control difference when comparing the 200 x 150 and 150 x 150 ms conditions. The significant condition is one in which I_2^* was less than I_1^*. No other contrasts yielded significant differences, $p > .05$.

In order to separate the effects due to mixture and the effects of timing preparation, the data originally trimmed for best trials at nonboundary intervals were trimmed for best trials at interval B(1). Log(sd)s were calculated for these data. The data are assumed to reflect subjects' best trials at nonboundary intervals as well as those trials in which the subjects were trying to produce the I_2^* at interval B(1). Any effects are assumed to be due to switching from I_1^* to I_2^*. The planned contrasts were not conducted due to the large number of missing cells. Figure 19 illustrates these data. Again, the critical comparison pertained to the control difference and the comparison difference. The control difference was the difference in the log(sd) at interval B(1) versus the log(sd) of nonboundary intervals at I_2^* when I_1^* and I_2^* were the same. The comparison difference was the difference in the log(sd) at interval B(1) versus the mean log(sd) at nonboundary intervals at I_2^* when I_1^* and I_2^* differed. In order to ensure that any changes in performance might reflect processes associated with changes in the timing demands of the task, the slopes of the two differences were compared. Planned contrast tests were not conducted due to missing data. Thus, no conclusions were drawn. The reader is left to evaluate the patterns of results as he/she see fit.

Figure 20 illustrates the same data grouped by I_2^*. The question of interest was wheather there were changes in performance at interval B(1) that might reflect timing preparation. Again, due to the lack of observations and small number of observations in some cells, planned contrast tests were not conducted. There are two unusual patterns seen in these data. First is the difference in the 200 x 200 ms condition. It is not clear why the log(sd) at interval B(1) is elevated compared to the mean log(sd) at the nonboundary intervals. The same question arises for the 400 x 400 ms condition. These conditions are ones in which there was no change in the timing demands of the task. Thus, the slopes of these conditions should be flat. Given the instability of the data, it is impossible to reach any firm conclusions from these results.

Summarizing the findings from the mean log(sd) data of Experiment 2 that relate to the issue of changes in the variability of tapping performance as a reflection of timing preparation, these data provide converging evidence with the mean IRI data. While there were no changes in performance at A(3) related to timing performance, there were two effects at interval B(1); the effect due to mixture and the effect due to switching. Contrast tests conducted on the data trimmed for best trials at nonboundary intervals revealed that the difference between log(sd) at interval B(1) and log(sd) at nonboundary intervals was greater in the 200 x 150 ms condition than for the 150 x 150 ms condition. The 200 x 150 ms condition is one in which I_2^* was less than I_1^*. The mean IRI data suggested that conditions most likely to be affected by mixture were those in which I_2^* was less than the I_1^*. Once the effects of mixture were removed, there were inconsistent findings relating to the effect of switching. A problematic pattern of results was the increased log(sd) at interval B(1) for the nonboundary log(sd)s of the200 x 200 and 400 x 400 conditions. Because these conditions did not involve changes in timing demands, it remains to be seen what caused the increase in log(sd) at interval B(1).

<u>Analyses Pertaining to Context Effects.</u> Experiment 2 was designed to examine a secondary question concerned with context dependencies of specific I_1^* and I_2^* combinations. To examine the effects of context, contrast tests were conducted on the nonboundary intervals of data trimmed for best trials at nonboundary intervals. The specific contrast compared the mean

log(sd) of nonboundary intervals for pairs of conditions in which I_1^*s were equal and the I_2^*s differed. These data are illustrated in Figure 17. Similar contrasts were conducted on pairs of conditions in which the I_2^*s were equal and the I_1^*s differed. These data are illustrated in Figure 18. No significant differences were yielded, $p > .05$.

Summary of Log(sd) Analyses. The primary question of Experiment 2 concerned the preparation of timing. There were no changes in the variability of tapping performance at I_1^* that reflected timing preparation of I_2^*. However, there were two effects seen at the interval immediately following the required switch, interval B(1). One effect was the effect due to mixture. That is, subjects did not always switch from I_1^* to I_2^* at the correct serial position. There was one condition that was susceptible to this effect; the 150 x 200 ms condition. The second effect was related to changes in the timing demands of the task. Once the effects due to mixture were removed, there was an unusual finding in that there were increases in log(sd)s at interval B(1) in two conditions assumed not to be effected by switching; 200 x 200 and 400 x 400. However, given the missing data and the small number of observations, it is difficult to draw strong conclusions from this data. Finally, there were no significant effects of context in the log(sd) data.

Coefficient of Variation

Analyses Pertaining to Timing Preparation. An ANOVA was conducted on the CV data to evaluate the effects of block (1, 2, 3, 4, 5) x I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x |D| (1, 2, 3) x ±D (preswitch, postswitch). Block was not significant and did not interact with any other variables. Thus, for further analyses the data were collapsed over block. Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.16.

In order to examine changes in performance that might reflect timing preparation, CVs were calculated for the data trimmed for best trials at nonboundary intervals. These data included trials in which IRIs produced at nonboundary intervals fell within ±35% of the I^*s. An ANOVA was conducted that evaluated the effects of I_1^* (150, 200, 400 ms) x I_2^* (150, 200, 400 ms) x |D| (1, 2,

3) x ±D (preswitch, postswitch). Several main effects and interactions were significant. The summary table for this analysis is provided in Appendix A.17.

The highest-order significant interaction was the four-way interaction of I_1^* x I_2^* x |D| x ±D, $F(8, 32) = 3.89$ $p < .002$. Figure 21 illustrates the interaction. In each of the three graphs I_1^* is constant. The left panels illustrate the mean CVs at each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels illustrate the mean CVs at each serial position at I_2^*. The result to note in this four-way interaction is the dramatic increase in CV at interval B(1).

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The patterns of these effects and interactions were captured in the four-way interactions. Therefore, these results are not discussed in detail. The significant three-way interactions included : I_1^* x I_2^* x |D|, $F(8, 32) = 4.88$, $p < .0005$; I_1^* x I_2^* x ±D, $F(4, 16) = 21.05$, $p < .0001$; I_1^* x |D| x ±D, $F(4, 16) = 11.67$, $p<.001$; and I_2^* x |D| x ±D, $F(4, 16) = 13.46$, $p < .0001$. Several two way interactions were significant: I_1^* x I_2^*, $F(4, 16) = 4.72$, $p < .01$; I_1^* x |D|, $F(4,16) = 11.71$, $p < .0001$; I_1^* x ±D, $F(2, 8) = 7.70$, $p < .01$; I_2^* x |D|, $F(4,16) = 8.36$, $p < .0001$; and |D| x ±D, $F(2, 8) = 21.84$, $p < .0006$. Three main effects were significant: I_1^*, $F(2, 8) = 21.60$, $p < .0006$; |D|, $F(2, 8) = 22.47$, $p < .0005$; and ±D, $F(1, 4) = 207.56$, $p < .0001$. No other effects or interactions were significant, $p> .40$.

To examine the effects in the data trimmed for best trials at nonboundary intervals, contrast tests were conducted on the four-way interaction of I_1^*, I_2^*, |D|, and ±D. The question of interest was whether there were changes in the CV of tapping performance at I_1^* that might reflect timing preparation of I_2^*. The contrast tests were the same as those used for the mean IRI and log(sd) data. The contrast compared two differences. The first difference served as the control. This was the difference in the mean CV at A(3) versus the mean CV of the I_1^*state performance at I_1^* when I_1^* and I_2^* were equal. The second difference served as the comparison. This was the difference in the mean CV at A(3) versus the mean CV of nonboundary intervals at I_1^* when I_1^* and I_2^* differed. To ensure that any changes in performance reflected processes associated with changes in the timing demands of the task, the control difference and the comparison difference were subjected to contrast tests. Contrasts were conducted twice for each I_1^* (150, 200, and 400 ms) condition. For example, for conditions in which I_1^* equalld 150 ms, the first contrast tested the 150 x 150 ms condition versus the 150 x 200 ms condition and the second contrast tested the 150 x 150 ms condition versus the 150 x 400 ms condition. This procedure was repeated for the data in each left panel in Figure 20. The result was that no significant differences emerged from the contrast tests, $p > 02$.

Figure 22 illustrates the same four way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. In this figure the data are grouped by I_2^*. Contrast tests were conducted on these data to examine the effects at interval B(1) that might reflect timing preparation. Again, the specific contrasts compared two differences, the control difference and the comparison difference. No significant differences were found, $p > .03$.

To separate the effects due to mixture and the effects due to changes in the timing demands of the task, the data originally trimmed for best trials at nonboundary intervals were trimmed for best trials at interval B(1). CVs were calculated for these data. Figure 23 illustrates the $I_1^* \times I_2^* \times |D| \times \pm D$ interaction grouped by I_1^*. The planned contrasts were not conducted due to the large number of missing observations. Looking at Figure 23 there were no changes in tapping performance at I_1^* that obviously reflect timing preparation. The critical comparison was the pattern of two differences, the control difference and the comparison difference. Keeping in mind the instability of the data, the reader is left to ponder these patterns as he/she sees fit.

Figure 24 illustrates the $I_1^* \times I_2^* \times |D| \times \pm D$ interaction grouped by I_2^*. The planned contrasts were not conducted due to the large number of missing observations. An unusual pattern is seen in these data which was also seen in the log(sd) data. It is not clear why in the 400 x 400 ms condition, the CV at interval B(1) is elevated compared to the CV at the nonboundary intervals. This condition is one in which there was no change in the timing demands of the task. Thus, the slope of this condition should be flat. Given the instability of the data, it is impossible to draw a firm conclusion from this result.

Summarizing the CV data that pertain to the primary issue of changes in tapping performance that might reflect timing preparation, there were no changes in performance at I_1^* or interval B(1) that were systematically related to timing preparation of I_2^*. Once the data were trimmed for best trials at interval B(1), there were puzzling patterns in the data. Most puzzling was the increase in mean CV at interval B(1) for the 400 x 400 ms condition. Since there were no changes in the timing demand of the task, how can the increased CV at interval B(1) be explained? Before trying to explain this unusual finding, replication is needed due to the instability of the data from which it came.

Analyses Pertaining to Context Effects. The CVs calculated from data trimmed for best trials at nonboundary intervals were used to address the secondary issue of context effects. The specific contrast compared the mean nonboundary CV for pairs of conditions in which I_1^*s were equal and the I_2^*s differed. Similar contrasts were conducted on pairs of conditions in which the I_2^*s were equal and the I_1^*s differed. Contrast tests indicated a significant difference, $F(1,4) = 14.43$, $MS = .001$, $p < .01$, between the 150 x 150 and the 400 x 150 ms conditions. When 150 was preceded by 400 ms, the mean CV was lower than the CV when 150 ms was preceded by 150 ms. No other contrast tests yielded significant differences, $p > .03$.

Summary of Coefficient of Variation Analyses. There were no changes in the CV of tapping performance at I_1^* that reflected timing preparation of I_2^*. Nor were there changes in the CV of performance at interval B(1) that reflected timing preparation of I_2^*. The data trimmed for best trials at the required switch yielded unusual results. The 400 x 400 ms condition had a large increase in CV at interval B(1). This finding is unusual due to the fact that these data are assumed to reflect the effects due to changes in the timing demands of the task. However, I_1^* and I_2^* were equal in this condition. The paucity of underlying data frees is from taking the result seriously;, however, replication would be useful.

In terms of context effects, when 150 ms was preceded by 400 ms, the CV at 150 ms was lower compared to the 150 x 150 ms condition. Following is a discussion of the Experiment 2 results which summarizes the findings and discusses the implications of Experiment 2.

Discussion

Experiment 2 was designed to investigate when advance timing information, presented in an auditory fashion, was used to specify the timing parameter of the motor program. The primary question was whether there were changes in tapping performance that might reflect timing preparation of I_2^*. A secondary question concerned a characteristic of the timing process. Were there context dependent effects of specific I_1^* and I_2^* combinations?

There were no changes in tapping performance at I_1^* that appeared to reflect timing preparation of I_2^*, either in mean IRI, log(sd), or CV data. However, there were two effects at interval B(1). First was an effect due to mixture. Second was an effect due to changes in the timing demands of the task. The effect due to mixture resulted from the fact that subjects did not always switch at the correct serial position. That is, subjects had problems parsing some sequences. The evidence for this effect was present in the mean IRI data trimmed on the basis of best trials at nonboundary intervals. When I_2^* was less than I_1^*, mean IRIs at interval B(1) were higher than the mean IRIs at nonboundary intervals of I_2^*. The mean IRIs at interval B(1) approximated a point halfway between I_1^* and I_2^*. For one condition, the 200 x 150 ms condition, the log(sd) at interval B(1) was higher than the log(sd) of the nonboundary I_2 intervals. This condition is one in which I_2^* was less than I_1^*.

Why did subjects switch at the wrong serial position? One explanation is that they had trouble parsing the sequence into those intervals belonging to I_1^* and those belonging to I_2^*. The difficulty might have stemmed from the fact that there were three intervals to be produced at I_1^* and four intervals to be produced at I_2^* (see Figure 10). If subjects tried to impose a hierarchical structure on the sequence on tones, they might have placed four intervals at I_1^* with the intention of placing four intervals at I_2^*. This would result in subjects switching at the wrong serial position. This explanation is easy to test. In Experiment 3, the number of intervals to be produced at I_1^* equal the number of intervals to be produced at I_2^*. Switching at the wrong serial position should not occur under this condition.

The second effect seen at interval B(1) was the effect due to changes in the timing demands of the task. This effect is assumed to reflect those processes involved in switching from I_1^* to I_2^* when I_1^* and I_2^* differed. The effect was examined by trimming the data for best trials at the required switch. Thus, only those trials where subjects tried to produce I_2^* at interval B(1) were examined. Unfortunately, planned contrast tests could not be conducted due to missing data points. Although no strong conclusions will be drawn from these data, there are several patterns to note in the data trimmed for best trials at the required switch. Mean IRIs at interval B(1) were elevated when I_2^* was less than I_1^* compared to conditions where I_1^* equalled I_2^*. The log(sd) of interval B(1) for the 200 x 150 ms condition was elevated compared to the log(sd) of interval B(1) for the 150 x 150 ms condition.

The results of Experiment 2 provide some support for the constant preparation time model briefly described in Experiment 1. According to this model a constant amount of time is needed to switch from I_1^* to I_2^*. If the switching time exceeds I_2^* and the process of switching from I_1^* to I_2^* does not begin until tapping at I_1^* is completed, this results in the mean IRI at interval B(1) being longer than I_2^*. Support for this model is found in the pattern of results from the data trimmed for best trials at the required switch. These data were assumed to represent those trials in which each subject tried to produce I_2^* at interval B(1). The mean IRIs at B(1) were elevated when I_2^* was less than I_1^* compared to conditions where I_1^* equalled I_2^*.

There are two problems with trying to draw conclusions from these results, however. First, due to missing data, planned contrast tests could not be conducted. Second, there was an unusual pattern of results in the log(sd) and CV data. In several conditions where I_1^* equalled I_2^*, there were elevations at interval B(1) compared to the nonboundary intervals. This pattern is unusual because there was no change in the timing demands of the task for these conditions. Thus, the task demands were not increased. The question remains: What was the source of the elevation in log(sd) and CV for these conditions? Experiment 3 was designed to control for possible sources of these problems and/or to replicate the results.

The second issue addressed in Experiment 2 was the possibility that reliable patterns in the data might be explained by context dependencies of specific I_1^* and I_2^* combinations. The results were inconsistent between the dependent measures. For mean IRIs, 400 ms was underestimated when 400 was followed by 200 ms compared to the 400 x 150 ms condition. For log(sd), 200 ms was higher when 200 was preceded by 150 ms compared to the 200 x 200 ms condition. For CVs, 150 was lower when 150 was preceded by 400 ms compared to the 150 x 150 ms condition. The context effects were inconsistent between the dependent measures in two ways. First, for each of the dependent measures different pairs of conditions yielded significant results. Second, there is no systematic way to describe the patterns of the significant differences. Thus, Experiment 3 was designed to further investigate context effects.

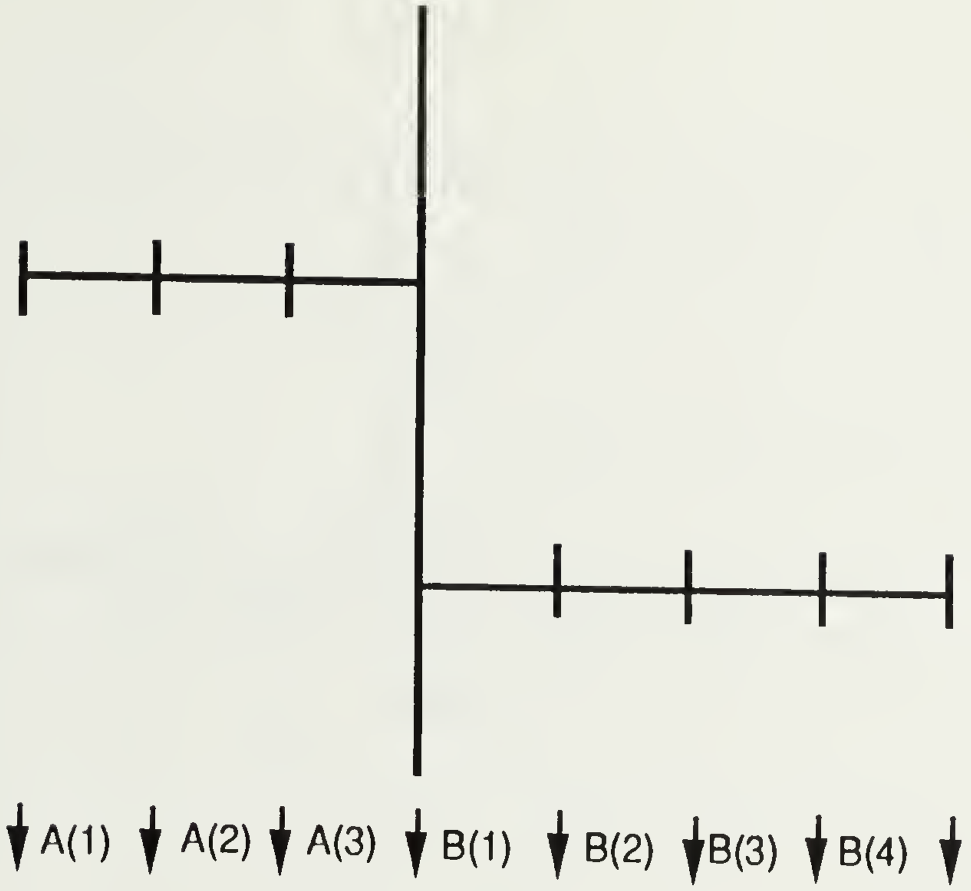

Figure 10. Example of the presentation of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^* for Experiment 2. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject is labelled according to its serial position within I_1^*, (A), or I_2^*, (B).

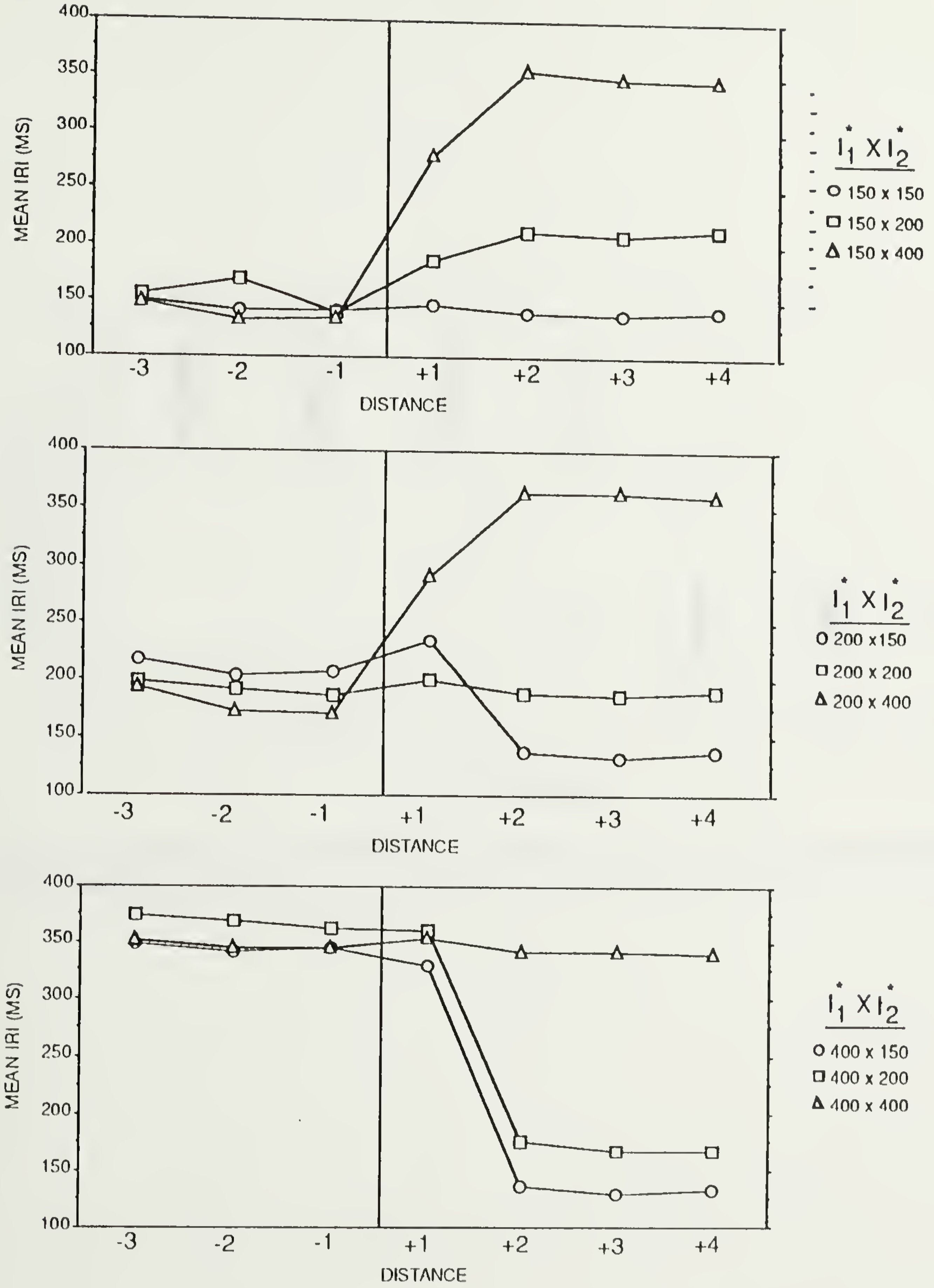

Figure 11. Mean IRI of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_1^* is constant.

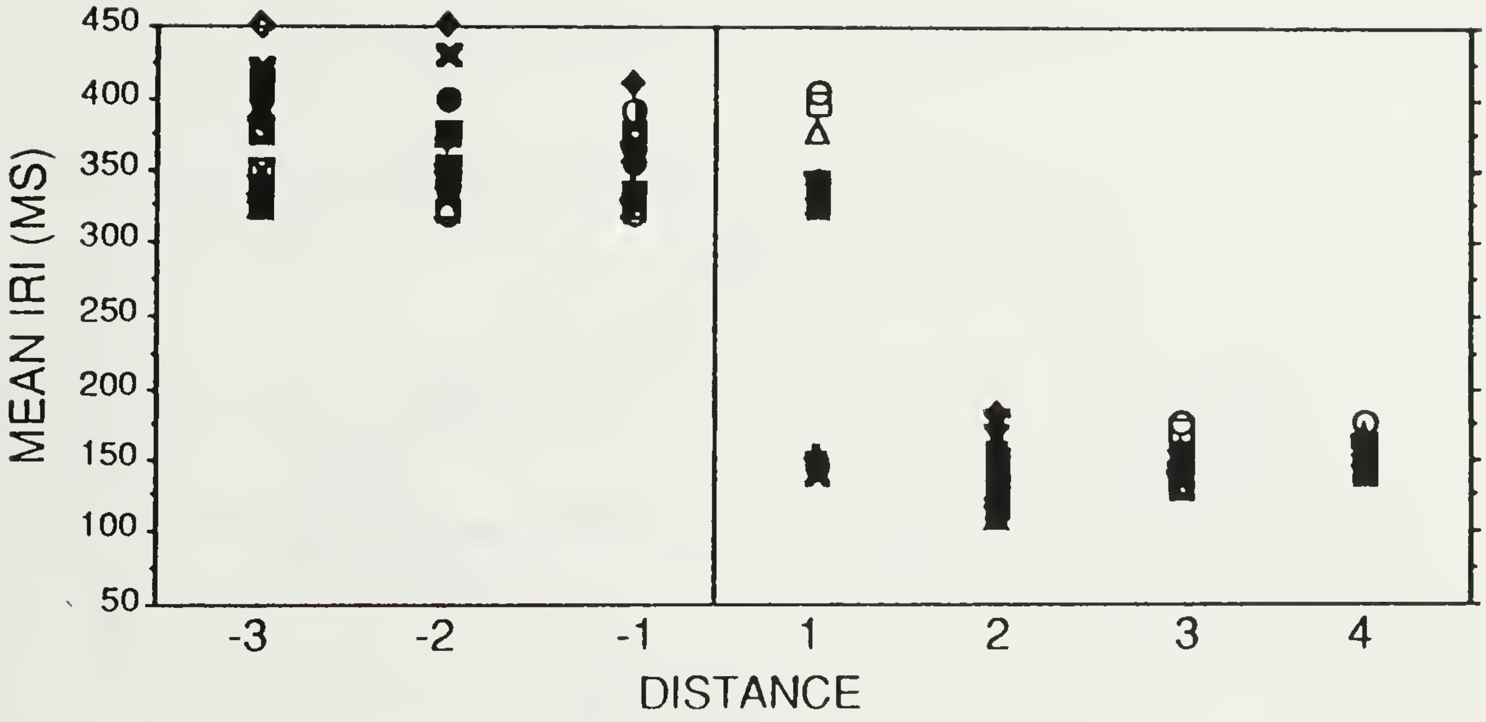

Figure 12. Representative scatterplot for a subject's mean IRI data showing a bimodal distribution at interval B(1).

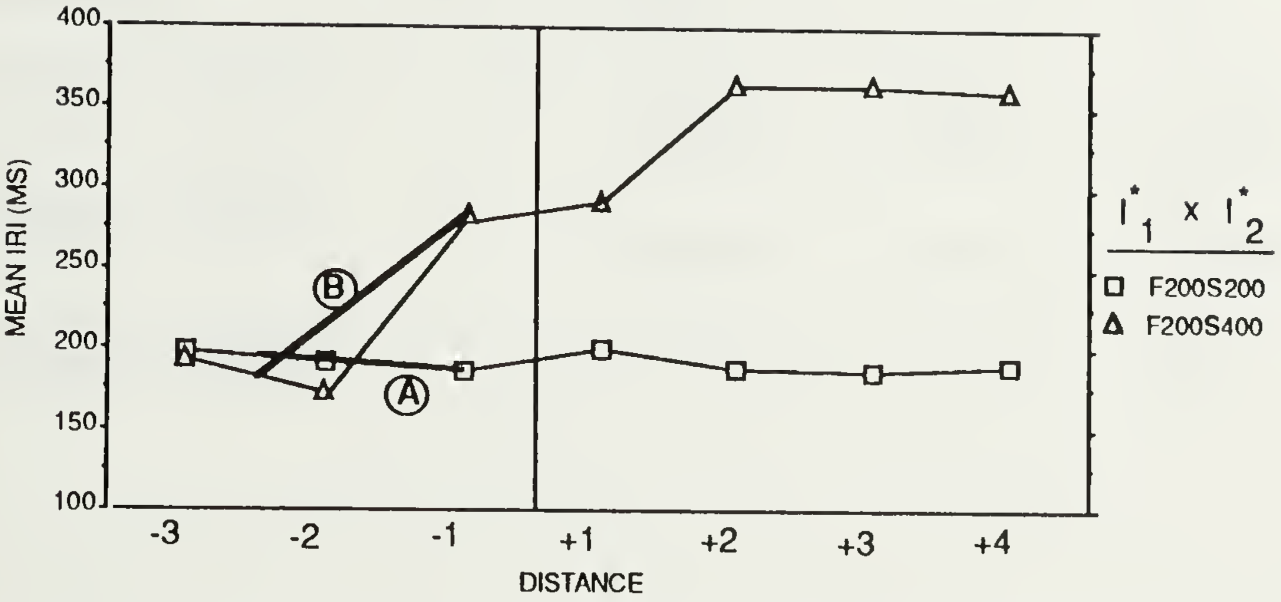

Figure 13. An illustration of the differences being subjected to contrast tests. The line labelled "A" represents the control difference. The line labelled "B" represents the comparison difference. See text for explanation.

Table 2. Summary table for contrast tests conducted on I_2^*s for mean IRI as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 2.

CONDITION	MSe	F	p≤
150/150 vs 200/150	165.45	99.29	.0006*
150/150 vs 400/150	366.95	186.67	.0002*
200/200 vs 150/200			.02
200/200 vs 400/200	618.09	97.13	.0006*
400/400 vs 150/400			.07
400/400 vs 200/400			.06

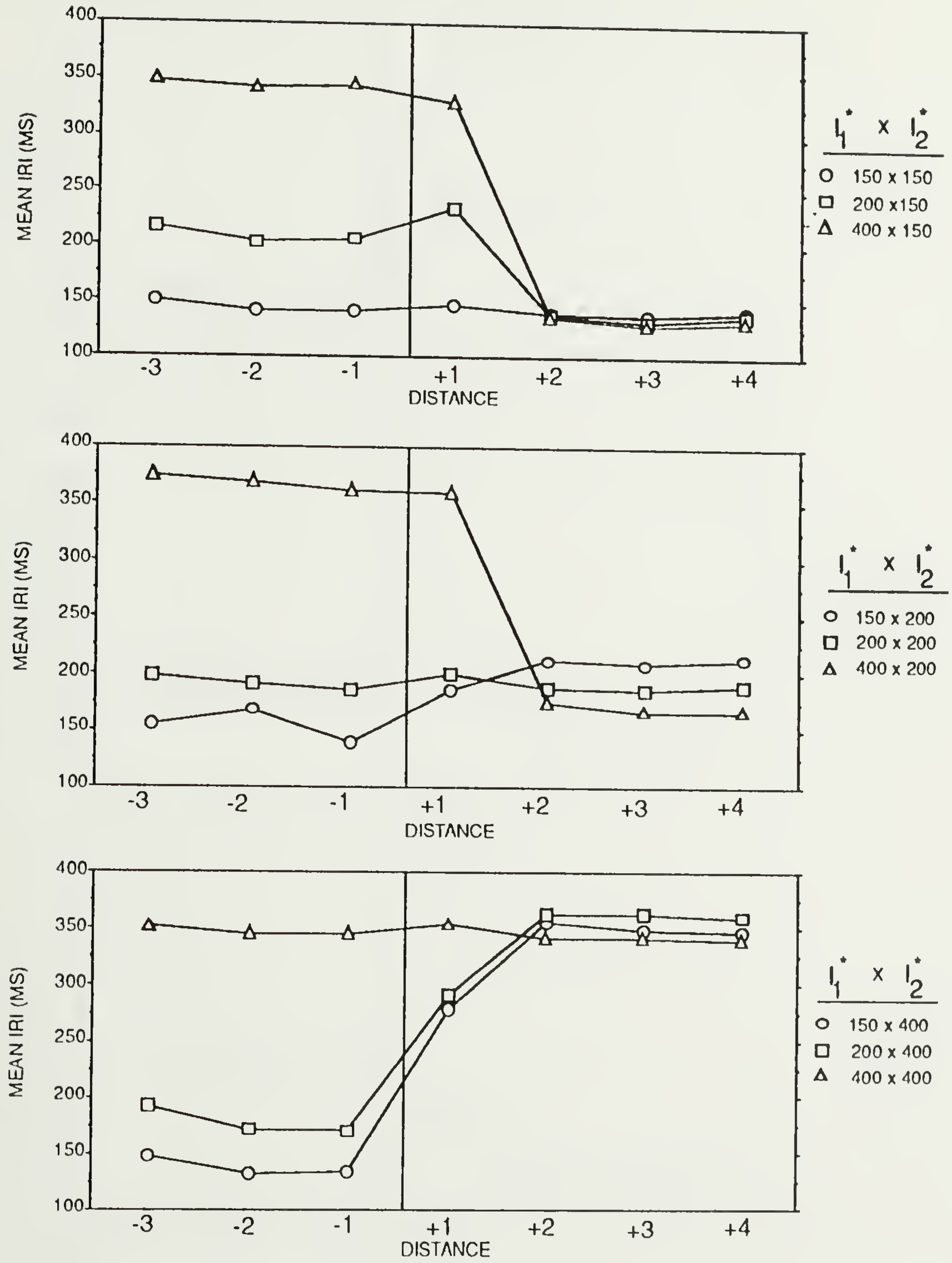

Figure 14. Mean IRI of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

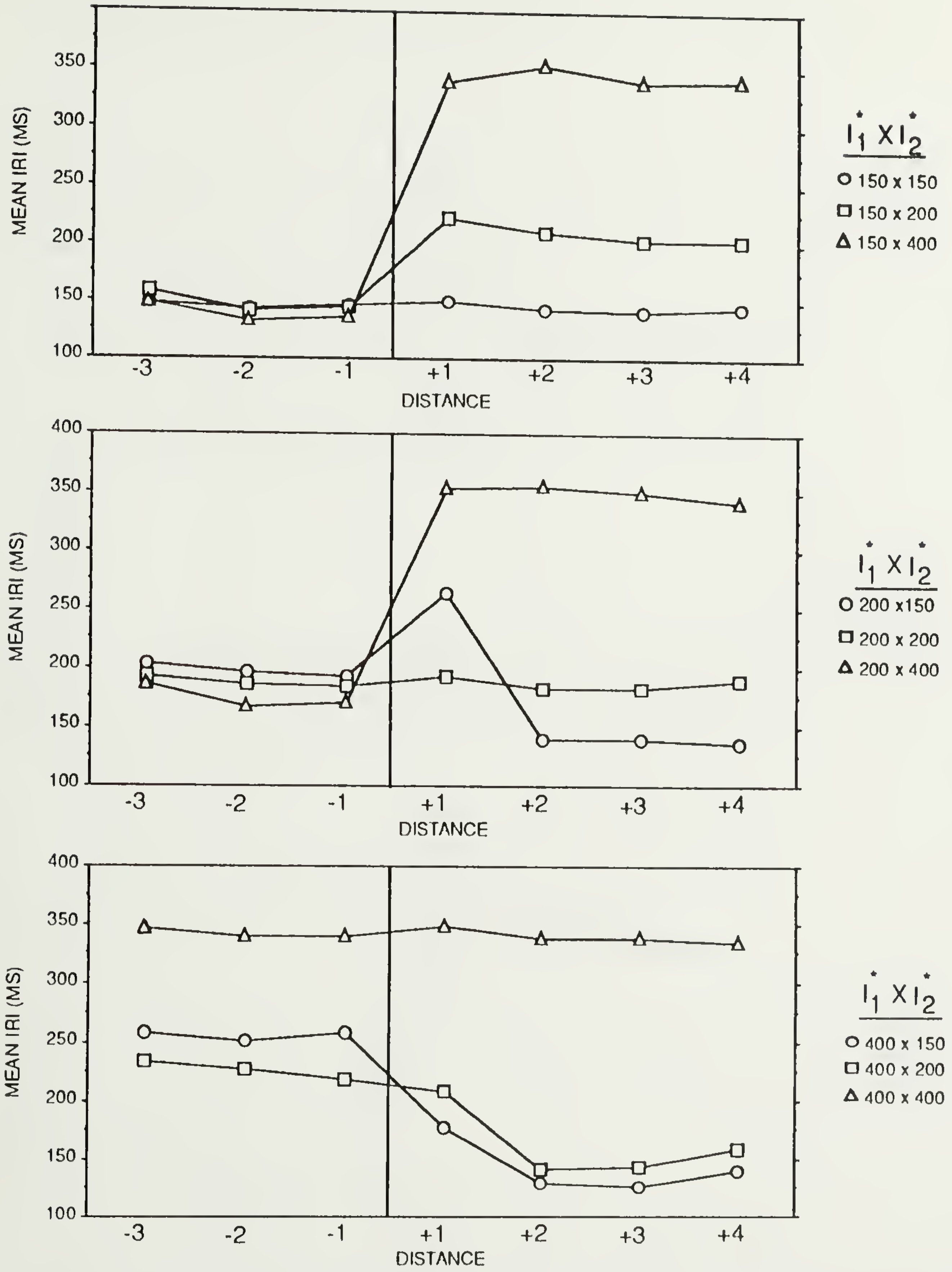

Figure 15. Mean IRI of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, $|D|$, and $\pm D$ for Experiment 2. In each graph I_1^* is constant.

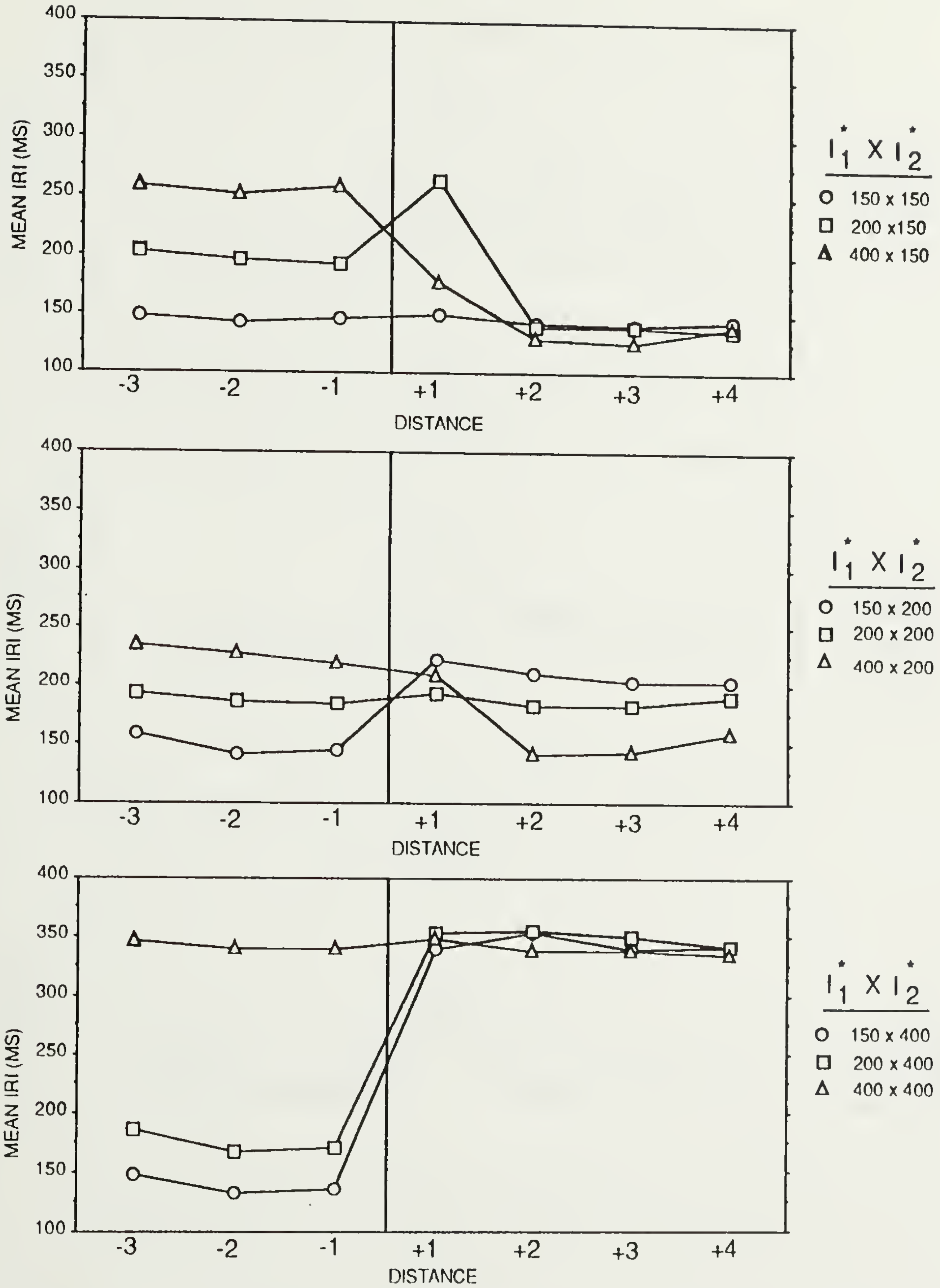

Figure 16. Mean IRI of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

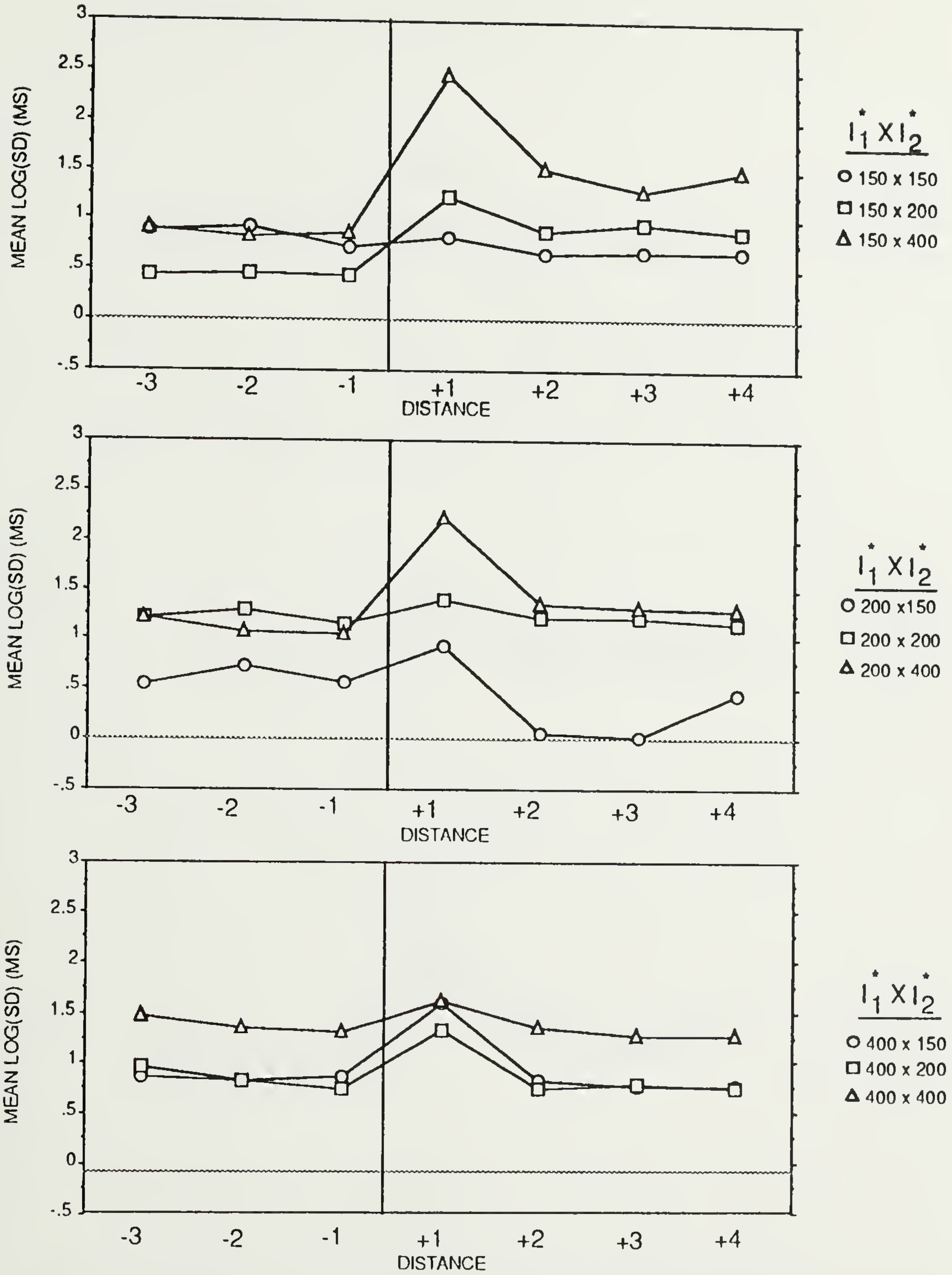

Figure 17. Mean log(sd) of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_1^* is constant.

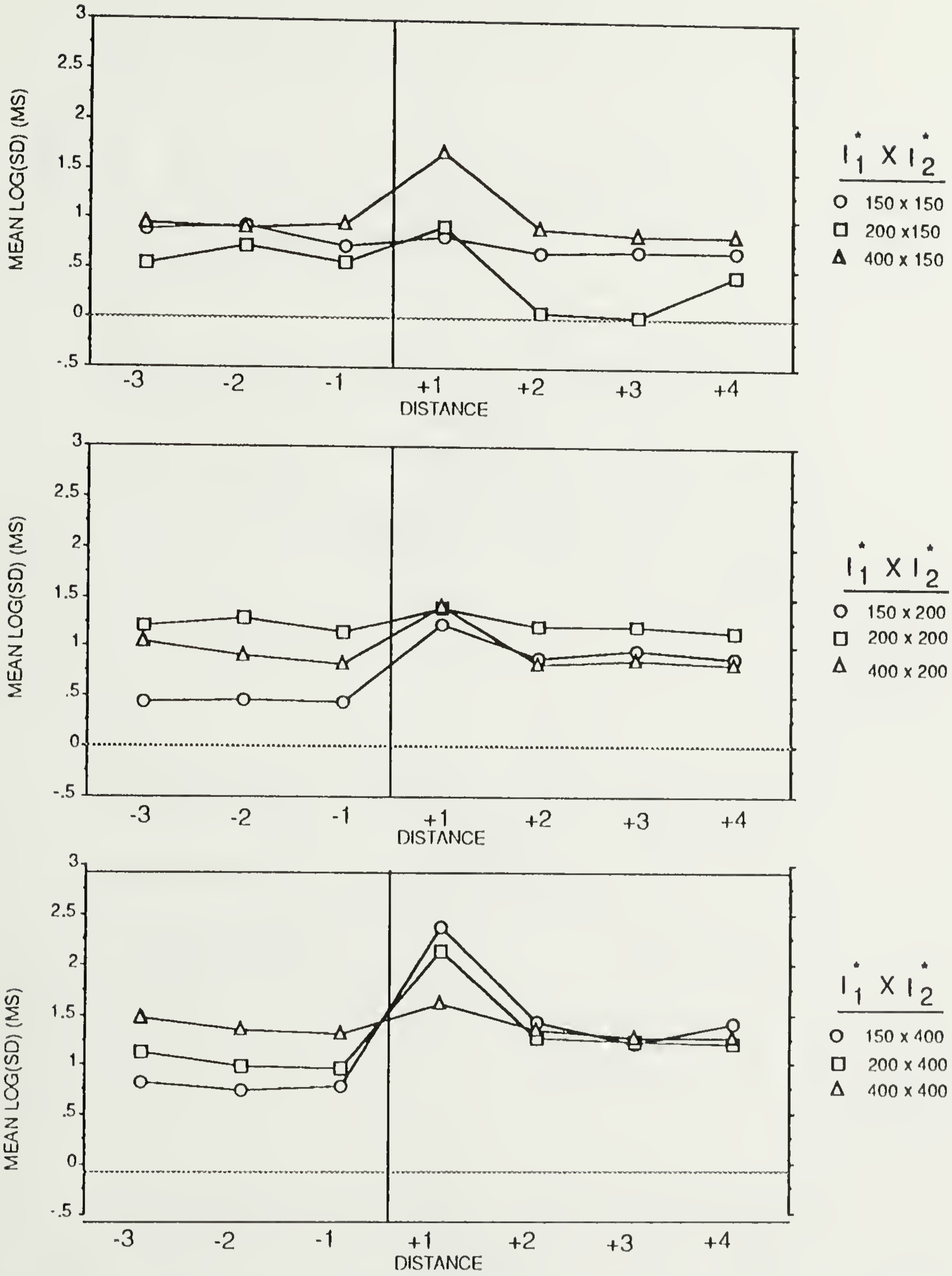

Figure 18. Mean log(sd) of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

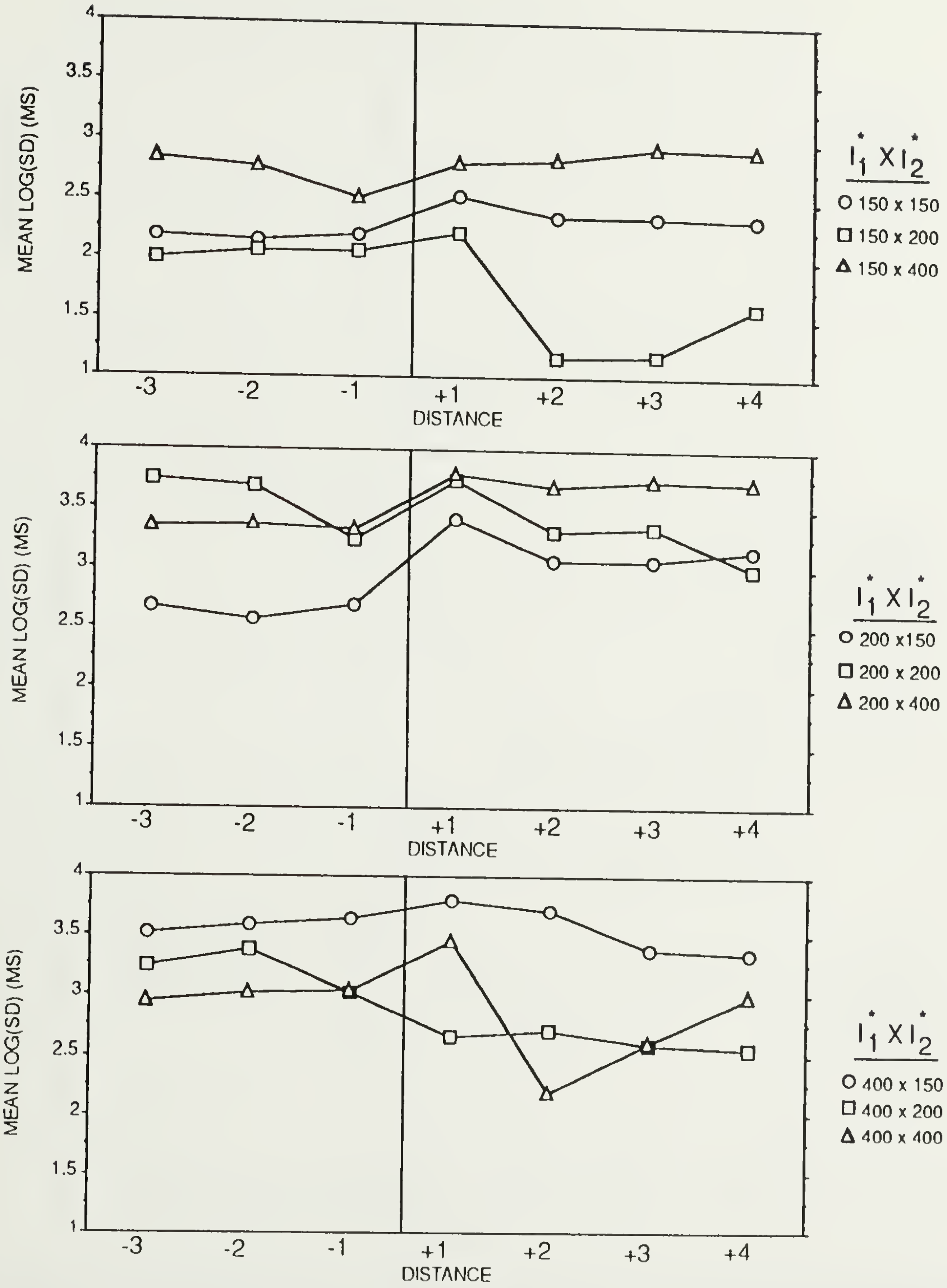

Figure 19. Mean log(sd) of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_1^* is constant.

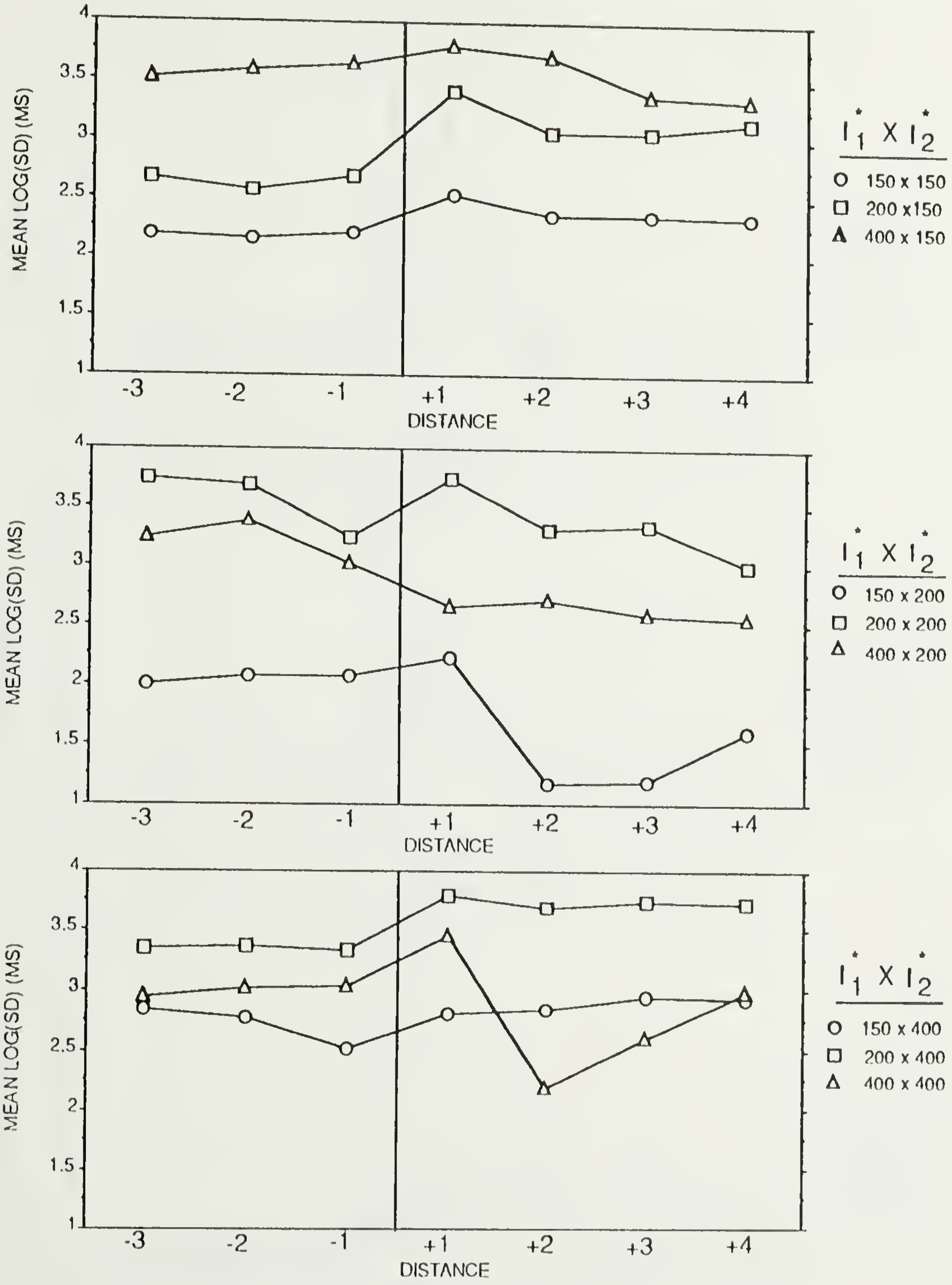

Figure 20. Mean log(sd) of data trimmed for best trials and best performance at Interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

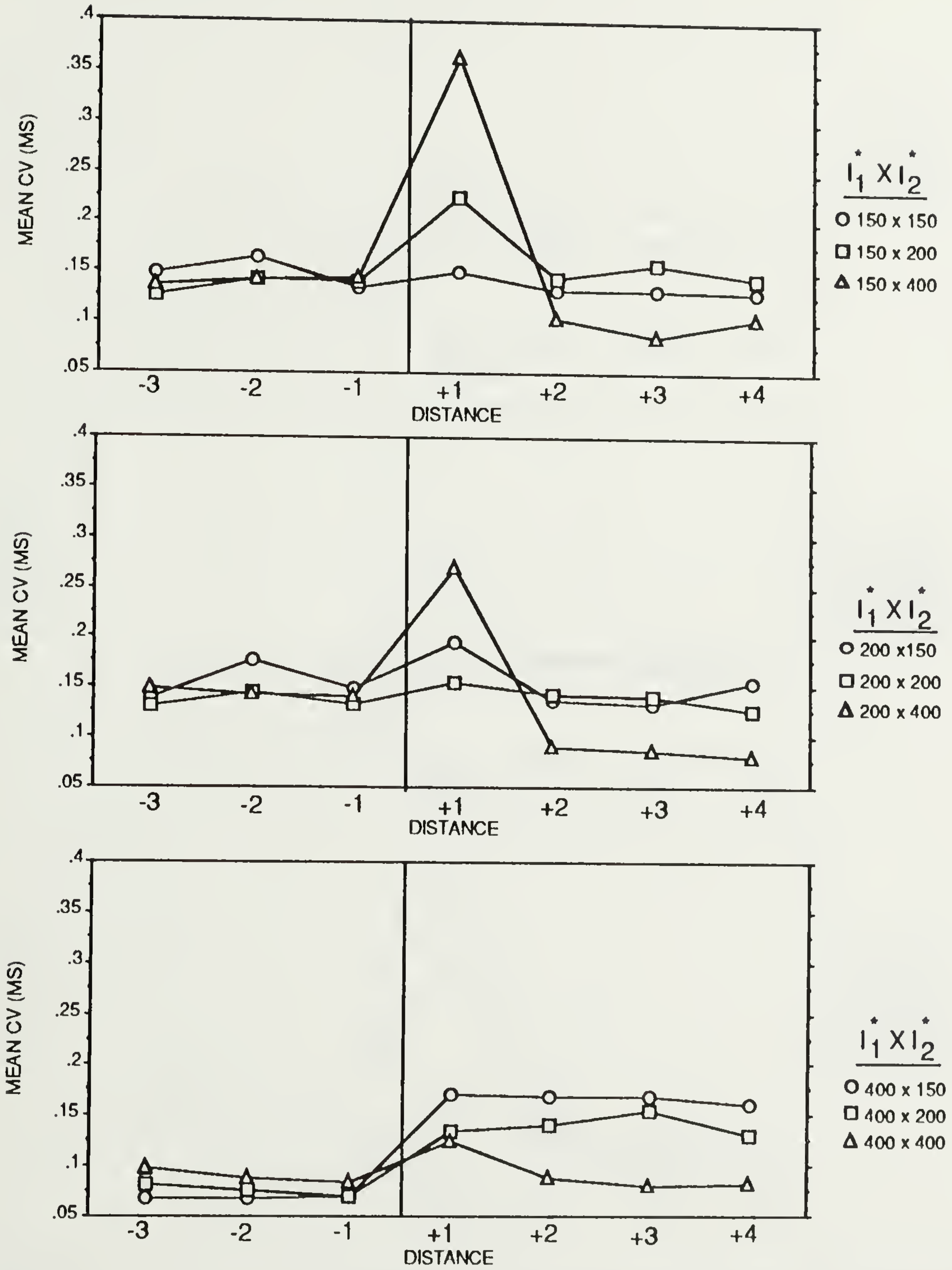

Figure 21. Mean CV of data trimmed for best trials as a function of I_1^*, I_2^*, $|D|$, and $\pm D$ for Experiment 2. In each graph I_1^* is constant.

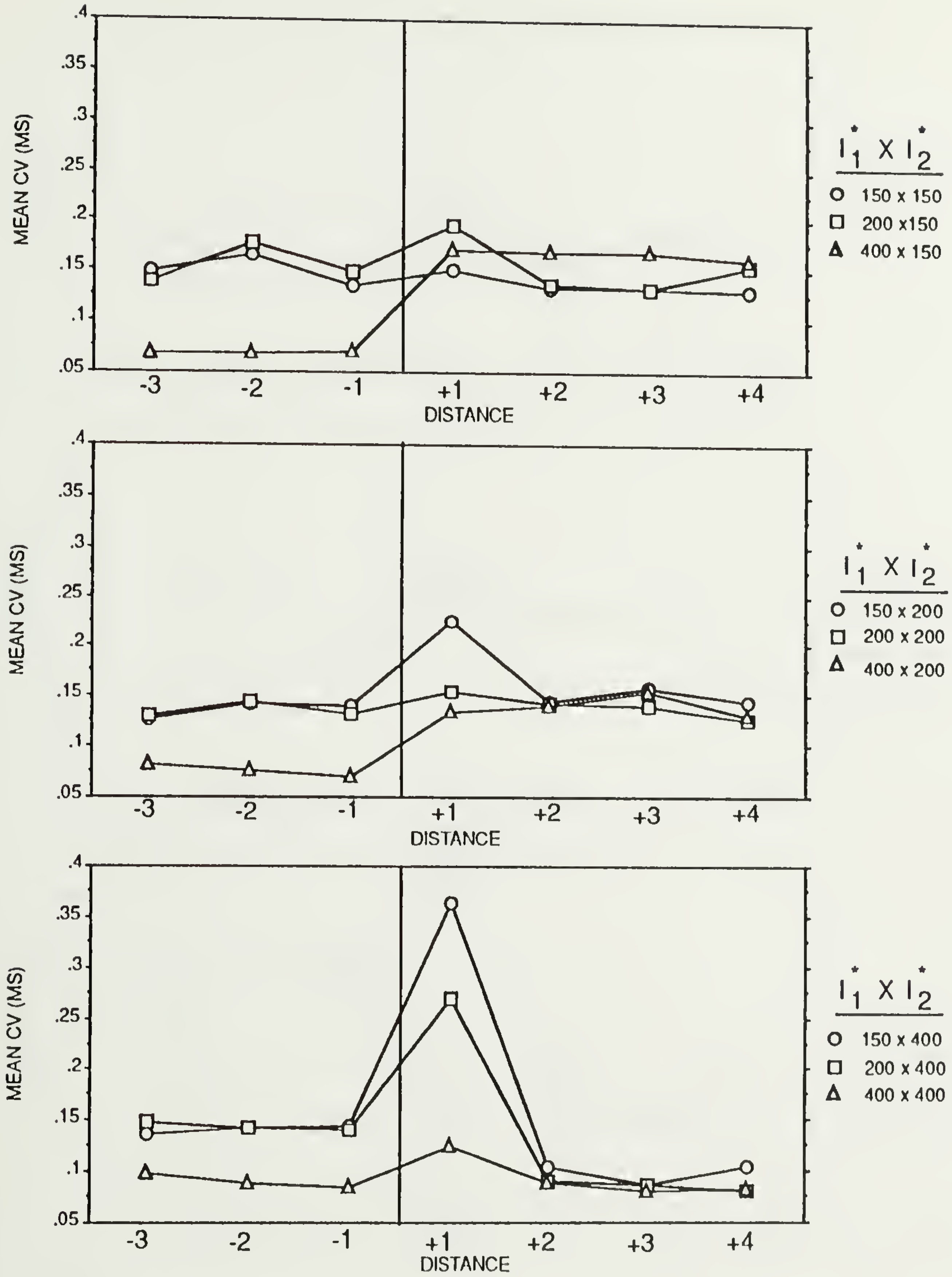

Figure 22. Mean CV of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

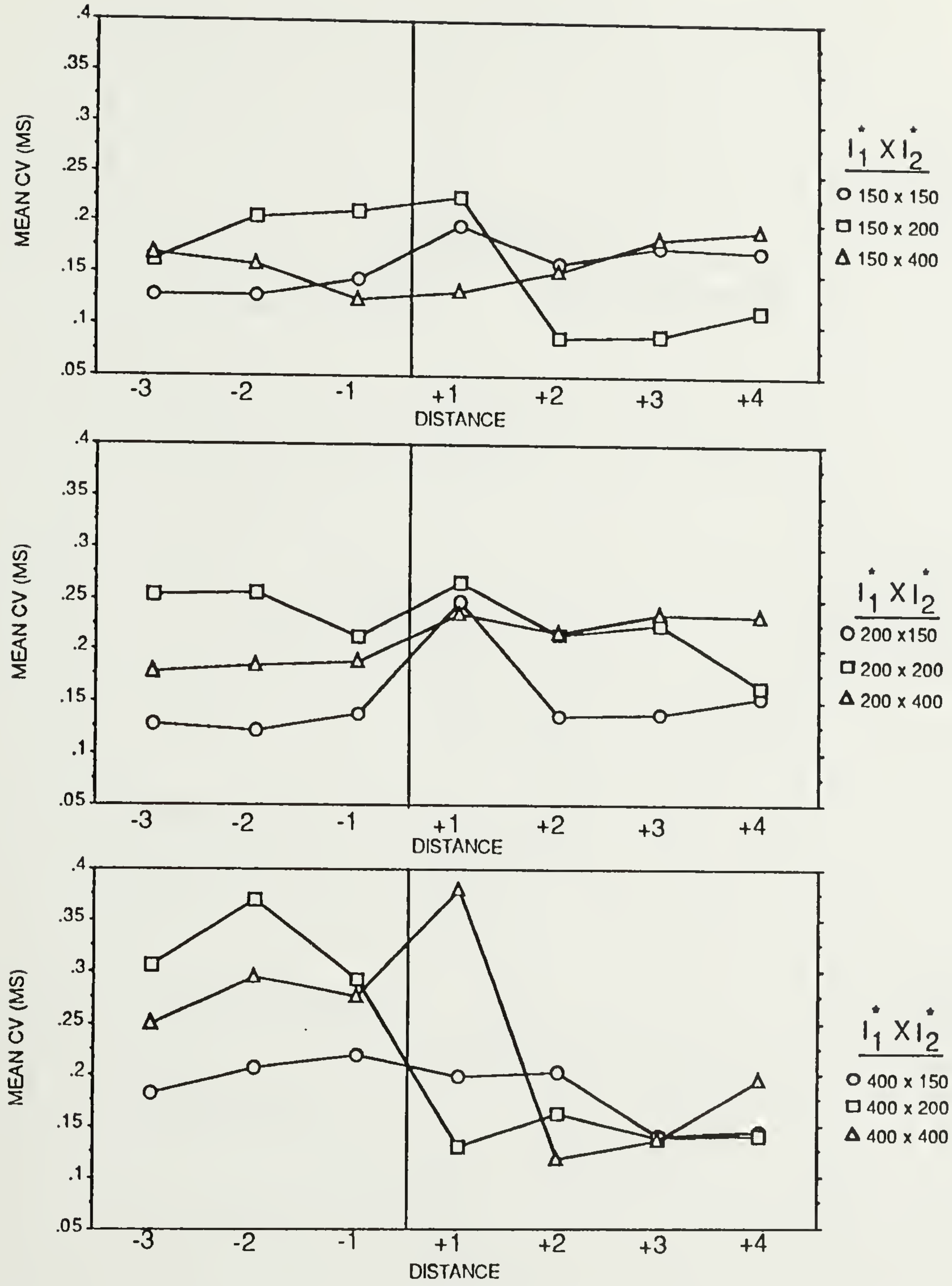

Figure 23. Mean CV of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_1^* is constant.

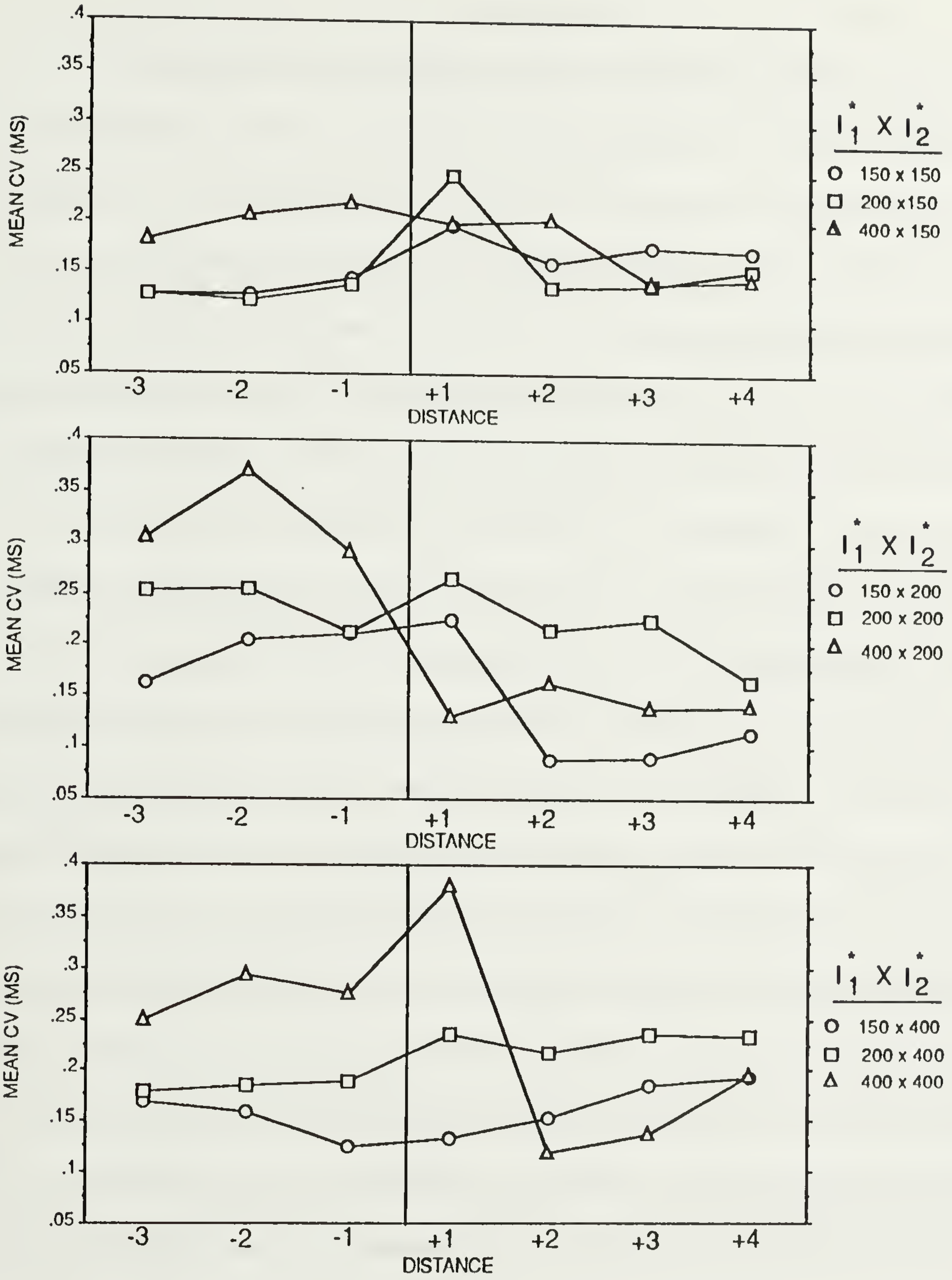

Figure 24. Mean CV of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 2. In each graph I_2^* is constant.

CHAPTER 4

EXPERIMENT 3

The primary aim of this research project has been to examine the nature of the process which prepares the timing of sequenced finger tapping. On the one hand, the results of Experiments 1 and 2 suggested the presence of some type of switching process taking place at the interval immediately following the required switch. The key evidence for the switching process was the increased mean, log(sd), and CV at the first interval after the required switch. On the other hand, the evidence for switching was clouded by mixture errors; sometimes subjects attempted to produce I_1^* at interval B(1) and sometimes they attempted to produce I_2^*.

Yet another explanation for the findings of Experiments 1 and 2 is that the results reflected biomechanical interactions. That is, instead of making changes in the timing parameter of a central motor program, the subjects may have made changes in the periphery to accommodate the new response rate and these changes could have been time consuming To address this possibility, a new experimental factor was introduced in Experiment 3. Subjects either performed the pre- and postswitch taps with one hand as in Experiments 1 and 2, or with alternate hands. The prediction of the biomechanical hypothesis was that if I_1^* and I_2^* were performed with different hands, this should allow the subject to prepare completely for I_2^* without being affected by I_1^*. It is assumed that biomechanical interactions involved with general changes in response rate will be reflected through significant interactions involving the factors of hand and ±D. Biomechanical interactions involved with specific changes in response rate will be reflected through significant interactions involving the factors of hand and $I_1^* \times I_2^*$. Finally, the lack of these interactions, will be taken to mean that biomechanical interactions are not a reflection of changes in the timing demands of this task (or that the dependent measures are not sensitive to changes in performance due to biomechanical interactions).

A secondary issue addressed in Experiment 3 concerned context dependencies of specific I_1^* and I_2^* combinations. The way a response is produced depends on its relationship to earlier and later responses (Jordan & Rosenbaum, 1989). The evidence for context effects in

Experiment 2 was inconsistent across independent measures. Experiment 3 was designed to further investigate the possibility that some of the variability in the produced IRIs can be accounted for by context dependencies of specific I_1^* and I_2^* combinations.

Method

Subjects

Eight right handed volunteers from the Assumption College community in Worcester, MA served as subjects. Five subjects were female; three were male. The mean age was 21.0 years; the standard deviation was 2.18 years. Subjects were paid $5.00 per hour for their participation. Each subject read and signed an informed consent.

Apparatus

The subject sat in a private testing room facing a Zenith 386 computer. Tapping responses were made on computer keyboard number pad. Subjects pressed the "0" key with the right hand or the "." key with the left hand. The experiment was controlled by a Turbo Basic computer program.

Procedure

The task and procedure were virtually the same as in Experiment 2. The major differences were the number of preswitch taps, the I^*s, and the addition of a hand factor. To test the generalizability of the findings of Experiments 1 and 2, a new set of I^*s was used: 200, 400, and 600 ms. The conditions were formed by crossing the hand factor, I_1^*, and I_2^* in all possible ways.

At the beginning of the experiment, each subject was assigned to one of four groups. The groups differed along the dimension of starting hand. Subjects assigned to group 1 performed each one-hand tapping condition with the left hand, and performed each two-hand tapping condition with the left hand and then the right hand. Subjects assigned to group 2 performed each one-hand tapping condition with the left hand, and performed each two-hand tapping condition with the right hand and then the left hand. Subjects assigned to group 3 performed each one-hand tapping condition with the right hand, and performed each two-hand tapping condition with the left hand and then the right hand. Subjects assigned to group 4 performed each one-hand tapping condition with the right hand, and performed each two-hand tapping condition with the right hand and then the left hand.

On a given trial, the number of hands to be used for that trial was indicated in the center of the computer screen. The instruction said either "1 HAND(S)" or "2 HAND(S)". If the instruction was to use one hand, the task was to reproduce the intertone intervals using either the left hand or the right hand depending on the group to which the subject was assigned. When the instruction called for two hands, the subject was to reproduce I_1^* with one hand and then switch hands to reproduce I_2^*. Thus, the hand and the I^*s "switched" at the same serial position. The I^*s were presented to the subject as tones generated by the computer. The first five tones represented I_1^* immediately followed by the second four tones, which represented I_2^*. Figure 25 illustrates an example of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^*. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject is labelled according to its serial position within I_1^*, (A), or I_2^*, (B). As seen in Figure 25, this created four IRIs at I_1^*, labelled A(1), A(2), A(3), and A(4), and four IRIs at I_2^*, labelled B(1), B(2), B(3), and B(4). The first tone marked the beginning of the first interval at I_1^*, A(1). The fifth tone marked the end of I_1^* while at the same time marking the beginning of the first interval at I_2^*, B(1). Subjects were instructed to use a counting strategy to aid in "counting out the tones." The counting strategy was "start, 1, 2, 3, 4, 1, 2, 3, 4." Each count represented one of the nine tones generated by the computer. The word "start" was used to mark the beginning of the first interval. A simplified version of Figure 25 was used to orient the subject to the task and to illustrate that the fifth tone or the first "4" in the counting strategy marked the end of I_1^* and the beginning of I_2^*.

Once the presentation of tones ended, there was a variable delay of .5 to 1.5 seconds, the hand instruction was cleared from the computer screen, and the subject began tapping when he/she was ready. The variable delay was needed for the computer program to complete the loop responsible for generating the tones. The variable delay was randomly distributed within each subject. There was no reaction time pressure to begin tapping. As the subject tapped, the IRI was measured to the nearest millisecond. After the subject completed nine taps, IRIs were graphed on the computer screen using the same procedure as in Experiments 1 and 2. As in the earlier xperiments, the subject also received feedback in the form of the percentage of taps in which the asterisks fell on the lines representing I_1^* and I_2^*. Figure 26 illustrates a sample trial presentation. Recall that in Experiments 1 and 2, the subject received feedback in the form of the percentage of taps in which the asterisks fell on the lines representing I_1^* and I_2^* for that trial and for all previous trials in that block. In Experiment 3, the subject received feedback in the form of the percentage of taps in which the asterisks fell on the lines representing I_1^* and I_2^* <u>for each serial position</u> for that trial and for all previous trials in that block. The purpose of this feedback was to draw the subject's attention to any interval in which the accuracy of performance was lower than any other interval. Also, if the subject consistently switched at the wrong interval, this Information was available after each trial. The purpose of this manipulation was, of course, to discourage subjects from switching at the wrong serial position.

Error feedback was also given to the subject after trials in which an error occurred. There were several ways in which a subject could make an error. First, if the subject started tapping too soon, before the hand instruction was cleared from the computer screen, an error message appeared on the computer screen saying, "YOU STARTED TOO SOON." Second, if the instruction was to use one hand and the subject used two hands or the instruction was to use two hands and the subject used one hand, an error message appeared on the computer screen saying, "WRONG HAND." Third, if the subject switched hands at the wrong serial position, an error message appeared on the computer screen saying, "WRONG HAND." The screen remained visible until the subject was ready to begin the next trial. When the subject was ready, he/she pressed a button to clear the screen and begin the next trial.

Each subject performed 48 repetitions of each hand x I_1^* x I_2^* condition. Conditions were presented in blocks such that within a block of trials, I_1^* was constant. The combination of hand and I_2^* was randomly presented such that within a block of trials the subject was presented one repetition of each hand and I_2^* condition. Blocks of trials were presented in sets of three such that each of the I_1^*s were presented once before any one was repeated. The first session consisted of a guided introduction to the procedure, one practice trial, and 24 blocks of experimental trials. The first session lasted 1 hour. The length of the remaining sessions was left to the subject's discretion (in order to accommodate schedules). The subject could choose to participate in 30 minute sessions in which 24 blocks of experimental trials were performed, or 1 hour sessions in which 48 blocks of experimental trials were performed. Experimental sessions were performed on consecutive days. During the final session each subject repeated trials in which an error occurred.

Results

Overview

Four dependent measures were analyzed: mean initiation time, and for each produced interval, mean IRI, log(sd), and CV. Mean initiation time was defined as the interval between the hand instruction being cleared from the computer screen and the first button response produced by the subject. Each subject began tapping when he/she was ready. There was no reaction time pressure. However, because the time subjects took to initiate a trial might reveal something interesting about the preparation of timing, mean initiation times were analyzed. The IRI was defined as the time between successive responses. The mean, log(sd), and CV of each IRI were calculated for each serial position for each condition for each subject. The smallest cell was comprised of a mean, log(sd), or CV based on 48 scores. Because of the complexity of the design, alpha was set at $p < .01$ for each analysis.

Each dependent measure was analyzed to evaluate the primary and secondary issues addressed in Experiment 3. The series of analyses was the same as in Experiment 2. The following is a preview of the series of analyses conducted to evaluate each issue. The details of each analysis are provided later.

The first series of analyses addressed the primary issue of changes in tapping performance which might reflect preparation for changes in the timing demands of the task and/or biomechanical interactions. To begin the series, an overall ANOVA was conducted on all data points for each subject (no trimming). Because these data were later trimmed and reanalyzed, these results are not discussed in detail. In order to take a closer look at changes in tapping performance which might reflect timing preparation and/or biomechanical interactions, the data were trimmed so that the remaining trials represented each subject's best trials at nonboundary intervals. An ANOVA and contrast tests were conducted on these data to investigate changes in tapping performance. These results are discussed in detail. The results of these analyses suggested that the subjects did not always switch from I_1^* to I_2^* at the correct serial position. In order to look closer at this possibility, the trimmed data were trimmed once again. The data trimmed first for best trials were trimmed a second time so that the remaining trials represented each subject's best trials at nonboundary intervals as well as best trials at the required switch. An ANOVA and contrast tests were conducted on these data to investigate switching effects. These data are discussed in detail.

The second series of analyses addressed the issue of context effects. Contrast tests were conducted on the data trimmed for best trials at nonboundary intervals in order to investigate the possibility that context dependencies of specific I_1^* and I_2^* combinations might account for variability in the data.

Mean Initiation Time

The initiation times were analyzed using a group (1 2, 3, 4) x hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) ANOVA. No effects or interactions were significant. The summary table for this analysis is provided in Appendix A.18.

Mean Interresponse Interval

Analyses Pertaining to Timing Preparation.

An ANOVA was conducted on the mean IRIs that evaluated the effects of group (1, 2, 3, 4) x hand (1, 2) x I_1^* (200, 400, and 600 ms) x I_2^* (200, 400, and 600 ms) x ±D (preswitch, postswitch). The effect of group was not significant and did not interact with any another variable, $p > .22$. Therefore, for further analyses the data were collapsed over group. The summary table for this analysis is provided in Appendix A.19.

The next ANOVA evaluated the effects of hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.20.

To examine changes in tapping performance which might reflect timing preparation and/or biomechanical interactions, it was necessary to use those trials which represented each subject's best performance. As in Experiments 1 and 2, best performance was defined as trials in which nonboundary intervals fell within ±35% of the I^*s. Nonboundary intervals included IRIs which did not surround the required switch. The trimming procedure was the same as used in Experiments 1 and 2. A trial was discarded if any nonboundary IRI fell outside the ±35% range of the I^*s. Thus, if one IRI fell outside the range, the entire trial was discarded. Table 3 shows the values used to trim the data for each I^*. Trimming the data with this procedure left unequal cell sizes for each condition for each subject. The number of untrimmed observations for each cell for each subject is provided in Appendix A.21. Note that subject S4 had a number of missing cells. Thus, the data from this subject were not included in any further analyses.

An ANOVA was conducted on the mean IRI data trimmed for best trials at nonboundary intervals that evaluated the effects of hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.22.

The highest-order significant interaction was the four-way interaction of I_1^* x I_2^* x |D| x ±D, $F(12, 84) = 3.11$, $p < .001$. Figure 27 illustrates this interaction. In each of the three graphs, I_1^* is constant. The left panels illustrate the mean IRIs for each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels illustrate the mean IRIs for each serial position at I_2^*. There are two noteworthy results from this four-way interaction. The first is that mean I_1s approximated the I^*s. The mean IRI produced when I_1^* equalled 200, 400, and 600 ms were 190ms, 397 ms, and 557 ms, respectively. The mean I_2s produced when I_2^* equalled 200, 400, and 600 ms were 196, 393 ms, and 560 ms, respectively. (The mean I_2s do not include B(1) because the mean value of I_2 at interval B(1) was systematically elevated.) The second result to note is that when I_1^* and I_2^* differed, mean I_2s at interval B(1) approximated a point halfway between I_1^* and I_2^*.

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The patterns of these effects and interactions were captured in the four-way interaction. Therefore, these results are not discussed in detail. Four three-way interactions were significant : $I_1^* \times I_2^* \times \pm D$, $F(4,28) = 8.28$, $p < .0002$; $I_1^* \times I_2^* \times |D|$, $F(12, 84) = 3.64$, $p < .0002$; $I_1^* \times |D| \times \pm D$, $F(6, 42) = 14.61$, $I_2^* < .0001$; and $I_2^* \times |D| \times \pm D$, $F(6, 42) = 19.39$, $p < .0001$. Several two way interactions were significant: $I_1^* \times I_2^*$, $F(4, 28) = 14.71$, $p < .0001$; $I_1^* \times \pm D$, $F(2, 14) = 544.50$, $p < .0001$; $I_2^* \times \pm D$, $F(2, 14) = 294.26$, $p < .0001$; $I_1^* \times |D|$, $F(6,42) = 14.12$, $p < .0001$; and $I_2^* \times |D|$, $F(6, 42) = 15.65$, $p < .0001$. Two main effects were significant: I_1^*, $F(2,14) = 632.38$, $p < .0001$, and I_2^*, $F(2,14) = 256.90$, $p < .0001$.

The three-way interaction of hand, I_1^*, and $|D|$ was significant, $F(6,42) = 3.17$, $p<.01$. Figure 28 illustrates this Interaction. When I_1^* equalled 200 ms, mean IRIs were consistently lower for the one-hand tapping conditions than for the two hand tapping conditions. Comparing the differences in mean IRIs when $|D|$ equalled 1 to the nonboundary intervals, when I_1^* equalled 200 ms, means IRIs were <u>less than</u> the mean IRIs at the nonboundary intervals, when I_1^* equalled 400 ms, mean IRIs were <u>equal to</u> mean IRIs at the nonboundary intervals, and when I_1^* equalled 600 ms, mean IRIs of were <u>greater than</u> mean IRIs at the nonboundary intervals. However, the result to note is that there were no significant interactions involving hand and $\pm D$ or hand and $I_1^* \times I_2^*$. This indicates that there were no biomechanical interactions due to switching from I_1^* to I_2^* or that the measure of mean IRI is insensitive to biomechanical interactions caused by rate changes. No other effects or interactions were significant, $p> .03$.

To examine more closely the effects in the data trimmed for best trials at nonboundary intervals, contrast tests were conducted on the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. These data are shown in Figure 27. The question of interest was whether there were changes in tapping performance at I_1^* that might reflect timing preparation of I_2^*. The contrast test was similar to that used in Experiment 2. Figure 12 provides a graphical representation of the contrast test used in

Experiment 2. The specific contrast compared two differences. The first difference served as the control. In Experiment 3, this was the difference in the mean IRI at interval A(4) versus the mean nonboundary intervals at I_1^* when I_1^* and I_2^* were equal. The second difference served as the comparison. In Experiment 3, this was the difference in the mean IRI at interval A(4) versus the mean nonboundary intervals at I_1^* when I_1^* and I_2^* differed. To ensure that any changes in performance reflected processes associated with changes in the timing demands of the task, the two differences just described, the control difference and the comparison difference, were subjected to contrast tests. Contrast tests were conducted twice for each I_1^* (200, 400, and 600 ms) shown in Figure 27. The result was that no significant differences were found, $p>.50$. Thus, there were no changes in tapping performance at I_1^* that were clearly related to timing preparation of I_2^*.

Nonetheless, there appeared to be changes in tapping performance at interval B(1) that potentally reflect timing preparation. Figure 29 illustrates the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. In each graph I_2^* is constant. The question of interest was whether there were changes in tapping performance at interval B(1) that reflected timing preparation of I_2^*. Again, the specific contrast compared two differences, the control difference and the comparison difference. The control difference was the difference in the mean IRI at interval B(1) versus the mean nonboundary intervals at I_2^* when I_1^* and I_2^* were equal. The comparison difference was the difference in the mean IRI at interval B(1) versus the mean nonboundary intervals at I_2^* when I_1^* and I_2^* differed. In order to ensure that any changes in performance reflected processes associated with changes in the timing demands of the task, the two differences were subjected to contrast tests. Contrast tests were conducted twice for each I_2^* shown in Figure 29. Several significant differences were found. Table 4 provides a summary of the results.

Every condition in which I_2^* was less than I_1^* resulted in a significant difference. One other condition was also significant: 600 x 600 versus 400 x 600. In each of these conditions, the comparison difference was greater than the control difference.

The finding that mean IRIs at interval B(1) approximated a point halfway between I_1^* and I_2^* when I_1^* and I_2^* differed indicated that the mixture effect seen in Experiment 2 was also present in Experiment 3. In order to partition the effects due to mixture and the effects due to changes in the timing demands of the task, the data were trimmed for best trials at the required switch. The procedure used was the same as in Experiment 2. The data were trimmed so that trials were discarded if the IRI at interval B(1) was ±35% away from I_1^*. The discarded trials represented each subject's best trials in trying to produce I_1^* at interval B(1). The remaining trials represented each subject's best trials at the nonboundary intervals and those trials in which subjects were trying to produce I_2^* at interval B(1). The number of remaining observations for each subject for each condition is provided in Appendix A.23.

Figure 30 shows mean IRIs trimmed both for best trials at nonboundary intervals and for best trials at the required switch as a function of I_1^*, I_2^*, |D|, and ±D. Planned contrast tests were not conducted due to missing data. Looking at Figure 30, there were no changes in tapping performance at I_1^* that obviously reflect timing preparation of I_2^*.

Figure 31 shows the same data as those shown in Figure 30. In this graph, I_2^* is constant. The question of interest was whether there were changes in performance at interval B(1) that might reflect preparation of I_2^*. Planned contrast tests were not conducted due to missing data. Looking at Figure 31, take note of two conditions: 200 x 600 and 600 x 200. In each of these conditions, the slopes of the comparison differences were steeper than the slopes of the control differences.

Summarizing the mean IRI data of Experiment 3 that might reflect timing preparation and/or biomechanical interactions, there were no changes in I_1s that clearly reflect timing preparation and/or biomechanical interactions. Further, there were no consistent biomechanical interactions that depended on switching from I_1^* to I_2^*. There were two effects at interval B(1); the effect due to mixture and the effect due to changes in the timing demands of the task. Planned contrast tests suggested that conditions most likely to be affected by mixture were ones in which I_2^* was less than I_1^*. Also, the 400 x 600 ms condition compared to the 600 x 600 ms condition showed a mixture effect. When trimmed for best trials at the required switch, the 600 x 200 and the 200 x 600 ms conditions seemed to have elevations In mean IRI at Interval B(1) compared to the mean IRI of nonboundary intervals. However, these differences could not be confirmed with contrast tests due to missing data.

Analyses Pertaining to Context Effects. The second series of analyses addressed the issue of context effects. Contrast tests were conducted on the data trimmed for best trials at nonboundary intervals to test for context dependencies of I_1^* and I_2^* combinations. The specific contrast compared the nonboundary intervals of those conditions in which I_1^*s were equal but the I_2^*s differed. For example, in the top graph of Figure 27, each line in the left panel represents the mean IRI produced by subjects when I_1^* equalled 200 ms. However, each time 200 ms was produced in a different context. In the 200 x 200 ms condition, the subjects produced 200 ms when I_2^* equalled 200 ms. In the 200 x 400 ms condition, the subjects produced 200 ms when I_2^* equalled 400 ms. In the 200 x 600 ms condition, the subjects produced 400 ms when I_2^* equalled 600 ms. Theoretically, whenever I_1^* equalled 200 ms, the mean IRIs should have been equal. Contrast tests were conducted on the nonboundary mean IRIs for data trimmed for best trials at nonboundary intervals to test this prediction. Table 5 provides the results from the contrast tests conducted on the I_1^*s. In the conditions where I_1^* and I_2^* differed, I_1^*s were overestimated compared to the I_1^*s of conditions where I_1^* and I_2^* were equal.

Table 6 provides the results from contrast tests conducted on the I_2^*s. These data are shown in Figure 31. For conditions yielding significnat contrasts, the mean of I_2^* was influenced by I_1^* in the following manner. If I_1^* was greater than I_2^*, I_2^* was overestimated in comparison to the respective I_2^* when I_1^* and I_2^* were equal. If I_1^* was less than I_2^*, the I_2^* was underestimated in comparison to the respective I_2^* when I_1^* and I_2^* were equal.

Summary of Mean IRI Analyses. There were no changes in mean IRI at I_1^* that clearly reflect timing preparation and/or biomechanical interactions. Further, the hand factor did not interact with any factors, ±D or $I_1^* \times I_2^*$, that would indicate that biomechanical interactions were involved with changes in the timing demands of the task. Again, this suggests that biomechanical interactions do not influence the timing demands of this task. There were two effects at interval B(1), the effect due to mixture and the effect due to changes in the timing demands of the task. According to planned contrast tests, the conditions in which the mixture effect occurred were those in which I_2^* was less than I_1^* and the 400 x 600 ms condition. When the data were trimmed for best trials at the required switch, there were too many missing data points to perform planned contrast tests.

The mean IRI data of Experiment 3 were also used to address the effect of context. The context effects were different depending on the production of I_1^* or I_2^*. In the conditions where I_1^* and I_2^* differed, I_1^*s were overestimated compared to the I_1^*s of conditions where I_1^* and I_2^* were equal. If I_1^* was greater than the I_2^*, I_2^* was overestimated in comparison to the respective I_2^* when I_1^* and I_2^* were equal. If I_1^* was less than I_2^*, the I_2^* was underestimated in comparison to the respective I_2^* when I_1^* and I_2^* were equal.

Log Standard Deviation

Analyses Pertaining to Timing Preparation. An ANOVA was conducted on the mean log(sd) that evaluated the effects of group (1, 2, 3, 4) x hand (1, 2) x I_1^* (200, 400, and 600 ms) x I_2^* (200, 400, and 600 ms) x ±D (preswitch, postswitch). The effect of group was not significant nor did it interact with any other variables. Thus, in further analyses the data were collapsed over group. Several other effects and interactions were significant. The summary table for this analysis is provided in Appendix A.24.

The next ANOVA evaluated the effects of hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.25.

To examine changes in tapping performance that might reflect timing preparation and/or biomechanical interactions, log(sd)s were calculated for the data trimmed for best trials at nonboundary intervals. An ANOVA was conducted on the trimmed data to evaluate the effects of hand (1, 2), I_1^* (200, 400, 600 ms), I_2^* (200, 400, 600 ms), |D| (1, 2, 3, 4)and ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.26.

The highest-order significant interaction was the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$, $F(12, 84) = 2.20$ $p < .01$. Figure 32 illustrates this interaction. In each of the three graphs I_1^* is constant. The left panels show the mean log(sd)s at each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels show the mean log(sd)s at each serial position at I_2^*. The result to note is the pattern at interval B(1). There was an increase in log(sd)s at interval B(1) for all conditions.

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The patterns of these effects and interactions were captured in the four-way interaction. Therefore, these results are not discussed in detail. Several three-way interactions were significant: $I_1^* \times I_2^* \times |D|$, $F(12, 84) = 3.05$, $p<.001$; $I_1^* \times I_2^* \times +D$, $F(12, 84) = 3.05$, $p < .001$; and $I_2^* \times |D| \times \pm D$, $F(6, 42) = 6.95$, $p < .0001$. Several two-way interactions were significant: $I_1^* \times I_2^*$, $F(4, 28) = 26.88$, $p < .0001$; $I_1^* \times \pm D$, $F(2, 14) = 51.28$, $p < .0001$; $I_2^* \times \pm D$, $F(2, 14) = 44.52$, $p < .0001$; and $|D|$ and $\pm D$, $F(3, 21) = 28.98$, $p < .0001$. Three main effects were significant: I_1^*, $F(2,14) = 51.43$, $p < .0001$; I_2^*, $F(2,14) = 25.34$, $p < .0001$; $|D|$, $F(3, 21) = 39.38$, $p <. 0001$; and $\pm D$, $F(1, 7) = 44.09$, $p < .0001$.

The three-way interaction of hand x I_1^* x $|D|$ was significant, $F(6, 42) = 3.06$, $p < .01$. Figure 33 shows the interaction. Looking at Figure 33, when I_1^* was 200 ms, the log(sd) at each serial position was less than the log(sd) when I_1^* was 400 or 600 ms. Further, when I_1^* was 200 ms, the difference in log(sd)s at $|D|$ equalled 1 versus the nonboundary intervals differed for 1 hand and 2 hands. The difference was greater for the two hand tapping conditions. No other effects or interactions were significant, $p> .03$.

The results to note from the log(sd) data were the dramatic increase of log(sd) at interval B(1) and the fact that the hand factor did not interact with factors involving changes in the timing demands of the task. To examine the changes in tapping performance more closely, contrast tests were conducted on the four-way interaction of I_1^*, I_2^*, $|D|$, and $\pm D$. These data are illustrated in Figure 31. The question of interest was whether there were changes in tapping performance at I_1^* that might reflect timing preparation of I_2^*. The specific contrast was the same as that used for the mean IRI data. Two differences, the control and the comparison, were subjected to contrast tests The contrast tests were conducted twice for each I_1^* condition shown in Figure 31. No significant results were found, $p>.50$.

Although there were no changes in tapping performance at I_1^* that clerly reflected timing preparation of I_2^*, there appeared to be changes in tapping performance at interval B(1) that appear to reflect timing preparation. Figure 34 shows the I_1^*, I_2^*, $|D|$, and $\pm D$ interaction. In each graph I_2^* is constant. The question of interest was whether ther were changes in tapping performance at interval B(1) that might reflect timing preparation. Again, the specific contrast compared two differences, the control difference and the comparison difference. Contrast tests were conducted twice for each I_2^* shown in Figure 34. Two significant differences were found: the 600 x 200 ms condition $F(1, 7) = 24.62$, $MS = .004$, $p < .001$, and the 200 x 600 ms condition $F(1, 7) = 13.27$, $MS = .029$, $p < .008$. In each case the comparison difference was greater than the control difference.

To separate the effects due to mixture and the effects due to changes in the timing demands of the task, the data originally trimmed for best trials at nonboundary intervals were trimmed for best trials at interval B(1). Log(sd) was calculated for these data. The data were assumed to represent each subject's best trials at nonboundary intervals as well as those trials in which the subjects tried to produce I_2^* at interval B(1). Planned contrasts were not conducted due to the large number of missing cells. Figure 35 shows these data. No changes in tapping performance at I_1^* are apparent in Figure 35.

Figure 36 illustrates the same data grouped by I_2^*. The question of interest was whether there were changes in performance at interval B(1) that might reflect timing preparation. Due to the small number of observations in some cells and the lack of observations in others, planned contrast tests were not conducted. However, it appears that the 200 x 400 and the 200 x 600 conditions have different slopes at interval B(1) compared to their respective control conditions.

Summarizing the log(sd) data that addressed the question of changes in performance that might reflect timing preparation and/or biomechanical interactions, there were no changes in tapping performance at I_1^*. Further, the hand factor did not interact with any factors involved with switching from I_1^* to I_2^*. There were two effects at interval B(1): the effect due to mixture and the effect due to changes in the timing demands of the task. The mixture effect was seen in conditions involving 200 and 600 ms. In each case the comparison difference was greater than the control difference. Once the effect due to mixture was removed, there were too many missing data points to perform planned contrast tests.

Analyses Pertaining to Context Effects. Context effects in log(sd) of performance were evaluated with contrast tests conducted on the data trimmed for best trials at nonboundary intervals. The specific contrast compared the mean log(sd) of nonboundary intervals for pairs of conditions in which the I_1^*s were equal and the I_2^*s differed. Table 7 presents the results for contrast tests conducted on the I_1^*s. If I_2^* was greater than I_1^*, I_1^* was overestimated. If I_2^* was less than I_1^*, I_1^* was underestimated.

Similar contrasts were conducted on pairs of conditions in which the I_2^*s were equal and the I_1^*s differed. Table 8 presents the results for the contrasts conducted on the I_2^*s. There is no simple description for the set of conditions which yielded significant results. Nor are the findings as systematic as the findings for the I_1^*s. When 400 ms was preceded by 600 ms, log(sd)s were higher when than when 400 ms was preceded by 400 ms. When I_2^* equalled 600 ms, log(sd)s were higher when it was preceded by 400 ms than when it was preceded by 200 ms. Finally, when 600 ms was preceded by 400 ms, log(sd)s were higher than when 600 ms was preceded by 600.

Summary of Log(Standard Deviation) Analyses. There were no changes in tapping performance at I_1^* that reflected timing preparation or biomechanical interactions. Further, the hand factor did not interact with any factors, ±D or $I_1^* \times I_2^*$, that would suggest biomechanical factors affected the timing demands of the task. Again, this suggests that biomechanical interactions are not involved with the specific changes in the timing demands of this task or that the measure is insensitive to biomechanical interaction. There were two effects at Interval B(1), the effect due to mixture and the effect due to changes in the timing demands of the task. The mixture effect was seen in conditions involving 200 and 600 ms. Once the effect due to mixture was removed, planned contrast tests were not conducted due to missing data.

Several effects of context were identified in the data. The most systematic effect was found in I_1^*s. When I_2^* was less than I_1^*, the log(sd) at I_1^* was overestimated. If I_2^* was less than I_1^*, I_1^* was underestimated. The effects of context were not so systematic for I_2^*. When 600 preceded 400 ms, log(sd)s were higher than when 400 preceded 400 ms. When 400 preceded 600 ms, log(sd)s were higher than when 200 preceded 600 ms. Finally, when 400 preceded 600 ms, log(sd)s were higher than when 600 preceded 600.

Coefficient of Variation

Analyses Pertaining to Timing Preparation. To evaluate the effects of group, CV was analyzed using an ANOVA that evaluated the effects of group (1, 2, 3, 4) x hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x ±D (preswitch, postswitch). Group was not significant and did not interact with any other variables. Thus, the data were collapsed over group for further analyses. The summary table for this analysis is provided in Appendix A.27.

The next ANOVA evaluated the effects of hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). The summary table for this analysis is provided in Appendix A.28.

In order to examine changes in tapping performance that might reflect changes in the timing demands of the task, it was necessary to use those trials which represented each subject's best trials at nonboundary intervals. An ANOVA was conducted on mean CV data trimmed for best trials at nonboundary intervals that evaluated the effects of hand (1, 2) x I_1^* (200, 400, 600 ms) x I_2^* (200, 400, 600 ms) x |D| (1, 2, 3, 4) x ±D (preswitch, postswitch). Several effects and interactions were significant. The summary table for this analysis is provided in Appendix A.29.

The highest-order significant interaction was the four-way interaction of I_1^*, I_2^*, |D| (1, 2, 3, 4), and ±D (preswitch, postswitch), $F(6, 42) = 3.36$, $p < .008$. Figure 37 shows this interaction. In each of the three graphs, I_1^* is constant. The left panels illustrate the mean CVs at each serial position at I_1^*, the vertical lines show the locations of the required switch, and the right panels illustrate the mean CVs at each serial position at I_2^*. The result to note is the increased CVs at interval B(1).

Whereas the above results concerned the four-way interaction, several lower-order interactions and main effects were significant. The three-way interaction of hand, I_1^*, and |D| was significant, $F(6,42) = 3.36$, $p < .009$. This interaction is illustrated in Figure 38. Looking at Figure 38, mean CVs were highest for |D| equalled 1. Also, for I_1^* equalled 200 and 600 ms, the mean CVs were higher for the two hand tapping conditions than for the one hand tapping conditions.

Several lower-order effects and interactions were also significant. The patterns of these effects and interactions were captured in the four-way interactions. Therefore, these results are not discussed in detail. Four two-way interactions were significant: $I_1^* \times I_2^*$, $F(4, 28) = 14.19$, $p < .0001$; $I_1^* \times \pm D$, $F(2, 14) = 10.02$, $p < .002$; $I_2^* \times \pm D$, $F(2,14) = 8.46$, $p < .0004$; and $|D| \times \pm D$, $F(3, 21) = 42.34$, $p < .0001$. Three main effects were significant: I_1^*, $F(2, 14) = 10.02$, $p < .002$; |D|, $F(3, 21) = 48.30$, $p < .0001$; and ±D, $F(1, 7) = 29.17$, $p < .001$. No other effects or interactions were significant, $p > .40$.

To examine the effects in the data trimmed for best trials at nonboundary intervals, contrast tests were conducted on the four-way interaction of I_1^*, I_2^*, |D|, and ±D. These data are shown in Figure 37. The question of interest was whether there were changes in the CV of tapping performance at I_1^* that might reflect timing preparation. The contrast tests were the same as those used for the mean IRI and log(sd) data. The contrast compared two differences, the control and the comparison. Contrast tests were conducted twice for each I_1^* (150, 200, and 400 ms) condition. No significant differences were found, $p>.50$.

Figure 39 illustrates the same four way interaction. In this figure the data are grouped by I_2^*. Contrast tests were conducted on these data to examine changes in tapping performance at interval B(1) that might reflect timing preparation. Again, the specific contrasts compared two differences, the control difference and the comparison difference. One significant difference was found $F(1, 7) = 34.17$, $MS = .0001$, $p < .0006$. The 400 x 600 ms condition was different from the 600 x 600 ms condition. The comparison difference was greater than the control difference.

To separate the effects due to mixture and the effects due to changes in the timing demands of the task, the data originally trimmed for best trials at nonboundary intervals were trimmed for best trials at interval B(1). CVs were calculated for these data. Figure 40 shows these data grouped by I_1^*. Planned contrast tests were not conducted due to missing data. Looking at this figure, it is clear that there were no changes in tapping performance at I_1^*.

Figure 41 shows the same data grouped by I_2^*. Again given the instability of the data, it is impossible to reach definitive conclusions about what they signify.

Summarizing the CV data that addressed the question of changes in tapping performance that clearly reflected timing preparation and/or biomechanical interactions, there were no changes in tapping performance at I_1^* that might reflect timing preparation and/or biomechanical interactions. Further, the hand factor did not interact with any factors involved with switching from I_1^* to I_2^*. The mixture effect was seen at interval B(1). The 400 x 600 ms condition compared to the 600 x 600 ms condition showed the mixture effect. Once the effect due to mixture was removed, planned contrast tests could not be conducted due to missing data points.

Analyses Pertaining to Context Effects. Context effects in CV were evaluated with contrast tests conducted on the data trimmed for best trials at nonboundary intervals. The specific contrast compared the mean nonboundary CV for pairs of conditions in which I_1^*s were equal and I_2^*s differed. The data are shown in Figure 37. Table 9 presents the results for contrasts conducted on the I_1^*s. Conditions in which significant differences were found involved the 400 x 400 and 600 x 600 ms conditions. In each significant contrast, the CV was higher for I_1^*s of the conditions in which I_1^* and I_2^* differed than for conditions in which I_1^* and I_2^* were the same.

Similar contrasts were conducted on pairs of conditions in which the I_2^*s were equal and the I_1^*s differed. These data are shown in Figure 39. Two effects of context were significant based on the contrast tests conducted on the I_2^* data. The CV for I_2^* was higher in the 600 x 400 ms condition than both the 200 x 400 and the 400 x 400 ms conditions. In both cases the I_1^*s were longer than the I_2^*s and the CVs of the I_2^*s were higher.

Summary of Coefficient of Variation Analyses. There were no changes in the CV at A(3) or at interval B(1) that reflected timing preparation or biomechanical interactions. Further, the hand factor did not interact with any factors, ±D or $I_1^* \times I_2^*$, that would indicate biomechanical interactions were involved with changes in the timing demands of the task. Again, this suggests that biomechanical interactions were not involved with the specific changes in the timing demands of this task or that the measure was insensitive to biomechanical interaction. There were two effects at interval B(1), the effect due to mixture and the effect due to changes in the timing demands of the task. The mixture effect was seen in comparing the 400 x 600 ms condition to the 600 x 600 ms condition. Once the effect due to mixture was removed, planned contrast tests could not be conducted due to missing data. However, the patterns in the data suggest that changes in tapping performance were due to changes in the timing demands.

A number of conditions were influenced by the effect of context. Conditions in which significant differences were found in the CVs at I_1^* involved the 400 x 400 and 600 x 600 ms conditions. In each significant contrast, the CV was higher for the I_1^*s of the conditions in which I_1^* and I_2^* differed than for conditions in which I_1^* and I_2^* were the same. Two effects of context were significant based on the contrast tests conducted on the I_2^* data. The CVs for I_2^* were higher in the 600 x 400 ms condition than in the 200 x 400 and the 400 x 400 ms conditions.

Discussion

The primary aim of Experiment 3 was to investigate the possibility that observed changes in tapping performance reflected biomechanical interactions. That is, instead of making changes in the timing parameter of a central motor program, subjects may have made changes in the motor periphery to accommodate the new response rates. There was no evidence that changes in tapping performance reflected biomechanical interactions involved with switching from I_1^* to I_2^*. The key evidence was the lack of an interaction involving the factor of hand with general rate changes (±D) or with specific changes from I_1^* to I_2^*.

However, there were changes in tapping performance that appeared to reflect the effects of mixture and/or changes in timing demands. The relevant evidence is seen at the first interval after the required switch, interval B(1). The effect due to mixture stemmed from the fact that subjects did not always switch from I_1^* to I_2^* at the correct serial position. The effect due to mixture was first seen in Experiment 2. In Experiment 2 it was hypothesized that subjects incorrectly tried to impose a hierarchical structure on the sequence of tones, which resulted in switching at the wrong serial position. The outcome of Experiment 3 suggests that this account is not accurate. In Experiment 3, the number of intervals at I_1^* equalled the number of intervals at I_2^*. Further, subjects were instructed to use a counting strategy to aid in correct parsing of the sequence. However, the effect due to mixture still appeared. Conditions in which the mixture effect occurred included conditions where I_2^* was less than I_1^* as well as the 400 x 600 ms condition. In each of these conditions, the mean IRI approximated a point halfway between I_1^* and I_2^*. The effect due to mixture was also present in the log(sd) data. For conditions involving 200 and 600 ms, the comparisons were higher than for the control differences. The effect due to mixture was also present in the CV data. The CV was higher at interval B(1) in the 400 x 600 ms condition compared to the 600 x 600 ms condition. The fact that the effect due to mixture was so prevalent in the data of Experiment 3, suggests that the source of the parsing difficulty remains to be identified. The implications of the parsing difficulty in Experiments 2 and 3 will be discussed in the General Discussion.

The second effect seen at interval B(1) was the effect of changes in timing demands. In Experiment 2 , this effect was seen in the data trimmed for best trials at the required switch. No conclusions were drawn from the findings of Experiment 2 relating to this effect due to the fact that planned contrast tests could not be conducted. Unfortunately, planned contrast tests could not be conducted on the data from Experiment 3 for the same reason. Thus, no conclusions about this issue can be drawn from the data. However, conjectures about of the findings can be given, and they are presented in the General Discussion.

Experiment 3 was also designed to investigate the possibility that some of the variability in the produced IRIs could be accounted for by context dependencies of specific I_1^* and I_2^* combinations. While the findings from Experiment 2 concerning context effects were inconsistent, the findings of Experiment 3 were highly systematic. Summarizing the mean IRI data, context effects were different depending on the relation of I_1^* and I_2^*. In the conditions where I_1^* and I_2^* differed, I_1^*s were overestimated compared to the I_1^*s of conditions where I_1^* and I_2^* were equal. If I_1^* was greater than I_2^*, I_2^* was overestimated in comparison to I_2^* when I_1^* and I_2^* were the same. If I_1^* was less than I_2^*, I_2^* was underestimated in comparison to I_2^* when I_1^* and I_2^* were equal.

The context effects found in the log(sd) data were not quite so systematic. The most systematic effect was found in the I_1^*s. When I_2^* was less than I_1^*, log(sd)s at I_1^* were higher than when I_1^* equalled I_2^*. If I_2^* was less than I_1^*, log(sd)s at I_1^* were lower than when I_1^* equalled I_2^*. The effects of context were not so systematic for the I_2^* data. When 600 preceded 400 ms, log(sd)s were higher than when 400 preceded 400 ms. When 400 preceded 600 ms, log(sd)s were higher than when 200 preceded 600 ms. Finally, when 400 preceded 600 ms, log(sd)s were higher than when 600 preceded 600. Conditions in which context effects were found in the CV data at I_1^* were all comparisons involving the 400 x 400 and 600 x 600 ms conditions. In each significant contrast, the CV was higher for the I_1^*s of the conditions in which I_1^* and I_2^* differed than for conditions in which I_1^* and I_2^* were equal. Two effects of context were significant on the I_2^* CV data. The CVs for I_2^* were higher in the 600 x 400 ms condition than both the 200 x 400 and the 400 x 400 ms conditions. Thus, the results of Experiment 3 provided strong support for context dependencies of specific I_1^* and I_2^* combinations.

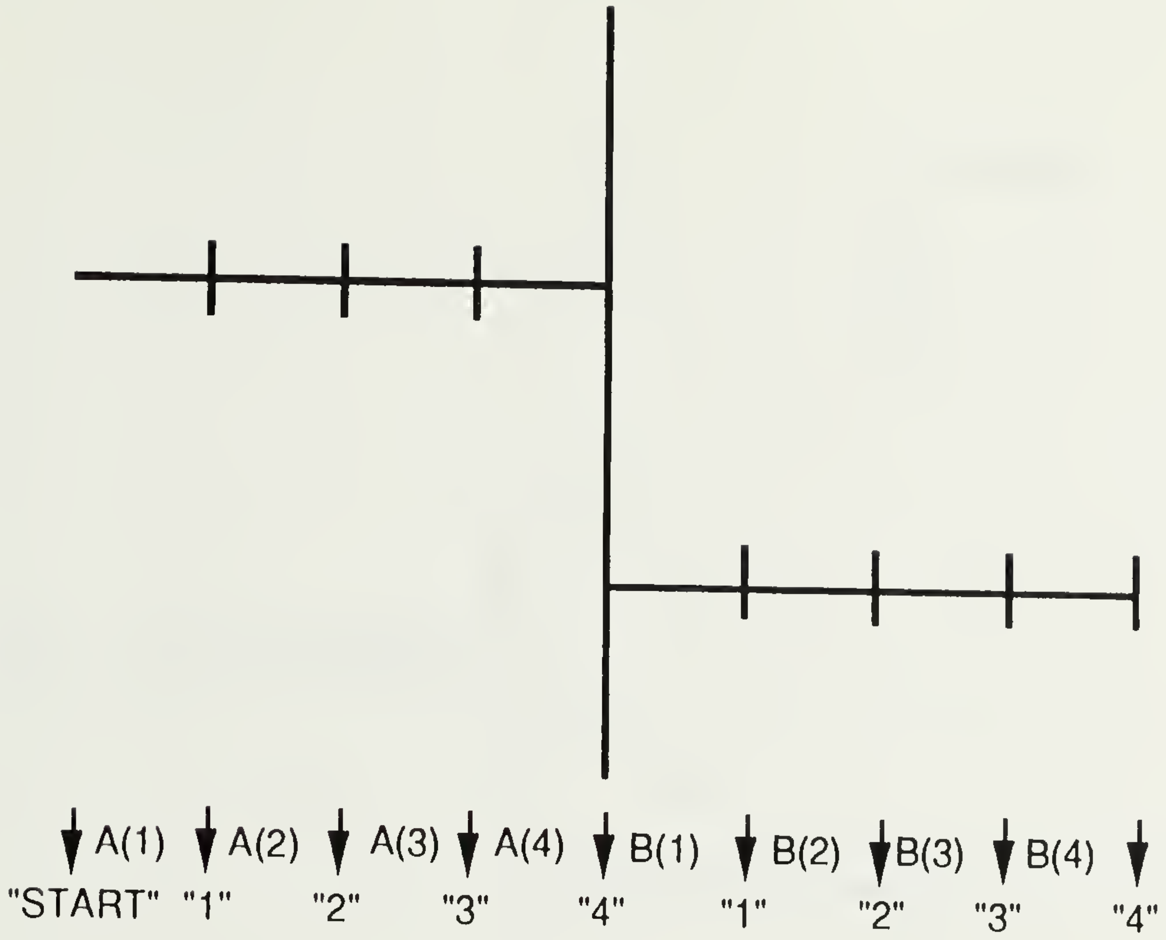

Figure 25. Example of the presentation of the IRIs produced by the subject mapped onto the presentation of I_1^* and I_2^* for Experiment 3. The arrows under the presentation of I_1^* and I_2^* represent the taps produced by the subject. Each IRI produced by the subject is labelled according to its serial position within I_1^*, (A), or I_2^*, (B).

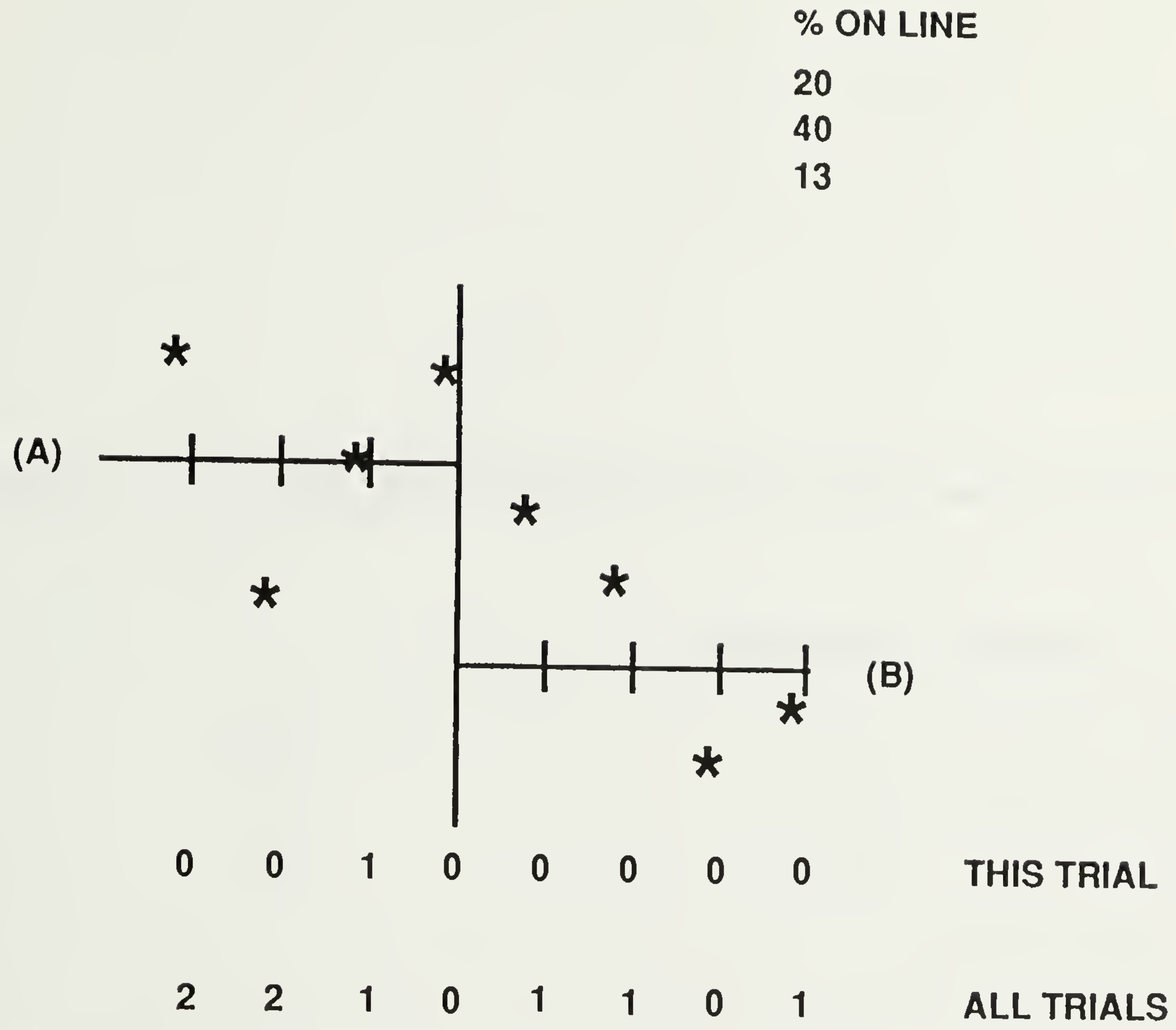

Figure 26. Example of presentation of I_1^* and I_2^* in Experiment 3. As the subject taps, interresponse intervals were measured and the corresponding interresponse times were graphed (*) on the screen in proportion to the I^*s. Interresponse time is represented on the ordinate. Sample number is represented on the abscissa.

Table 3. The actual values (in ms) used to trim the data for each I^* using 35% trimming criterion for Experiment 2.

I^*	LOWER LIMIT	UPPER LIMIT
150	97	203
200	130	270
400	260	540

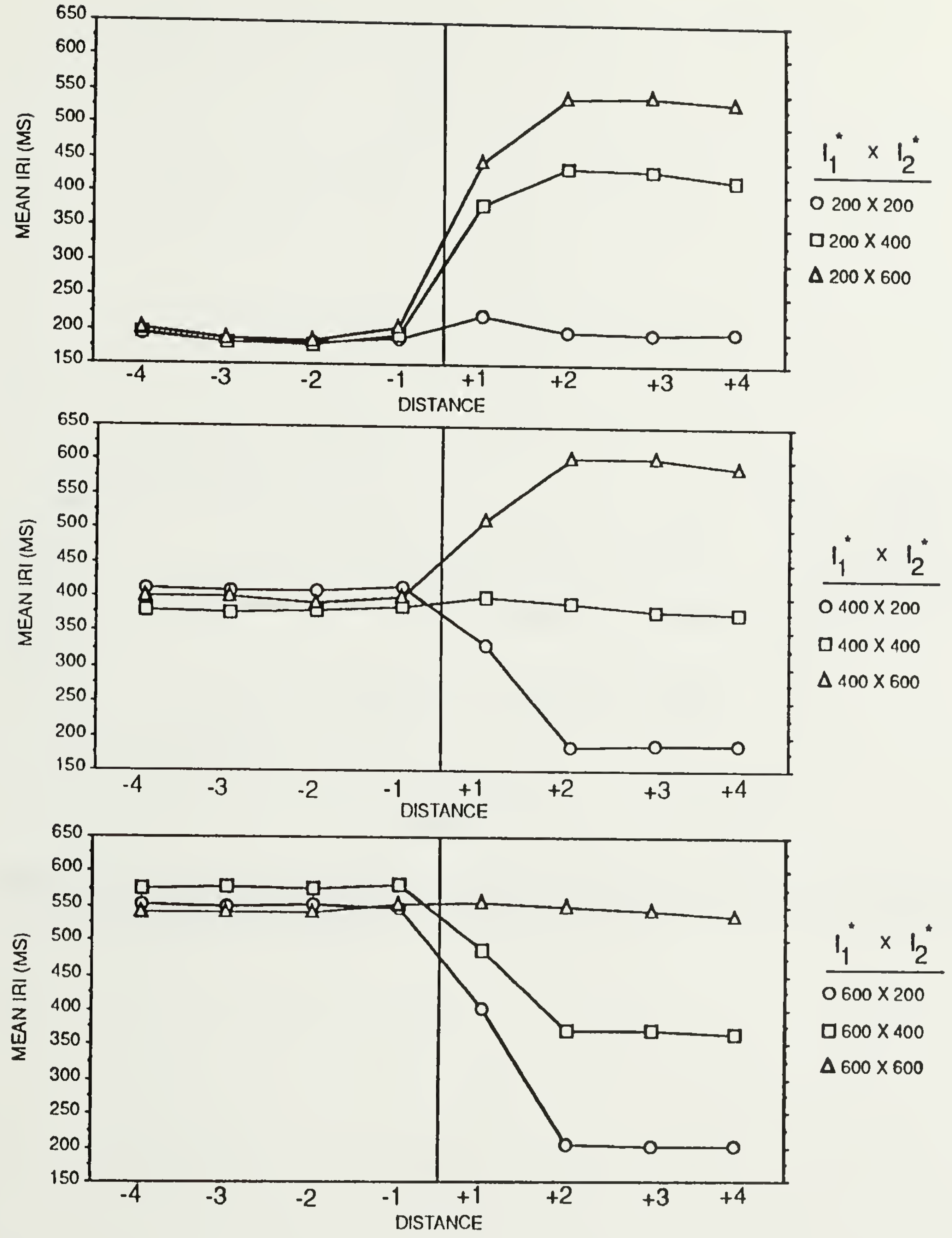

Figure 27. Mean IRI of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

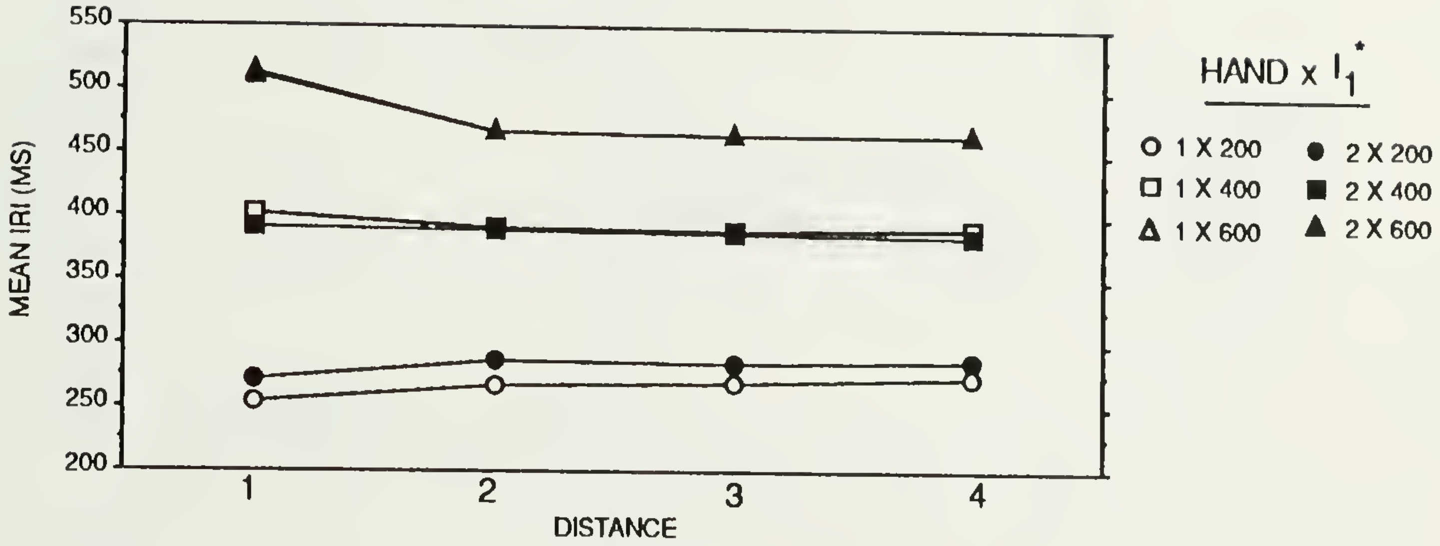

Figure 28. Mean IRI of data trimmed for best trials as a function of hand, I_1^*, and |D| for Experiment 3. In each graph I_1^* is constant.

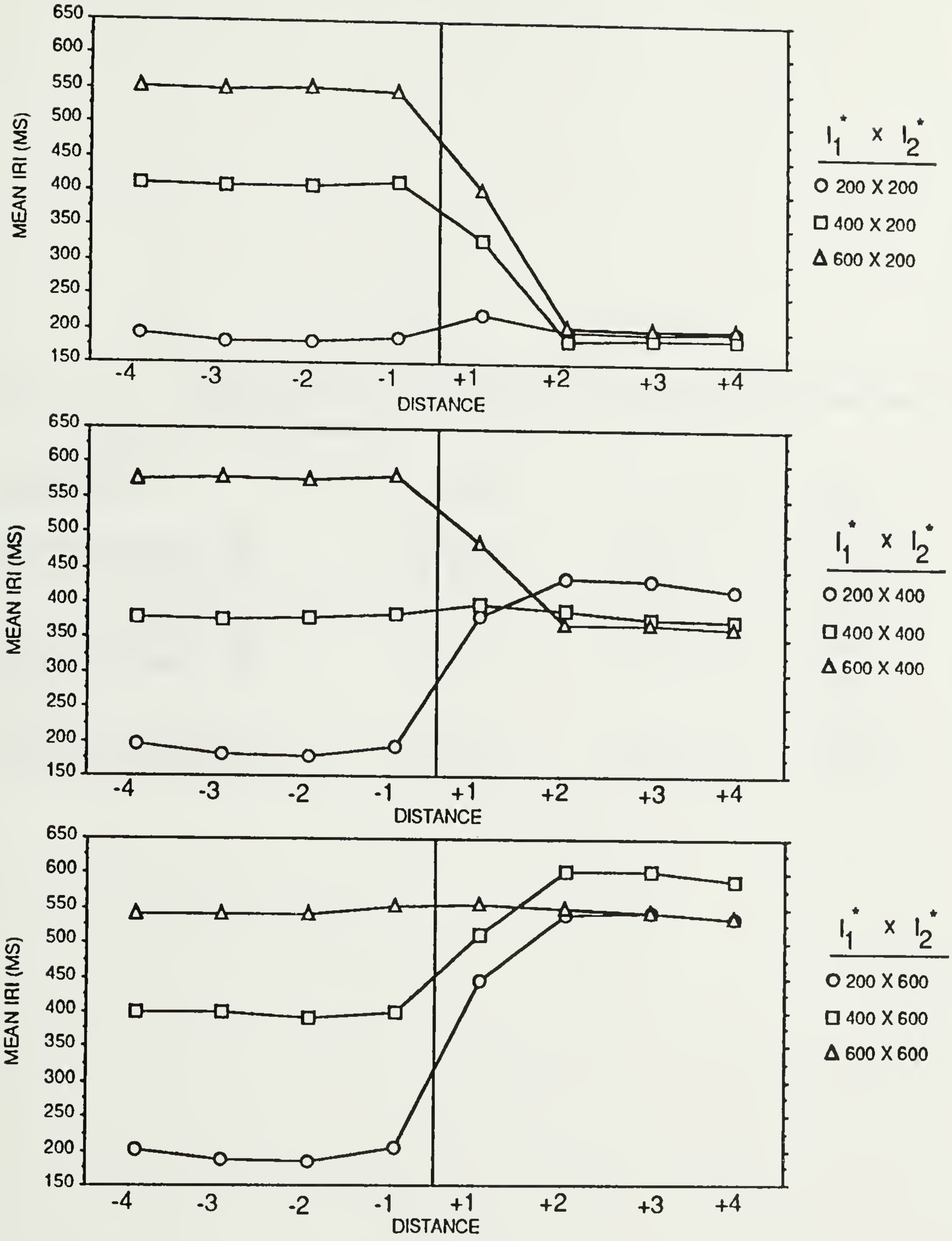

Figure 29. Mean IRI of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_2^* is constant.

Table 4. Summary table for contrast tests conducted on I_2^*s for mean IRI as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	p≤
200 x 200 vs 400 x 200	2425.95	13.50	.007*
200 x 200 vs 400 x 600	42.87.66	14.49	.006*
400 x 400 vs 200 x 400			.04
400 x 400 vs 600 x 400	1337.39	14.46	.006*
600 x 600 vs 200 x 600			.03
600 x 200 vs 400 x 600	2146.84	14.67	.006*

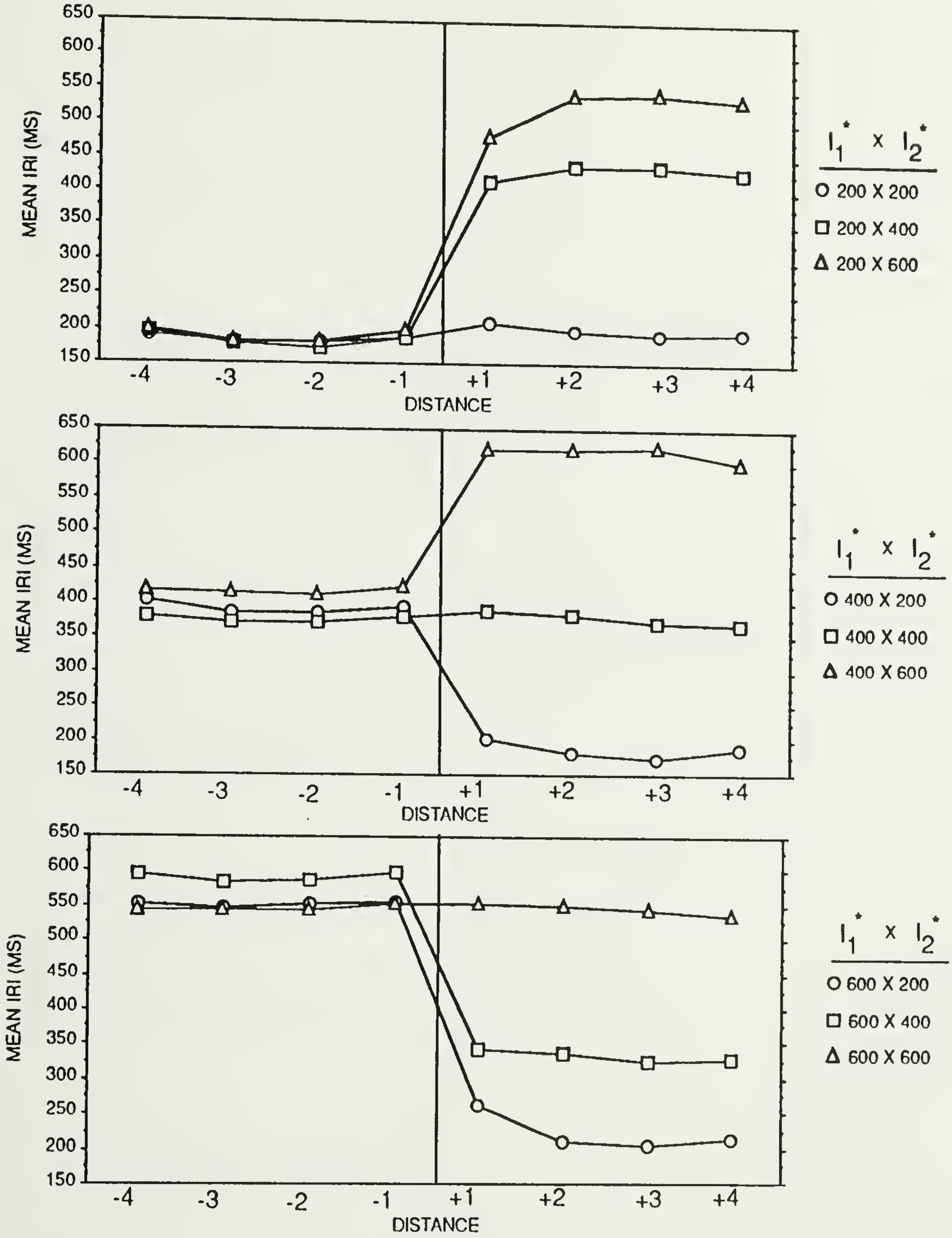

Figure 30. Mean IRI of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

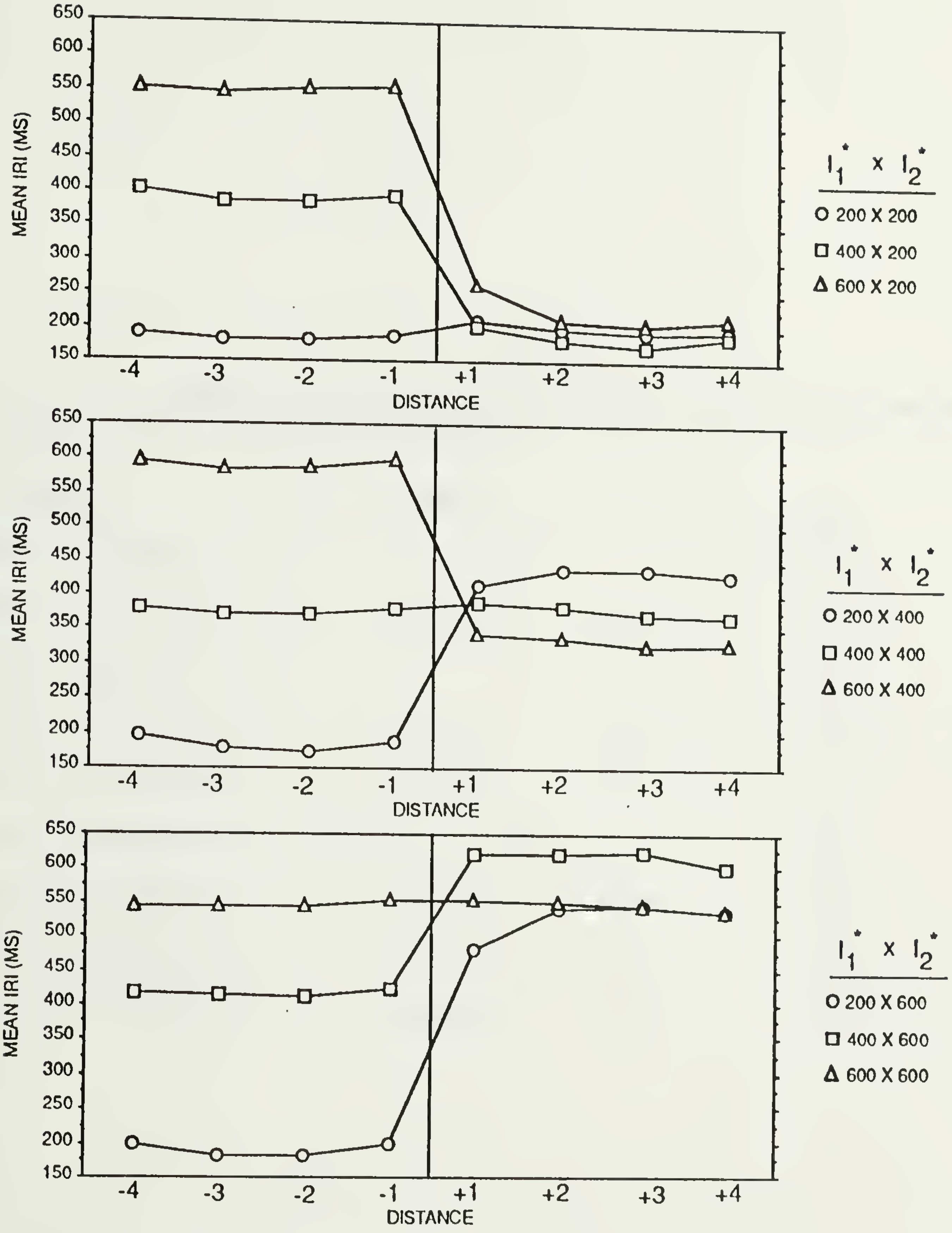

Figure 31. Mean IRI of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_2^* is constant.

Table 5. Summary table for context effect contrasts conducted on the I_1^*s of mean IRI as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	p<
200 x 200 vs 200 x 400			NS
200 x 200 vs 200 x 600	58.69	14.45	.006*
200 x 400 vs 200 x 600			NS
400 x 400 vs 400 x 200	179.14	64.54	.0001*
400 x 400 vs 400 x 600	515.43	9.63	.01*
400 x 200 vs 400 x 600			NS
600 x 600 vs 600 x 200	470.19	28.36	.001*
600 x 600 vs 600 x 400	102.76	9.19	.01*
600 x 200 vs 600 x 400	485.52	14.79	.006*

Table 6. Summary table for context effect contrasts conducted on the I_2^*s of mean IRI as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	p≤
200 x 200 vs 400 x 200			.04
200 x 200 vs 600 x 200			.08
400 x 200 vs 600 x 200			.04
400 x 400 vs 200 x 400	826.62	45.79	.003*
400 x 400 vs 600 x 400			.80
200 x 400 vs 600 x 400	3743.51	11.57	.01*
600 x 600 vs 200 x 600			.51
600 x 600 vs 400 x 600	6188.45	11.11	.01*
200 x 600 vs 400 x 600	2274.35	18.55	.003*

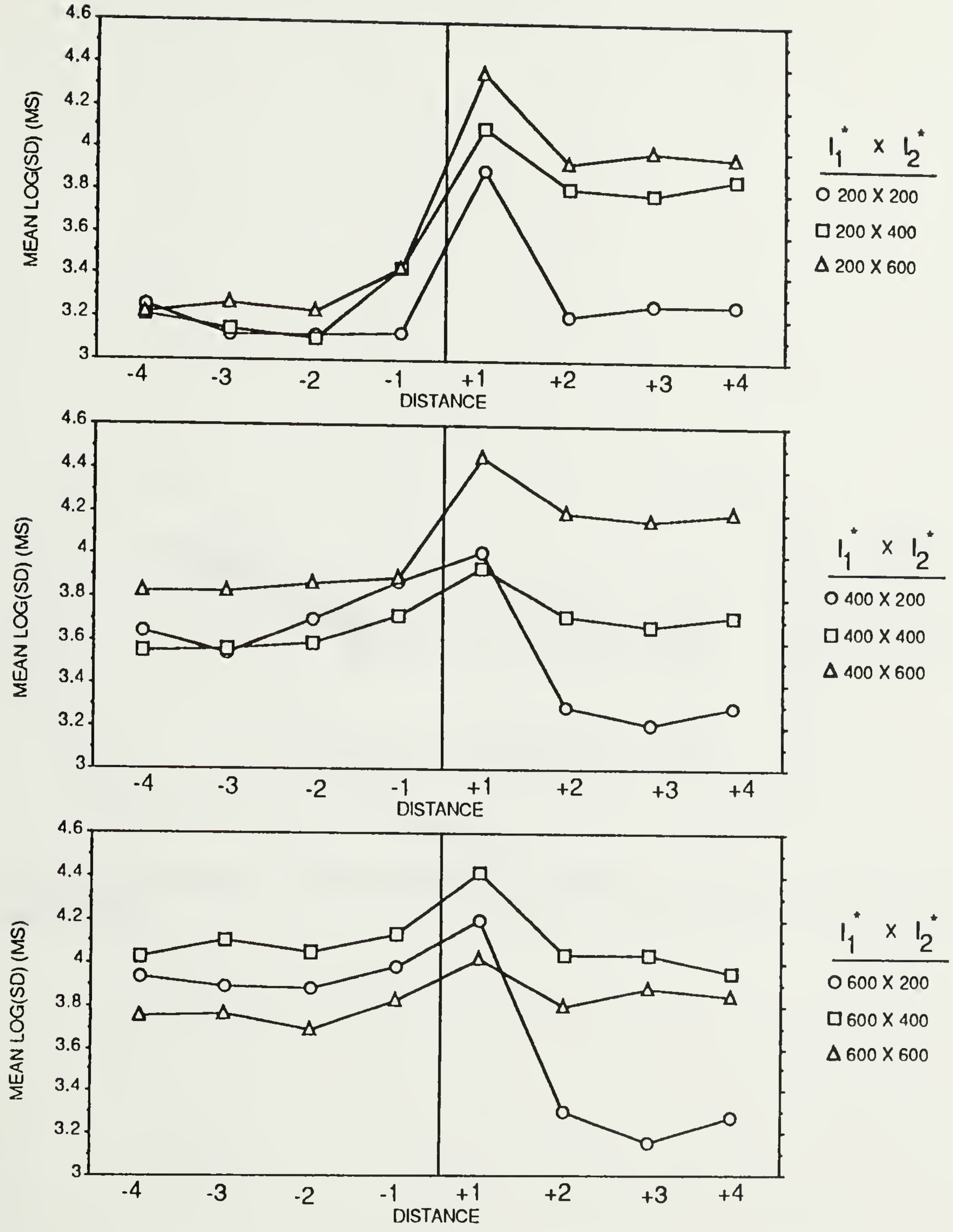

Figure 32. Mean log(sd) of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

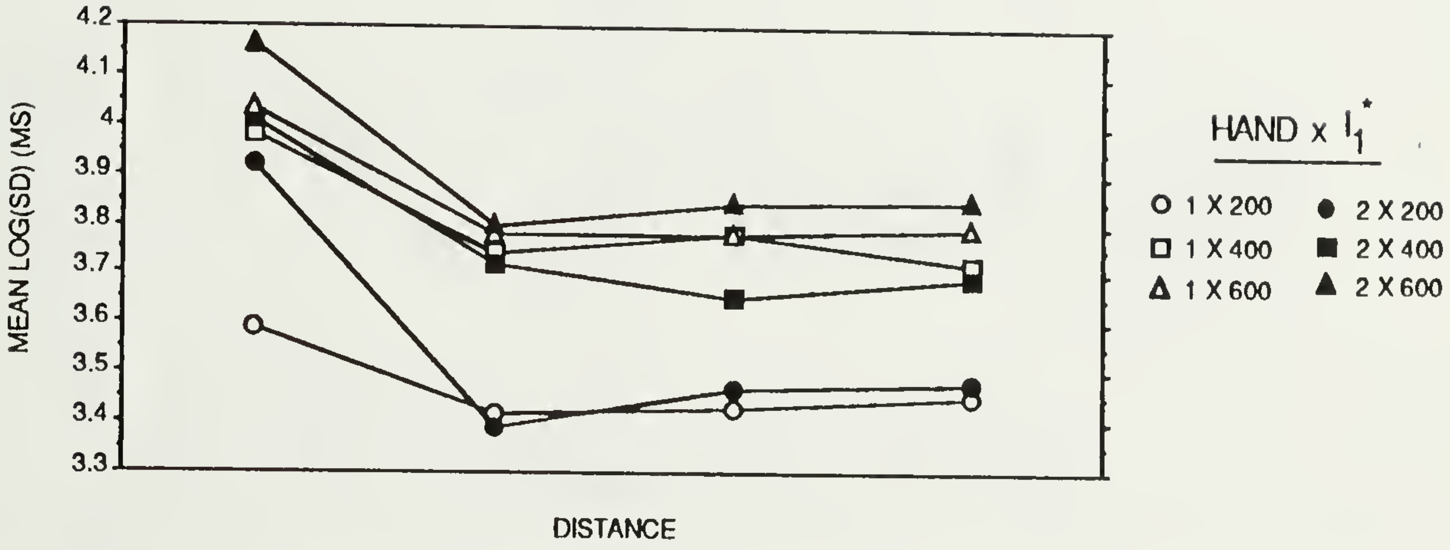

Figure 33. Mean log(sd) of data trimmed for best trials as a function of hand, I_1^*, and |D| for Experiment 3.

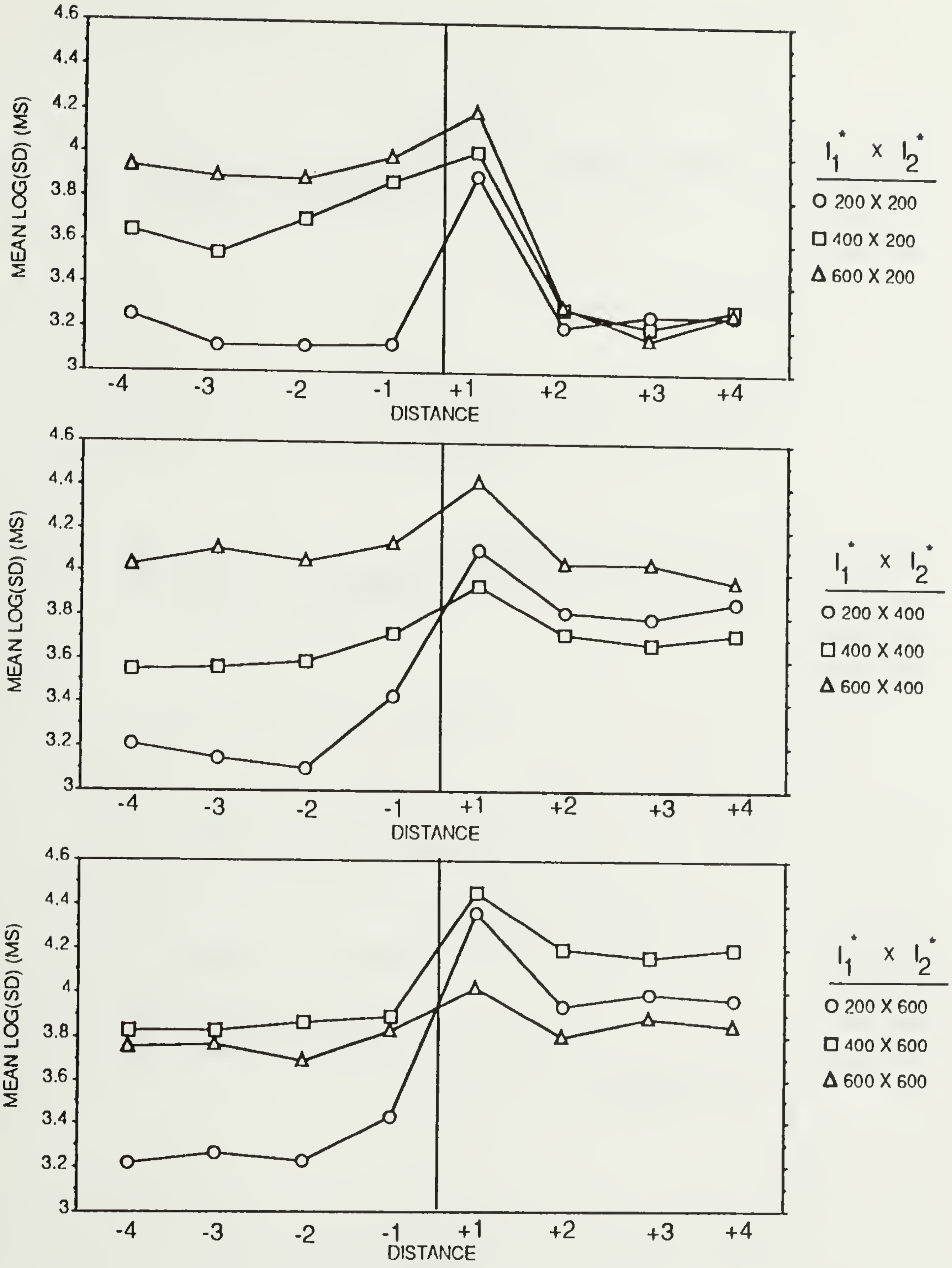

Figure 34. Mean log(sd) of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_2^* is constant.

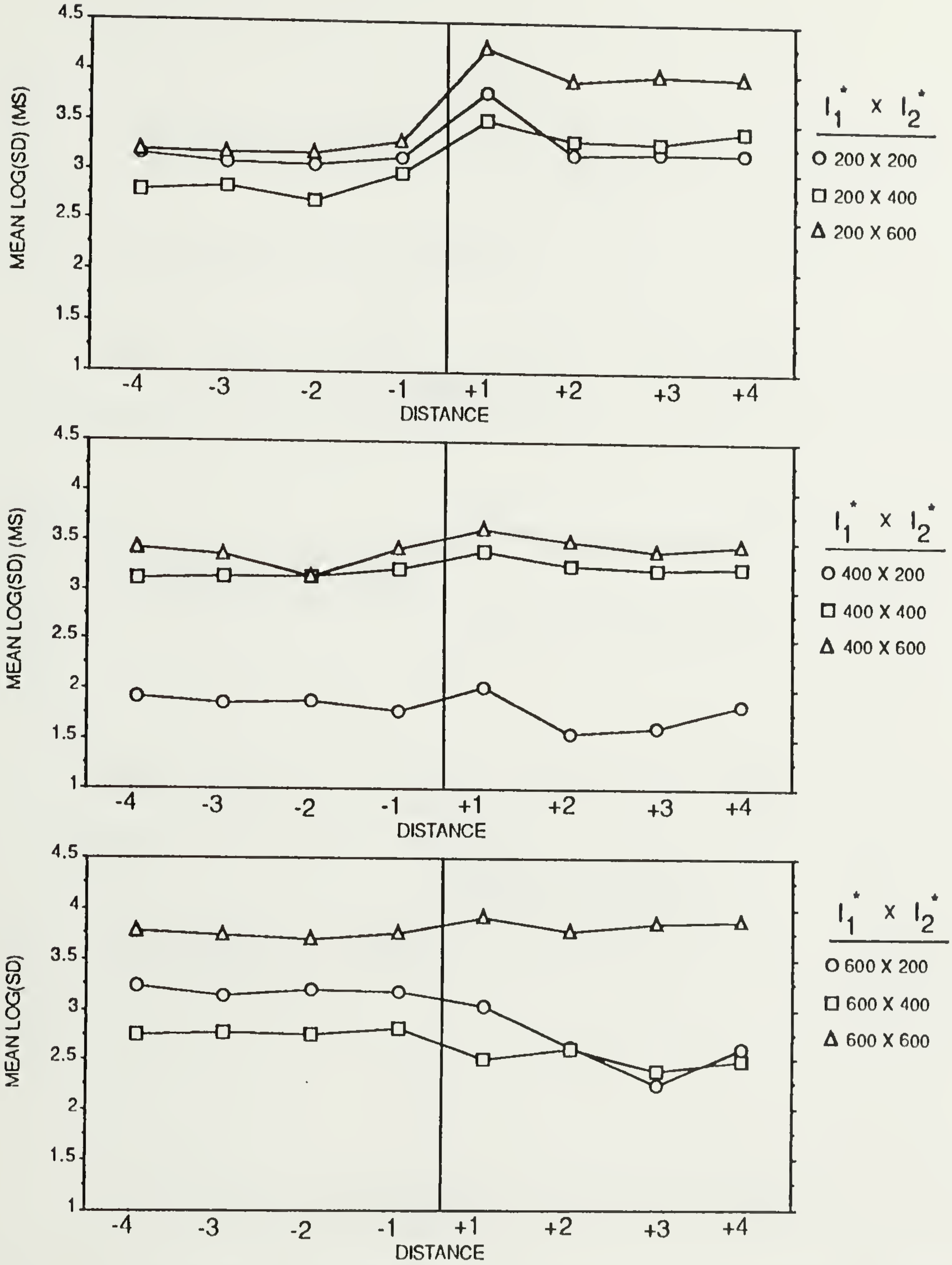

Figure 35. Mean log(sd) of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

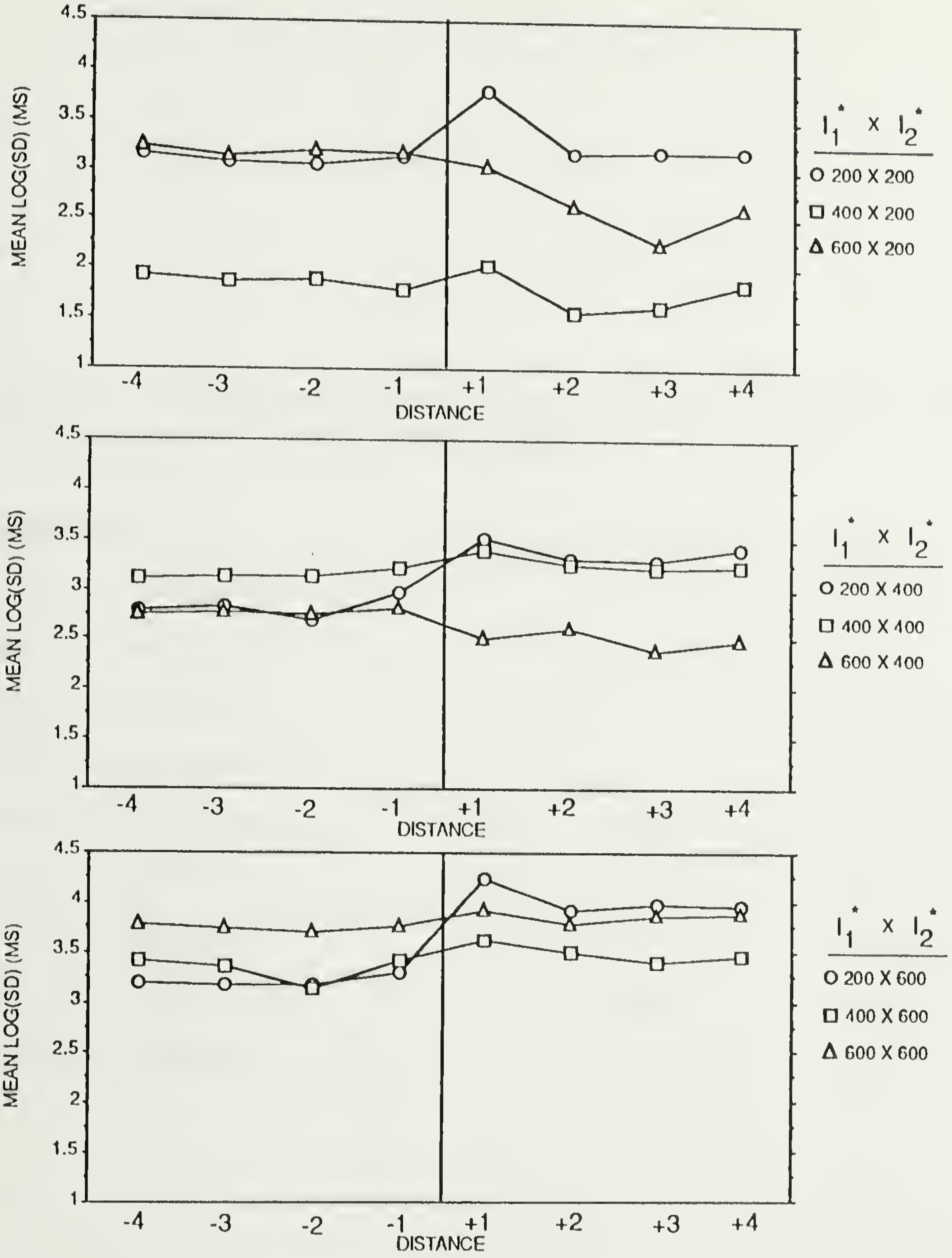

Figure 36. Mean log(sd) of data trimmed for best trials and best performance at Interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_2^* is constant.

Table 7. Summary table for context effect contrasts conducted on the I_1^*s of mean log(sd) as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	p≤
200 x 200 vs 200 x 400			.82
200 x 200 vs 200 x 600			.02
200 x 400 vs 200 x 600			.47
400 x 400 vs 400 x 200			.40
400 x 400 vs 400 x 600	.026	45.77	.0003*
400 x 200 vs 400 x 600	.04	17.96	.003*
600 x 600 vs 600 x 200			.03
600 x 600 vs 600 x 400	.04	33.80	.0007*
600 x 200 vs 600 x 400			.06

Table 8. Summary table for context effect contrasts conducted on the I_2^*s of mean log(sd) as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	p≤
200 x 200 vs 400 x 200			.70
200 x 200 vs 600 x 200			.60
400 x 200 vs 600 x 200			.40
400 x 400 vs 200 x 400			.03
400 x 400 vs 600 x 400	.04	27.96	.001
200 x 400 vs 600 x 400			.04
600 x 600 vs 200 x 600			.07
600 x 600 vs 400 x 600	.05	30.00	.0006
200 x 600 vs 400 x 600	.039	21.22	.002

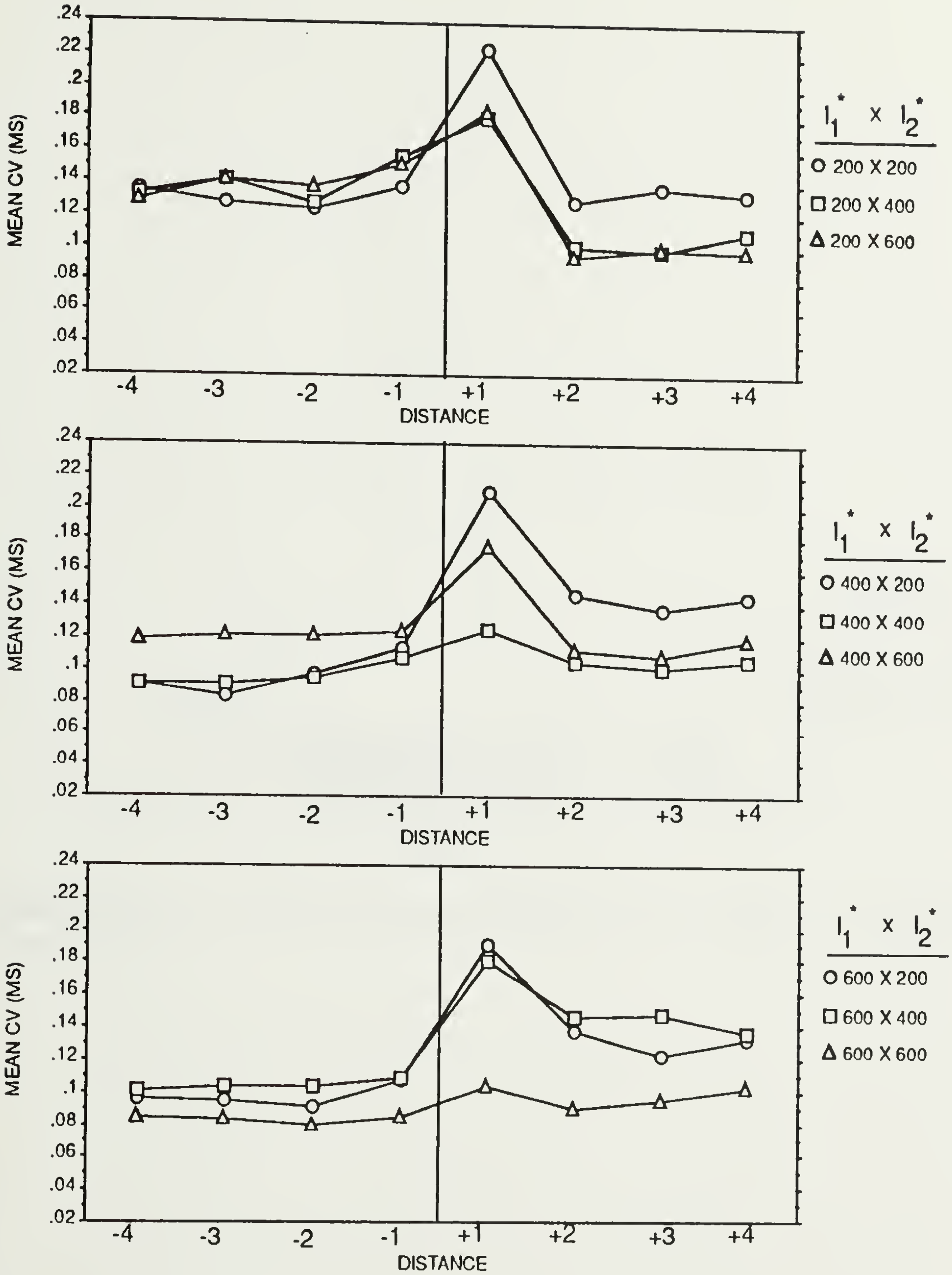

Figure 37. Mean CV of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

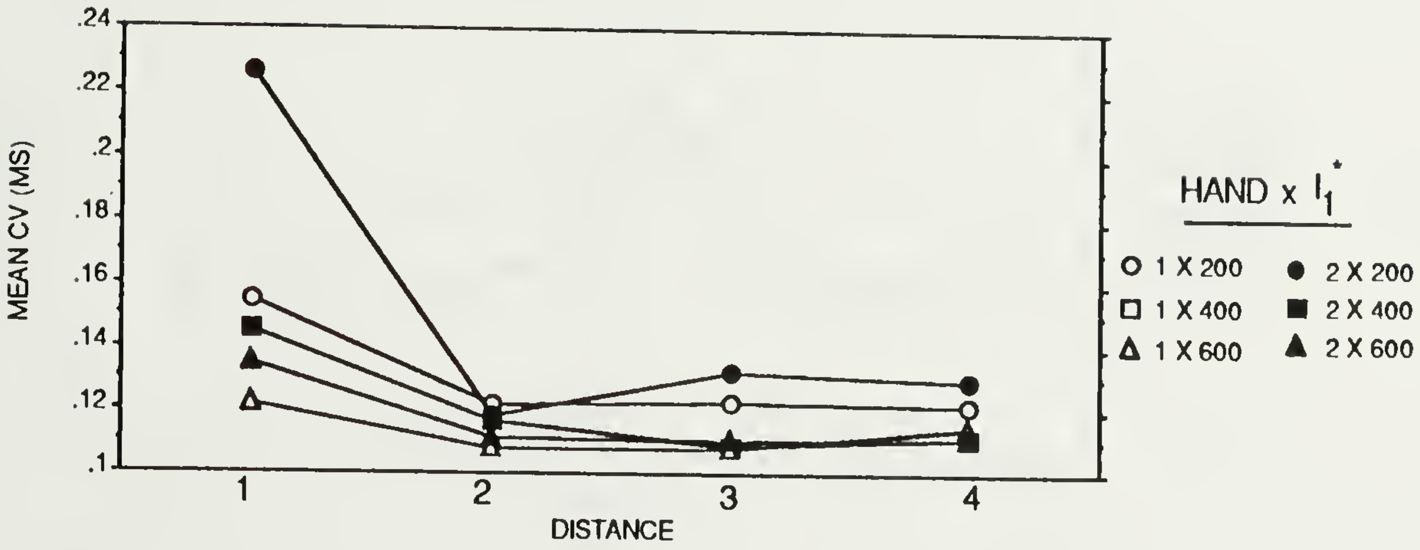

Figure 38. Mean CV of data trimmed for best trials as a function of hand, I_1^*, and |D| for Experiment 3.

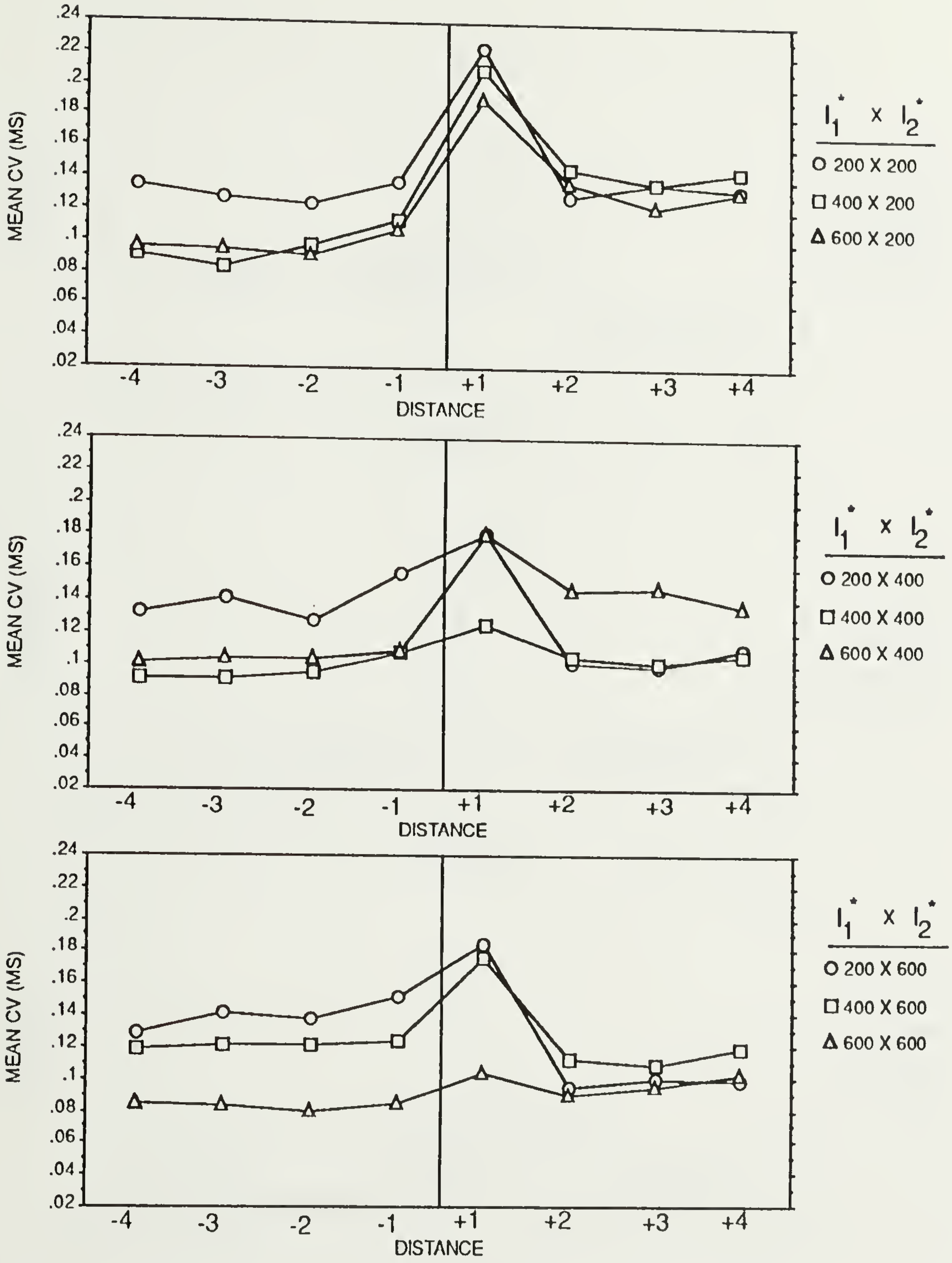

Figure 39. Mean CV of data trimmed for best trials as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_2^* is constant.

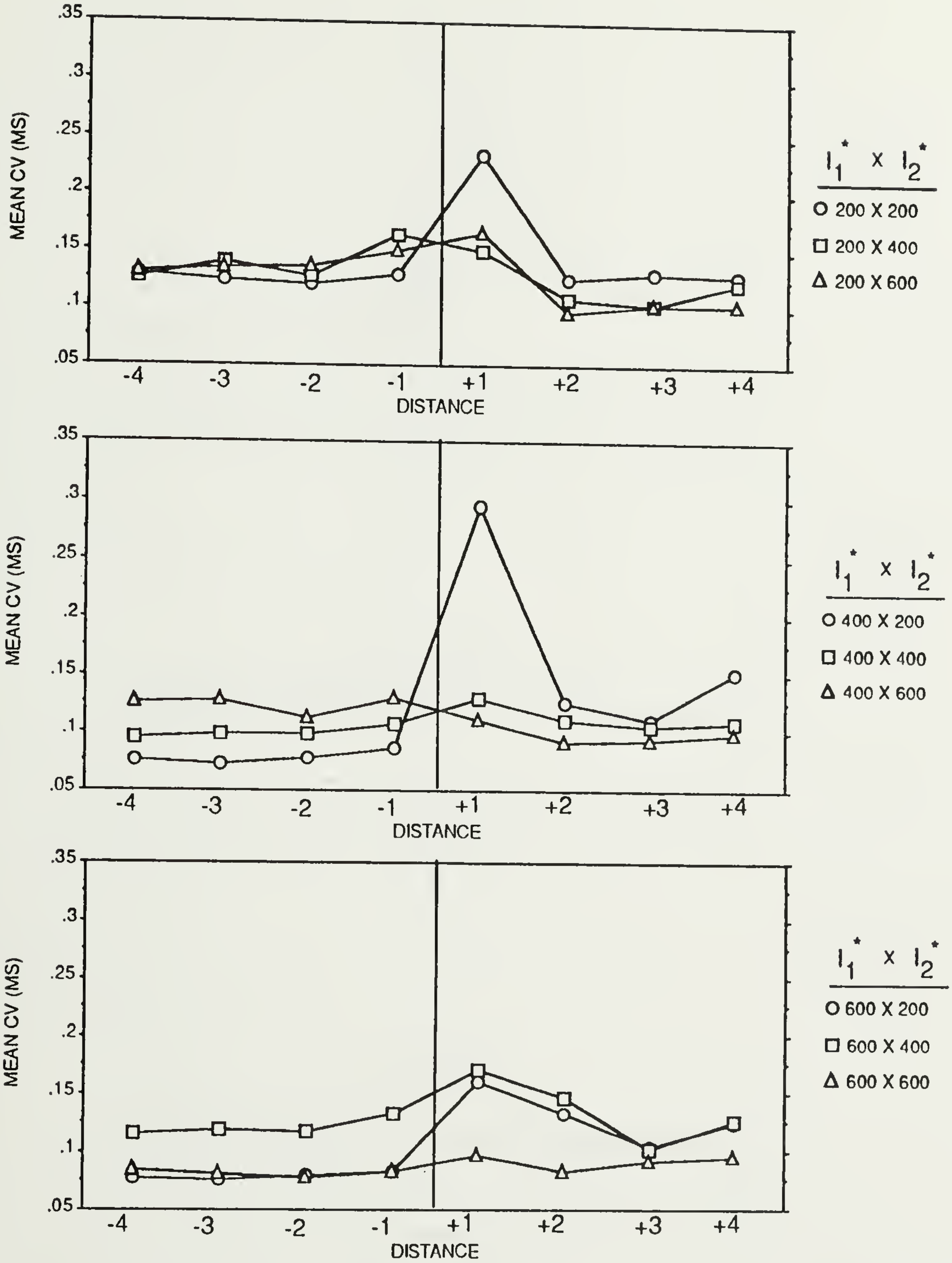

Figure 40. Mean CV of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, |D|, and ±D for Experiment 3. In each graph I_1^* is constant.

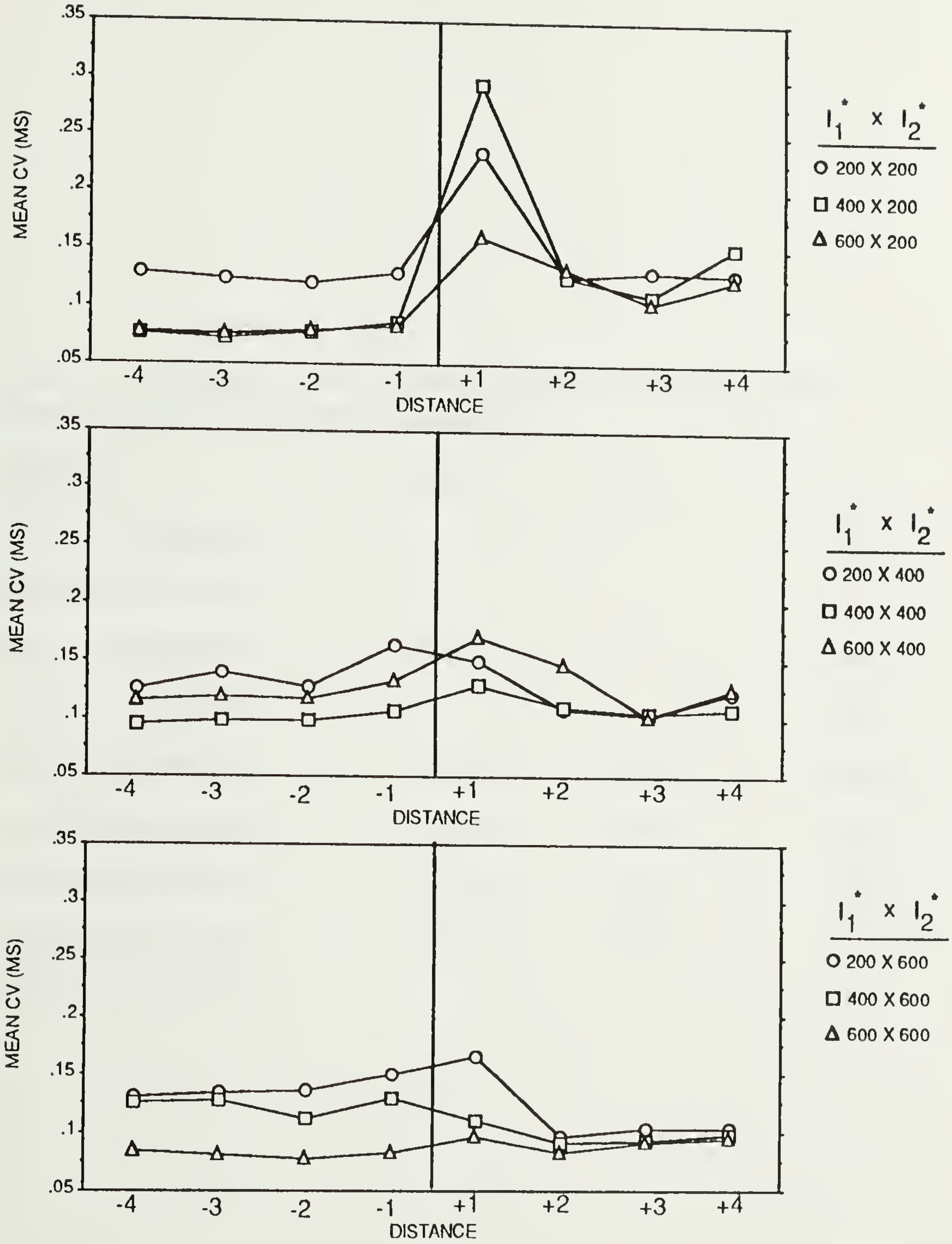

Figure 41. Mean CV of data trimmed for best trials and best performance at interval B(1) as a function of I_1^*, I_2^*, $|D|$, and $\pm D$ for Experiment 3. In each graph I_2^* is constant.

Table 9. Summary table for context effect contrasts conducted on the I_1^*s of mean CV as a function of $I_1^* \times I_2^* \times |D| \times \pm D$ for Experiment 3.

CONDITION	MSe	F	$p \leq$
200 x 200 vs 200 x 400			.13
200 x 200 vs 200 x 600			.11
200 x 400 vs 200 x 600			.95
400 x 400 vs 400 x 200			.73
400 x 400 vs 400 x 600	.0001	33.29	.0007*
400 x 200 vs 400 x 600	.0001	24.24	.001*
600 x 600 vs 600 x 200	.0002	14.33	.006*
600 x 600 vs 600 x 400	.0001	29.07	.0001*
600 x 200 vs 600 x 400			.12

CHAPTER 5

GENERAL DISCUSSION

The primary aim of this research project was to examine the nature of the process which prepares the timing of sequenced finger tapping. Evidence from Experiments 1, 2, and 3 suggested that subjects did not take advantage of advance timing information to prepare for the later portion of a sequenced finger tapping task. Instead, it appears that subjects prepared for the later portion of the tapping task once tapping at I_1^* was completed. This finding was supported by mean IRI, log(sd), and CV data from each of the experiments. The results of Experiment 3 ruled out the possibility that the effects found in Experiments 1, 2 and 3 were merely biomechanical interactions involved with changes in the timing demands of the task. However, the details of the process which prepares the timing of sequences finger tapping remain unclear.

The results of Experiments 2 and 3 were clouded by mixture errors. Mixture errors resulted from the fact that subjects did not always switch from I_1^* to I_2^* at the correct serial position. That is, subjects seem to have had problems parsing some sequences. This effect was present in the mean IRI data trimmed on the basis of best trials at nonboundary intervals. In Experiment 2, the conditions that were most prone to mixture errors were conditions in which I_2^* was less than I_1^*. Why did subjects switch at the wrong serial position? One explanation was that the difficulty stemmed from the fact that there were three intervals to be produced at I_1^* and four intervals to be produced at I_2^*. If subjects tried to impose a hierarchical structure on the sequence of tones, they might have placed four intervals at I_1^* with the intention of placing four intervals at I_2^*. This would result in subjects switching at the wrong serial position. This alternative was rejected by the results of Experiment 3. In Experiment 3, the number of intervals to be produced at I_1^* were equal to the number of intervals to be produced at I_2^*. Further, subjects participating in Experiment 3 were instructed to use a counting strategy to aid their parsing of the sequence. Again, mixture errors occurred and the conditions most prone to mixture errors were conditions where I_2^* was less than I_1^*. Thus, the structure model is inadequate for explaining the mixture effect.

The following discussion presents a tentative model to explain some of the findings of this research project as well as critical tests of the model. The question of timing and serial order has been of interest to motor control researches since the days of Lashley and his historical 1951 paper, *The Problem of Serial Order in Behavior.* Recently, researchers (Peters, 1985; Peters & Schwartz, 1989) have suggested that attention is intimately related to the control of timing. Drawing from these areas, I will describe the Disengagement Model which is presented to account for some of the findings of Experiments 1, 2, and 3.

The Disengagement Model states that when a subject is involved in a task requiring strict temporal control and the timing demands of the task are going to change, the allocation of attention plays an important role. If a subject is engaged in a task requiring strict temporal control and the timing demands of the task are going to change, the subject must first focus his/her attention directly on the preparation and execution of the first portion of the task. If the first portion of the task is long enough, execution becomes more automatic. As the task becomes automatic, the subject is free to allocate attention to preparation of the later portion of the task. However, if the first portion of the task is so short that execution does not become automatic, the subject is not free to allocate attention toward preparation of the later portion of the task. In this case, preparation for the second portion of the task can take place only after the first portion of the task has been completed. Another aspect of the Disengagement Model is that there is a cost involved in changing the focus of attention. That is, when the focus of attention changes from the first portion of the task to the second, the task demands are increased, resulting in changes in tapping performance.

Looking at the results of Experiments 1, 2, and 3 one sees a number of findings which support the Disengagement Model. In Experiment 1, when I_1^* was the longest (400 ms) and when n_1 was the greatest (12 taps), the mean initiation time was shorter compared to the other conditions. This result is taken as evidence that some preparation took place after tapping began. That is, the motor system can prepare and execute actions simultaneously. The system took advantage of this capability when I_1^* was the longest (400 ms) and when n_1 was the greatest (12 taps). According to the Disengagement Model, this condition (I_1^* equalled 400 ms and n_1 equalled12 taps), represents the onlt condition where execution became automatic and subjects were free to allocate attention to the prparation of the later portion of the task. The key determinant for automating an action appears to be the interaction of the time spent performing the task and the number of responses in the task. If the key determinant were only the time spent performing the task, mean initation times for conditions where I_1^* was greater than or equal to 400 ms should have been lower than mean initation times for conditions where I_1^* was less then 400 ms. This result was not found. If the key determinant was only the number of responses in the task, all conditions where n_1 equalled 12 taps should have resulted in shorter mean initiation times compared to conditions where n_1 was less than 12 taps. This result was not foumd. The condition that resulted in simultaneous preparation, was the condition where I_1^* was 400 ms and n_1 was 12 taps in Experiment 1. In Experiments 2 and 3, where n_1 equalled 4 or 5, the tapping task did not become automatic and did not allow subjects to simultaneously prepare and execute the tapping task. In these experiments, the subjects were left to prepare for the second portion of the tapping task only after tapping at I_1^* was completed. Based on the findings of this project, the interaction of the amount of time spent performing the action and the number of responses in the task is the important determinant of automating action. Further, the results of this project suggest that this tapping task became automatic somewhere between 4 and 12 taps. A test of the Disengagement Model would be an experiment in which n_1 would be manipulated in order to replicate and extend the results of Experiment 1.

The key to the Disengagement Model is that there is a cost involved with changing the focus of attention. That is, when the focus of attention changes from the first portion of the task to the second, the task demands increase, resulting in changes in the quality of tapping performance. For the task used in the research project, the focus of attention changed when the I^*s changed. This might have been the source of the mixture effects. According to the model, subjects had problems parsing the sequences because there was no opportunity to disengage attention from I_1^* before beginning I_2^*. In each experiment, the tap that represented the end of

I_1^* also represented the beginning of I_2^*. In Experiment 1 the stimuli were presented in a visual manner. Subjects received feedback after each tap. These two factors may have helped subjects switch their attention from I_1^* to I_2^*. In Experiment 1 the effect due to mixture was not present. In Experiments 2 and 3 the stimuli were presented in an auditory fashion. Subjects did not receive visual feedback until a trial was completed. Thus, there was no explicit representation of the tones that represented I_1^* and the tones that represented I_2^*. In Experiment 3 a counting strategy was provided to the subjects to aid in parsing the sequence. However, this was not enough to disengage attention.

How were the tones that represented I_1^* and I_2^* stored in memory? The evidence that information concerning I_1^* and I_2^* was stored in memory comes from the context effects. If information about I_2^* was not stored in memort there should be no context effects on I_1 performance based on I_2^*. The fact that context effects were found in I_1 based on specific I_2^* combinations indicates that information concerning I_2^* was in memory. The same logic is used to support the idea that information concerning I_1^* was stored in memory. If information about I_1^* was not stored in memort there should be no context effects on I_2 performance based on I_1^*. There were context effects found on I_2 based on specific I_1^* combinations. This is taken as evidence that although subjects did not act on advance timing information, they had information concerning the timing demands of the task stored in memory.

The Wing and Kristofferson model for timing production provides an answer to the question: How were the tones that represented I_1^* and I_2^* stored in memory? The Wing and Kristofferson model is a two process model with a timekepper component and the motor delay component. The timekeeper component is a "clock" that meters out the delay between the signals that trigger successive responses. The motor component Is the delay between the trigger of a repsonse and its exectuion. According to Wing and Kristofferson, subjects store a number corresponding to the "clock" delay in memory. The timekeeper then counts the number of pulses until the number stored in memory has been reached. Once the number of pulses and the number stored in memory match, the signal which triggers the associated response is sent.

Based on the Wing and Kristofferson model, the interval between the tones is stored as a number in memory corresponding to the required number of timekeeper pulses to meter out the IRI.

Another application of the Wing and Kristofferson model can be used as a critcal test of the Disengagement Model. The Wing and Kristofferson model provides a mathematical means for estimating the variance of the timekeeper process and the variance of the motor delay process. The model has been used by a number investigators (Keele & Ivry, 1987; Wing & Kristofferson, 1973;Wing,1980). One of the main findings resulting from this model is that as the IRI increases, the estimated clock variances increases but the motor delay variance remains constant. According to the Disengagement Model, the clock variance should increase when the demands of the task increase. Furthermore, the context effects seen in the log(sd) data should be seen in the estimated clock variance and not the motor delay variance. Experiments where the decomposition of the variance has been used to analyze the data typically use from 12 to 31 IRIs to estimate the variances. Where the current experiments only had 3 or 4 IRIs at n_1 and 4 IRIs at n_2, the estiamtes of the variances are not stable enough to use the Wing and Kristofferson approach to decompose the variance. In order, to apply Wing and Kristofferson's decomposition process, the number of responses at n_1 and n_2 should be increased. The Wing and Kristofferson model can then be used to decompose the observed variance to the clock and motor variances to test the predictions of the Disengagement Model.

In Experiments 2 and 3, the time between I_1^* and I_2^* was 0 ms. According to the Disengagement Model, a simpler task would be one in which the time between I_1^* and I_2^* is greater than 0 ms. One test of the Disengagement Model would be to perform an experiment in which n_1 is sufficiently long to allow for advance preparation of the later portion of the task and manipulate the time between the last tap at I_1^* and the first tap at I_2^*. The model predicts that when the time between I_1^* and I_2^* is long enough to allow for disengagement of attention, the mean IRI, log(sd), and the CV at the first interval at I_2^* should be equal to the nonboundary intervals.

A final test of the Disengagement Model involves a series of experiments in which the allocation of attention is manipulated. If the allocation of attention must be directed toward tasks other than accurate tapping performance control, the accuracy of timing should decrease. One might speculate that there are different types of attention for different tasks. For example, one can imagine attention for cognitive tasks. Similarly, one might imagine attention for motor tasks (Cohen, in press). The Disengagement Model hypothesizes that decreasing the allocation of "cognitive attention" should not result in a decrement in tapping performance. However, decreasing the allocation of "motor attention" should result in decreased accuracy in a motor timing task. One way to test these predictions would be to use a probe paradigm. Probe techniques have traditionally invloved presenting a probe to which a subject must respond during the execution of a movement. The reaction time to respond to the probe plotted as a function of the presentation time of the probe has been used to measure the attentional demands of the task. One example of reducing the "motor" demands of the task was demonstrated by McLeod (1980). In one of his experiments subjects were engaged in a manual pointing task with the right hand. Subjects were required to repsond to a probe by tapping a button with the left hand or by making a vocal response (between subjects condition). The findings was that the voal responses to the probe were faster than the manual responses. McLeod took these results to show that "movments do not have an absolute attential demand which can be measured by any sort of probe" (p. 588). In the same spirit, by identifying cognitive probes and motor probes, one can use these probes to to test the predictions of the Disengagement Model.

In conclusion, the purpose of this research project was to examine the nature of the process which prepares the timing of sequenced finger tapping. Based on the results of Experiments 1, 2, and 3, the Disengagement Model was developed. The model states that the allocation of attention plays an important role in the preparation and execution of sequenced finger tapping. Several experiments were proposed as critical tests of the Disengagement Model.

APPENDIX TABLE

Appendix A.1

Source	SS	df	MS	F	Prob.
MEAN	3.31E+8	1	3.31E+8	9.12	0.0567
X	1.09E+8	3	3.63E+7		
Z	1.94E+7	2	9.70E+6	0.97	0.4322
F	2.08E+6	2	1.04E+6	1.88	0.2321
S	8.54E+5	2	4.27E+5	1.44	0.3077
A	1.30E+5	1	1.30E+5	0.32	0.6088
XZ	6.01E+7	6	1.00E+7		
XF	3.32E+6	6	5.53E+5		
ZF	2.46E+5	4	6.15E+4	0.20	0.9340
XS	1.77E+6	6	2.96E+5		
ZS	9.33E+5	4	2.33E+5	0.97	0.4576
FS	1.45E+6	4	3.64E+5	1.48	0.2686
XA	1.20E+6	3	4.01E+5		
ZA	8.73E+5	2	4.36E+5	1.87	0.2336
FA	4.11E+4	2	2.06E+4	0.16	0.8526
SA	2.53E+5	2	1.27E+5	9.52	0.0138
XZF	3.70E+6	12	3.09E+5		
XZS	2.88E+6	12	2.40E+5		
XFS	2.95E+6	12	2.46E+5		
ZFS	1.45E+6	8	1.81E+5	0.45	0.8774
XZA	1.40E+6	6	2.33E+5		
XFA	7.54E+5	6	1.26E+5		
ZFA	5.75E+5	4	1.44E+5	1.44	0.2789
XSA	7.98E+4	6	1.33E+4		
ZSA	1.14E+6	4	2.86E+5	2.09	0.1445
FSA	2.42E+5	4	6.04E+4	0.25	0.9042
XZFS	9.61E+6	24	4.01E+5		
XZFA	1.19E+6	12	9.94E+4		
XZSA	1.64E+6	12	1.36E+5		
XFSA	2.90E+6	12	2.42E+5		
ZFSA	2.04E+6	8	2.55E+5	1.34	0.2733
XZFSA	4.57E+6	24	1.91E+5		

Appendix A.2

Source	SS	df	MS	F	Prob.
MEAN	1.25E+13	1	1.25E+13	191.81	0.0008
X	1.96E+11	3	6.54E+10		
Z	8.11E+8	2	4.06E+8	1.26	0.3483
F	5.40E+11	2	2.70E+11	296.52	0.0000
S	2.82E+11	2	1.41E+11	206.62	0.0000
A	2.49E+8	1	2.49E+8	2.12	0.2411
D	1.45E+11	3	4.83E+10	1.35	0.3179
T	2.51E+10	1	2.51E+10	1.39	0.3237
XZ	1.93E+10	6	3.21E+8		
XF	5.46E+9	6	9.11E+8		
ZF	7.98E+8	4	1.99E+8	0.93	0.4782
XS	4.09E+9	6	6.82E+8		
ZS	3.73E+9	4	9.32E+8	2.48	0.1004
FS	4.67E+10	4	1.17E+10	1.64	0.2273
XA	3.51E+8	3	1.17E+8		
ZA	4.80E+7	2	2.40E+7	0.13	0.8816
FA	6.03E+8	2	3.02E+8	2.46	0.1656
SA	2.05E+8	2	1.03E+8	0.21	0.8195
XD	3.21E+11	9	3.57E+10		
ZD	1.39E+10	6	2.31E+9	1.40	0.2695
FD	1.70E+10	6	2.84E+9	5.48	0.0022
SD	2.49E+10	6	4.16E+9	12.30	0.0000
AD	7.76E+9	3	2.59E+9	2.22	0.1547
XT	5.42E+10	3	1.81E+10		
ZT	3.20E+10	2	1.60E+9	1.30	0.3386
FT	2.81E+11	2	1.41E+11	80.92	0.0000
ST	2.68E+11	2	1.34E+11	111.69	0.0000
AT	1.72E+9	1	1.72E+9	6.46	0.0845
DT	6.91E+10	3	2.30E+10	1.66	0.2449
XZF	2.57E+9	12	2.14E+9		
XZS	4.52E+9	12	3.76E+9		
XFS	8.52E+10	12	7.10E+9		
ZFS	2.56E+9	8	3.20E+9	0.99	0.4658
XZA	1.12E+9	6	1.86E+8		
XFA	7.34E+8	6	1.22E+8		
ZFA	5.05E+8	4	1.26E+8	1.20	0.3597
XSA	2.99E+9	6	4.99E+8		
ZSA	1.75E+9	4	4.39E+8	2.52	0.0963
FSA	3.98E+8	4	9.94E+7	0.63	0.6513
XZD	2.98E+10	18	1.66E+9		
XFD	9.32E+9	18	5.18E+8		
ZFD	2.81E+9	12	2.34E+8	1.19	0.3254
XSD	6.08E+9	18	3.38E+8		
ZSD	2.48E+9	12	2.07E+8	1.28	0.2730
FSD	8.29E+10	12	6.91E+9	1.40	0.2105
XAD	1.05E+9	9	1.16E+8		
ZAD	4.59E+9	6	7.65E+8	1.22	0.3430
FAD	1.14E+9	6	1.90E+8	0.54	0.7726
SAD	8.26E+8	6	1.38E+8	1.06	0.4188
XZT	7.35E+9	6	1.23E+9		
XFT	1.04E+10	6	1.74E+9		
ZFT	4.34E+9	4	1.09E+9	3.60	0.0377
XST	7.21E+9	6	1.20E+9		
ZST	2.51E+9	4	6.28E+8	1.26	0.3370

Continued, next page

A.2 continued

FST	1.58E+10	4	3.95E+9	1.39	0.2963
XAT	7.96E+8	3	2.65E+8		
ZAT	4.55E+8	2	2.28E+8	0.95	0.4375
FAT	7.33E+8	2	3.67E+8	0.83	0.4803
SAT	6.61E+8	2	3.30E+8	.85	0.4737
XDT	1.25E+11	9	1.39E+10		
ZDT	6.75E+9	6	1.13E+9	1.08	0.4081
FDT	2.81E+10	6	4.69E+9	3.42	0.0198
SDT	2.91E+10	6	4.84E+9	8.39	0.0002
ADT	2.16E+8	3	7.21E+7	0.79	0.5285
XZFS	7.73E+9	24	3.22E+8		
XZFA	1.26E+9	12	1.05E+8		
XZSA	2.09E+9	12	1.74E+8		
XFSA	1.90E+9	12	1.58E+8		
ZFSA	1.24E+9	8	1.55E+8	0.68	0.7037
XZFD	7.07E+9	36	1.96E+8		
XZSD	5.82E+9	36	1.62E+8		
XFSD	1.78E+11	36	4.93E+9		
ZFSD	8.56E+9	24	3.57E+8	1.24	0.2399
XZAD	1.13E+10	18	6.29E+8		
XFAD	6.37E+9	18	3.54E+8		
ZFAD	4.21E+9	12	3.51E+8	1.06	0.4202
XSAD	2.33E+9	18	1.29E+8		
ZSAD	4.11E+9	12	3.43E+8	1.18	0.3354
FSAD	1.12E+9	12	9.35E+7	0.69	0.7526
XZFT	3.62E+9	12	3.02E+8		
XZST	5.96E+9	12	4.97E+8		
XFST	3.42E+10	12	2.85E+9		
ZFST	2.96E+9	8	3.70E+8	1.20	0.3382
XZAT	1.44E+9	6	2.39E+8		
XFAT	2.65E+9	6	4.41E+8		
ZFAT	1.60E+9	4	4.00E+8	2.02	0.1557
XSAT	2.34E+9	6	3.89E+8		
ZSAT	1.22E+9	4	3.06E+8	1.18	0.3666
FSAT	4.92E+8	4	1.23E+8	1.89	0.1765
XZDT	1.87E+10	18	1.04E+9		
XFDT	2.47E+10	18	1.37E+9		
ZFDT	1.77E+9	12	1.47E+8	0.71	0.7294
XSDT	1.04E+10	18	5.77E+8		
ZSDT	1.72E+9	12	1.43E+8	0.95	0.5132
FSDT	3.80E+10	12	3.16E+9	1.53	0.1597
XADT	8.20E+8	9	9.11E+7		
ZADT	2.18E+9	6	3.64E+8	1.41	0.2632
FADT	2.31E+9	6	3.85E+8	1.50	0.2348
SADT	1.19E+9	6	1.98E+8	1.30	0.3078
XZFSA	5.46E+9	24	2.27E+8		
XZFSD	2.07E+10	72	2.88E+8		
XZFAD	1.19E+10	36	3.31E+8		
XZSAD	1.05E+10	36	2.91E+8		
XFSAD	4.90E+9	36	1.36E+8		
ZFSAD	4.68E+9	24	1.95E+8	1.04	0.4313
XZFST	7.39E+9	24	3.08E+8		
XZFAT	2.37E+9	12	1.98E+8		
XZSAT	3.10E+9	12	2.58E+8		
XFSAT	7.80E+8	12	6.50E+7		

Continued, next page

A.2 continued

ZFSAT	1.76E+9	8	2.20E+8	2.53	0.0372
XZFDT	7.45E+9	36	2.07E+8		
XZSDT	5.45E+9	36	1.51E+8		
XFSDT	7.46E+10	36	2.07E+9		
ZFSDT	6.56E+9	24	2.73E+8	0.86	0.6498
XZADT	4.63E+9	18	2.57E+8		
XFADT	4.63E+9	18	2.57E+8		
ZFADT	3.09E+9	12	2.58E+8	0.75	0.6965
XSADT	2.75E+9	18	1.53E+8		
ZSADT	4.16E+9	12	3.47E+8	1.19	0.3247
FSADT	9.82E+8	12	8.18E+7	0.60	0.8262
XZFSAD	1.35E+10	72	1.88E+8		
XZFSAT	2.09E+9	24	8.70E+7		
XZFSDT	2.29E+10	72	3.17E+8		
XZFADT	1.24E+10	36	3.44E+8		
XZSADT	1.05E+10	36	2.91E+8		
XFSADT	4.89E+9	36	1.36E+8		
ZFSADT	5.76E+9	24	2.40E+8	1.36	0.1598
XZFSADT	1.27E+10	72	1.77E+8		

Appendix A.3

CONDITIONS	S1	S2	S3	S4
150/150				
$n_1 = 4$	7	8	8	5
$n_1 = 12$	8	8	7	5
150/200				
$n_1 = 4$	5	4	5	6
$n_1 = 12$	5	6	6	2
150/400				
$n_1 = 4$	4	5	6	6
$n_1 = 12$	5	5	8	7
200/150				
$n_1 = 4$	8	3	7	2
$n_1 = 12$	5	6	8	2
200/200				
$n_1 = 4$	7	5	8	6
$n_1 = 12$	6	8	8	6
200/400				
$n_1 = 4$	4	7	6	7
$n_1 = 12$	5	8	8	6
400/150				
$n_1 = 4$	4	6	7	5
$n_1 = 12$	0	7	8	4
400/200				
$n_1 = 4$	6	4	8	6
$n_1 = 12$	5	5	8	3
400/400				
$n_1 = 4$	5	8	7	8
$n_1 = 12$	7	8	8	8

Appendix A.4

Source	SS	df	MS	F	Prob.	
MEAN	3.95E+12	1	3.95E+12	312.21	0.0004	
X	3.80E+5	3	1.26E+5			
F	1.69E+6	2	8.E+546	873.85	0.0000	
S	1.18E+6	2	5.93E+5	2233.57	0.0000	
A	3.64E+2	1	3.64E+2	0.44	0.5565	
L	1.61E+5	1	1.61E+5	1.40	0.3221	
D	5.84E+5	3	1.94E+5	1.46	0.2887	
XF	5.81E+3	6	9.68E+2			
XS	1.59E+3	6	2.65E+2			
FS	1.21E+5	4	3.04E+4	1.61	0.2349	
XA	2.50E+3	3	8.36E+2			
FA	1.49E+2	2	7.46E+1	0.08	0.9220	
SA	7.08E+3	2	3.54E+3	1.58	0.2805	
XL	3.47E+5	3	1.15E+5			
FL	1.26E+6	2	6.30E+5	435.50	0.0000	
SL	1.18E+6	2	5.91E+5	416.96	0.0000	
AL	2.18E+3	1	2.18E+3	1.09	0.3727	
XD	1.19E+6	9	1.33E+5			
FD	2.10E+4	6	3.50E+3	2.75	0.0447	
SD	6.28E+4	6	1.04E+4	13.46	0.0000	
AD	2.70E+3	3	9.01E+2	26.27	0.0001	
LD	5.06E+5	3	1.6E+5	1.38	0.3106	
XFS	2.27E+5	12	1.89E+4			
XFA	5.44E+3	6	9.06E+2			
XSA	1.34E+4	6	2.23E+3			
FSA	3.72E+3	4	9.30E+2	1.29	0.3279	
XFL	8.68E+3	6	1.44E+3			
XSL	8.50E+3	6	1.41E+3			
FSL	9.21E+4	4	2.30E+4	1.51	0.2490	
XAL	6.00E+3	3	2.00E+3			
FAL	7.15E+2	2	3.57E+2	0.21	0.8163	
SAL	2.00E+3	2	1.00E+3	0.33	0.7300	
XFD	2.29E+4	18	1.27E+3			
XSD	1.40E+4	18	7.78E+2			
FSD	3.22E+5	12	2.68E+4	1.56	0.1474	
XAD	3.08E+2	9	3.43E+1			
FAD	4.51E+3	6	7.53E+2	1.02	0.4459	
SAD	1.48E+4	6	2.47E+3	1.80	0.1566	
XLD	1.10E+6	9	1.22E+5			
FLD	4.22E+4	6	7.03E+3	5.00	0.0036	
SLD	9.06E+4	6	1.51E+4	3.68	0.0000	
ALD	5.79E+3	3	1.93E+3	2.66	0.1114	
XFSA	8.65E+3	12	7.21E+2			
XFSL	1.77E+5	12	1.48E+2			
XFAL	1.02E+4	6	1.70E+3			
XSAL	1.80E+4	6	3.01E+3			
FSAL	5.51E+3	4	1.37E+3	0.79	0.5543	XFSD
	6.18E+5	36	1.71E+4			
XFAD	1.33E+4	18	7.41E+2			
XSAD	2.47E+4	18	1.37E+3			
FSAD	6.36E+3	12	5.30E+2	1.08	0.4027	XFLD
	2.53E+4	18	1.40E+3			
XSLD	1.98E+4	18	1.10E+3			
FSLD	2.74E+5	12	2.28E+4	1.38	0.2225	

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A.4 continued

XALD	6.52E+3	9	7.25E+2			
FALD	1.67E+3	6	2.78E+2	0.13	0.9901	SALD
	9.19E+3	6	1.53E+3	0.54	0.7714	
XFSAL	2.09E+4	12	1.74E+3			
XFSAD	1.76E+4	36	4.90E+2			
XFSLD	5.99E+5	36	1.66E+4			
XFALD	3.75E+4	18	2.08E+3			
XSALD	5.11E+4	18	2.84E+3			
FSALD	1.52E+4	12	1.26E+3	1.10	0.3891	
XFSALD	4.15E+4	36	1153.22			

Appendix A.5.

Source	SS	df	MS	F	Prob.
MEAN	2.28E+4	1	2.28E+4	314.92	0.0004
X	2.17E+2	3	7.24E+1		
Z	2.49E+1	2	1.24E+1	2.30	0.1813
F	1.35E+0	2	0.67E+0	0.96	0.4342
S	1.31E+1	2	6.58E+0	9.16	0.0150
A	6.00E+0	1	6.00E+0	2.91	0.1865
D	3.96E+1	3	1.32E+1	2.42	0.1329
T	1.84E+1	1	1.84E+1	76.54	0.0031
XZ	3.25E+1	6	5.42E+0		
XF	4.22E+0	6	0.70E+0		
ZF	3.46E+0	4	0.86E+0	1.07	0.4137
XS	4.30E+0	6	0.71E+0		
ZS	2.92E+0	4	0.73E+0	0.67	0.6233
FS	7.23E+1	4	1.80E+1	6.38	0.0054
XA	6.19E+0	3	2.06E+0		
ZA	0.69E-1	2	0.34E-1	0.05	0.9501
FA	1.35E+0	2	0.67E+0	0.57	0.5931
SA	0.36E+0	2	0.18E+0	0.38	0.7005
XD	4.90E+1	9	5.45E+0		
ZD	3.04E+0	6	0.50E+0	0.68	0.6699
FD	2.64E+0	6	0.44E+0	1.40	0.2665
SD	0.35E+0	6	0.59E-1	0.14	0.9890
AD	1.96E+0	3	0.65E+0	1.80	0.2166
XT	0.72E+0	3	0.24E+0		
ZT	2.19E+0	2	1.09E+0	1.49	0.2976
FT	2.27E+1	2	1.31E+1	12.86	0.0068
ST	8.86E+0	2	4.43E+0	5.04	0.0520
AT	9.44E+0	1	9.44E+0	8.23	0.0641
DT	2.68E+1	3	8.94E+0	10.24	0.0029
XZF	9.71E+0	12	0.80E+0		
XZS	1.30E+1	12	1.08E+0		
XFS	3.40E+1	12	2.83E+0		
ZFS	1.88E+0	8	0.23E+0	0.46	0.8731
XZA	4.01E+0	6	0.66E+0		
XFA	7.10E+0	6	1.18E+0		
ZFA	1.03E+0	4	0.25E+0	0.55	0.7937
XSA	2.92E+0	6	0.48E+0		
ZSA	0.93E+0	4	0.23E+0	0.37	0.8275
FSA	2.11E+0	4	0.52E+0	1.40	0.2908
XZD	1.34E+1	18	0.74E+0		
XFD	5.64E+0	18	0.31E+0		
ZFD	1.89E+0	12	0.15E+0	0.57	0.8497
XSD	7.67E+0	18	0.42E+0		
ZSD	6.03E+0	12	0.50E+0	2.51	0.0164
FSD	3.63E+1	12	3.83E+0	3.22	0.0053
XAD	3.27E+0	9	0.36E+0		
ZAD	1.40E+0	6	0.23E+0	0.59	0.7375
FAD	1.66E+0	6	0.27E+0	0.67	0.6740
SAD	1.19E+0	6	0.19E+0	0.87	0.3381
XZT	4.41E+0	6	0.73E+0		
XFT	5.30E+0	6	0.88E+0		
ZFT	2.44E+0	4	0.61E+0	1.47	0.2727
XST	5.28E+0	6	0.88E+0		

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A.5 continued

ZST	2.47E+0	4	0.61E+0	1.65	0.2260
FST	2.02E+1	4	5.05E+0	8.77	0.0015
XAT	3.44E+0	3	1.14E+0		
ZAT	0.11E-2	2	0.56E+0	0.00	0.9975
FAT	3.16E+0	2	1.58E+0	6.32	0.0334
SAT	1.55E+0	2	0.77E+0	3.33	0.1899
XDT	7.85E+0	9	0.87E+0		
ZDT	2.26E+0	6	0.37E+0	1.22	0.3412
FDT	3.24E+0	6	0.54E+0	1.07	0.4182
SDT	2.32E+0	6	0.38E+0	0.89	0.5237
ADT	5.26E+0	3	1.75E+0	8.63	0.0052
XZFS	1.23E+0	24	0.51E+0		
XZFA	5.67E+0	12	0.47E+0		
XZSA	7.62E+1	12	0.63E+0		
XFSA	4.52E+0	12	0.37E+0		
ZFSA	5.37E+0	8	0.67E+0	1.41	0.2418
XZFD	9.96E+0	36	0.27E+0		
XZSD	7.21E+0	36	0.20E+0		
XFSD	3.39E+0	36	0.94E+0		
ZFSD	6.58E+1	24	0.27E+0	1.07	0.3936
XZAD	7.19E+0	18	0.39E+0		
XFAD	7.43E+0	18	0.41E+0		
ZFAD	3.12E+0	12	0.26E+0	1.10	0.3898
XSAD	4.13E+0	18	0.22E+0		
ZSAD	2.10E+0	12	0.17E+0	0.96	0.5017
FSAD	2.62E+0	12	0.21E+0	0.50	0.9024
XZFT	5.00E+0	12	0.41E+0		
XZST	4.50E+0	12	0.37E+0		
XFST	6.92E+0	12	0.57E+0		
ZFST	4.28E+0	8	0.53E+0	1.12	0.3831
XZAT	1.34E+0	6	0.22E+0		
XFAT	1.50E+0	6	0.25E+0		
ZFAT	1.42E+0	4	0.35E+0	1.51	0.2603
XSAT	2.09E+0	6	0.34E+0		
ZSAT	1.74E+0	4	0.43E+0	1.11	0.3980
FSAT	2.12E+0	4	0.53E+0	1.71	0.2115
XZDT	5.56E+0	18	0.30E+0		
XFDT	9.13E+0	18	0.50E+0		
ZFDT	3.01E+0	12	0.25E+0	1.18	0.3361
XSDT	7.85E+0	18	0.43E+0		
ZSDT	3.45E+0	12	0.28E+0	1.39	0.2152
FSDT	9.50E+0	12	0.79E+0	2.37	0.0224
XADT	1.82E+0	9	0.20E+0		
ZADT	2.82E+0	6	0.47E+0	1.37	0.2807
FADT	1.44E+0	6	0.24E+0	0.88	0.5274
SADT	3.01E+0	6	0.50E+0	2.04	0.1122
XZFSA	1.14E+1	24	0.47E+0		
XZFSD	1.84E+1	72	0.25E+0		
XZFAD	8.52E+0	36	0.23E+0		
XZSAD	6.56E+0	36	0.18E+0		
XFSAD	1.58E+1	36	0.44E+0		
ZFSAD	8.66E+0	24	0.36E+8	2.19	0.0057
XZFST	1.14E+1	24	0.47E+8		
XZFAT	2.83E+0	12	0.23E+8		
XZSAT	4.72E+0	12	0.39E+8		

Continued, next page

A.5 continued

XFSAT	3.71E+0	12	0.30E+7		
ZFSAT	1.49E+0	8	0.18E+8	0.69	0.6956
XZFDT	7.70E+0	36	0.21E+8		
XZSDT	7.45E+0	36	0.20E+8		
XFSDT	1.20E+1	36	0.33E+9		
ZFSDT	6.50E+0	24	0.27E+8	0.99	0.4938
XZADT	6.20E+0	18	0.34E+8		
XFADT	4.90E+0	18	0.27E+8		
ZFADT	2.66E+0	12	0.22E+8	0.62	0.8122
XSADT	4.43E+0	18	0.24E+8		
ZSADT	3.21E+0	12	0.26E+8	0.95	0.5090
FSADT	3.59E+0	12	0.29E+7	1.38	0.2178
XZFSAD	1.18E+1	72	0.16E+0		
XZFSAT	6.50E+0	24	0.27E+0		
XZFSDT	1.97E+1	72	0.27E+0		
XZFADT	1.29E+1	36	0.35E+0		
XZSADT	1.01E+1	36	0.28E+0		
XFSADT	7.77E+0	36	0.21E+0		
ZFSADT	4.94E+0	24	0.20E+0	0.63	0.8994
XZFSADT	2.36E+1	72	0.32E+0		

Appendix A.6

Source	SS	df	MS	F	Prob.	
MEAN	5.94E+3	1	5.94E+3	181.61	0.0000	
X	5.60	3	1.86			
F	4.90	2	2.45	2.99	0.1259	
S	1.18E+1	2	5.90	7.28	0.0249	
A	5.72E-1	1	5.72E-1	3.40	0.1625	
L	6.70	1	6.70	38.11	0.0086	
D	2.50E+1	3	8.36	4.18	0.0412	
XF	4.92	6	8.20E-1			
XS	4.86	6	8.11E-1			
FS	7.71	4	1.92	2.13	0.1390	
XA	5.05E-1	3	1.68E-1			
FA	2.30	2	1.15	2.53	0.1598	
SA	3.19E-1	2	1.59E-1	1.01	0.4187	
XL	5.27E-1	3	1.75E-1			
FL	6.37	2	3.18	9.08	0.0153	
SL	5.65	2	2.82	16.89	0.0034	
AL	2.27	1	2.27	28.35	0.0129	
XD	1.79E+1	9	1.99			
FD	1.11	6	1.85E-1	0.65	0.6909	
SD	9.64E-1	6	1.60E-1	0.55	0.7619	
AD	1.03	3	3.44E-1	1.94	0.1931	
LD	1.77E+1	3	5.90	9.93	0.0032	
XFS	1.08E+1	12	9.04E-1			
XFA	2.72	6	4.54E-1			
XSA	9.50E-1	6	1.58E-1			
FSA	2.81	4	7.04E-1	2.17	0.1338	
XFL	2.10	6	3.51E-1			
XSL	1.00	6	1.67E-1			
FSL	7.83	4	1.95	4.92	0.0139	
XAL	2.40E-1	3	8.01E-2			
FAL	9.81E-1	2	4.90E-1	3.76	0.0875	
SAL	1.10E-1	2	5.51E-2	0.67	0.5461	
XFD	5.15	18	2.86E-1			
XSD	5.23	18	2.91E-1			
FSD	1.42E+1	12	1.18	3.46	0.0019	
XAD	1.59	9	1.77E-1			
FAD	8.26E-1	6	1.37E-1	1.05	0.4286	
SAD	7.89E-1	6	1.31E-1	0.38	0.8816	
XLD	5.34	9	5.94E-1			
FLD	1.78	6	2.98E-1	0.81	0.5783	
SLD	2.63	6	4.39E-1	1.47	0.2432	
ALD	1.28E-1	3	4.29E-2	0.12	0.9451	XFSA
	3.89	12	3.24E-1			
XFSL	4.77	12	3.98E-1			
XFAL	7.83E-1	6	1.30E-1			
XSAL	4.93E-1	6	8.22E-2			
FSAL	5.79E-1	4	1.44E-1	0.50	0.7379	XFSD
	1.23E+1	36	3.43E-1			
XFAD	2.36	18	1.31E-1			
XSAD	6.22	18	3.45E-1			
FSAD	7.00E-1	12	5.84E-2	0.55	0.8669	XFLD
	6.65	18	3.69E-1			
XSLD	5.37	18	2.98E-1			
FSLD	1.05E+1	12	8.75E-1	2.36	0.0234	

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A.6 continued

XALD	3.17	9	3.53E-1		
FALD	5.21E-1	6	8.69E-2	0.42	0.8536
SALD	2.21	6	3.68E-1	3.08	0.0296
XFSAL	3.49E+0	12	2.91E-1		
XFSAD	3.82E+0	36	1.06E-1		
XFSLD	1.33E+1	36	3.71E-1		
XFALD	3.69E+0	18	2.05E-1		
XSALD	2.15E+0	18	1.19E-1		
FSALD	1.70E+0	12	1.41E-1	0.78	0.6699
XFSALD	6.57E+0	36	1.82E-1		

Appendix A.7

Source	SS	df	MS	F	Prob.
MEAN	7.49E+1	1	7.49E+1	20.68	0.0199
X	1.09E+1	3	3.62E+0		
Z	1.53	2	7.67E-1	1.70	0.2603
F	1.82	2	9.10E-1	13.39	0.0061
S	0.297	2	1.49E-1	3.63	0.0928
A	1.22E-1	1	1.22E-1	1.74	0.2789
D	1.27E+0	3	4.23E-1	2.34	0.1418
T	1.85E-1	1	1.85E-1	5.93	0.0928
XZ	2.71E+0	6	4.51E-1		
XF	4.08E-1	6	6.80E-2		
ZF	2.31E-1	4	5.77E-2	2.02	0.1549
XS	2.46E-1	6	4.10E-2		
ZS	1.76E-1	4	4.39E-2	0.65	0.6360
FS	2.56E+0	4	6.41E-1	3.56	0.0390
XA	2.10E-1	3	7.00E-2		
ZA	8.08E-3	2	4.04E-3	0.11	0.8964
FA	8.85E-2	2	4.43E-2	0.49	0.6343
SA	4.57E-2	2	2.28E-2	0.56	0.5975
XD	1.63E+0	9	1.81E-1		
ZD	1.90E-1	6	3.17E-2	0.85	0.5457
FD	3.76E-1	6	6.26E-2	2.69	0.0484
SD	2.86E-1	6	4.76E-2	2.61	0.0532
AD	1.57E-1	3	5.23E-2	1.51	0.2774
XT	9.36E-2	3	3.12E-2		
ZT	5.94E-2	2	2.97E-2	0.70	0.5322
FT	2.41E-1	2	1.21E-1	9.57	0.0136
ST	6.86E-1	2	3.43E-1	4.77	0.0576
AT	1.97E-1	1	1.97E-1	4.79	0.1163
DT	7.50E-1	3	2.50E-1	2.49	0.1266
XZF	3.42E-1	12	2.85E-2		
XZS	8.07E-1	12	6.72E-2		
XFS	2.16E+0	12	1.80E-1		
ZFS	2.31E-1	8	2.88E-2	1.06	0.4219
XZA	2.18E-1	6	3.63E-2		
XFA	5.40E-1	6	9.01E-2		
ZFA	5.95E-2	4	1.49E-2	0.48	0.7478
XSA	2.44E-1	6	4.07E-2		
ZSA	8.46E-2	4	2.11E-2	0.42	0.7912
FSA	2.17E-1	4	5.43E-2	1.57	0.2445
XZD	6.67E-1	18	3.70E-2		
XFD	4.20E-1	18	2.33E-2		
ZFD	1.15E-1	12	9.56E-3	0.65	0.7836
XSD	3.28E-1	18	1.82E-2		
ZSD	2.97E-1	12	2.47E-2	1.82	0.0818
FSD	1.29E+0	12	1.07E-1	2.26	0.0292
XAD	3.12E-1	9	3.46E-2		
ZAD	1.78E-1	6	2.97E-2	0.94	0.4899
FAD	1.10E-1	6	1.83E-2	0.91	0.5071
SAD	2.72E-2	6	4.54E-3	0.34	0.9083
XZT	2.54E-1	6	4.23E-2		
XFT	7.57E-2	6	1.26E-2		
ZFT	1.90E-1	4	4.75E-2	2.32	0.1168
XST	4.32E-1	6	7.20E-2		

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A.7 continued

ZST	1.77E-1	4	4.44E-2	1.32	0.3174
FST	2.80E-1	4	6.99E-2	2.64	0.0872
XAT	1.24E-1	3	4.12E-2		
ZAT	3.94E-3	2	1.97E-3	0.15	0.8638
FAT	1.02E-1	2	5.14E-2	3.16	0.1155
SAT	4.75E-2	2	2.38E-2	0.95	0.4397
XDT	9.05E-1	9	1.01E-1		
ZDT	2.25E-1	6	3.75E-2	1.74	0.1679
FDT	8.91E-2	6	1.49E-2	0.98	0.4692
SDT	2.24E-1	6	3.73E-2	1.58	0.2088
ADT	2.84E-1	3	9.47E-2	3.32	0.0704
XZFS	6.53E-1	24	2.72E-2		
XZFA	3.69E-1	12	3.08E-2		
XZSA	6.04E-1	12	5.03E-2		
XFSA	4.14E-1	12	3.45E-2		
ZFSA	3.68E-1	8	4.61E-2	1.34	0.2735
XZFD	5.28E-1	36	1.47E-2		
XZSD	4.89E-1	36	1.36E-2		
XFSD	1.71E+0	36	4.75E-2		
ZFSD	3.53E-1	24	1.47E-2	0.97	0.5197
XZAD	5.68E-1	18	3.16E-2		
XFAD	3.60E-1	18	2.00E-2		
ZFAD	1.48E-1	12	1.23E-2	0.84	0.6092
XSAD	2.43E-1	18	1.35E-2		
ZSAD	2.17E-1	12	1.81E-2	1.10	0.3903
FSAD	2.30E-1	12	1.92E-2	0.70	0.7422
XZFT	2.46E-1	12	2.05E-2		
XZST	4.04E-1	12	3.36E-2		
XFST	3.19E-1	12	2.66E-2		
ZFST	2.94E-1	8	3.67E-2	1.12	0.3864
XZAT	7.87E-2	6	1.31E-2		
XFAT	9.75E-2	6	1.63E-2		
ZFAT	2.34E-2	4	5.84E-3	0.25	0.9040
XSAT	1.51E-1	6	2.51E-2		
ZSAT	4.77E-2	4	1.19E-2	0.44	0.7799
FSAT	2.25E-1	4	5.63E-2	3.45	0.0425
XZDT	3.87E-1	18	2.15E-2		
XFDT	2.74E-1	18	1.52E-2		
ZFDT	2.64E-1	12	2.20E-2	1.18	0.3354
XSDT	4.24E-1	18	2.35E-2		
ZSDT	2.93E-1	12	2.44E-2	1.68	0.1138
FSDT	2.35E-1	12	1.96E-2	0.67	0.7679
XADT	2.56E-1	9	2.85E-2		
ZADT	2.11E-1	6	3.52E-2	1.37	0.2783
FADT	1.30E-1	6	2.17E-2	1.07	0.4160
SADT	1.94E-1	6	3.24E-2	0.98	0.4643
XZFSA	8.27E-1	24	3.45E-2		
XZFSD	1.10E+0	72	1.52E-2		
XZFAD	5.28E-1	36	1.47E-2		
XZSAD	5.91E-1	36	1.64E-2		
XFSAD	9.89E-1	36	2.75E-2		
ZFSAD	6.78E-1	24	2.83E-2	2.10	0.0083
XZFST	7.89E-1	24	3.29E-2		
XZFAT	2.80E-1	12	2.33E-2		
XZSAT	3.28E-1	12	2.73E-2		

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A.7 continued

XFSAT	1.96E-1	12	1.63E-2		
ZFSAT	6.30E-2	8	7.87E-3	0.57	0.7905
XZFDT	6.73E-1	36	1.87E-2		
XZSDT	5.23E-1	36	1.45E-2		
XFSDT	1.05E+0	36	2.93E-2		
ZFSDT	3.91E-1	24	1.63E-2	0.93	0.5603
XZADT	4.61E-1	18	2.56E-2		
XFADT	3.65E-1	18	2.03E-2		
ZFADT	1.50E-1	12	1.25E-2	0.65	0.7835
XSADT	5.93E-1	18	3.29E-2		
ZSADT	1.96E-1	12	1.63E-2	1.00	0.4707
FSADT	2.62E-1	12	2.18E-2	1.01	0.4634
XZFSAD	9.66E-1	72	1.34E-2		
XZFSAT	3.30E-1	24	1.38E-2		
XZFSDT	1.26E+0	72	1.75E-2		
XZFADT	6.91E-1	36	1.92E-2		
XZSADT	5.88E-1	36	1.63E-2		
XFSADT	7.82E-1	36	2.17E-2		
ZFSADT	4.20E-1	24	1.75E-2	0.83	0.6929
XZFSADT	1.52E+0	72	2.12E-2		

Appendix A.8.

Source	SS	df	MS	F	Prob.	
MEAN	9.44E+0	1	9.44E+0	229.45	0.0006	
X	1.23E-1	3	4.11E-2			
F	1.31E-1	2	6.56E-2	5.94	0.0378	
S	1.09E-2	2	5.47E-3	0.35	0.7181	
A	7.43E-3	1	7.43E-3	0.86	0.4210	
L	8.60E-2	1	8.60E-2	9.27	0.0556	
D	5.67E-1	3	1.89E-1	4.26	0.0394	
XF	6.63E-2	6	1.10E-2			
XS	9.39E-2	6	1.56E-3			
FS	1.10E-1	4	2.75E-2	1.40	0.2923	
XA	2.57E-2	3	8.59E-3			
FA	4.58E-2	2	2.29E-2	2.38	0.1733	
SA	2.24E-2	2	1.12E-2	2.16	0.1965	
XL	2.78E-2	3	9.27E-3			
FL	6.56E-2	2	3.28E-2	2.68	0.1473	
SL	1.12E-1	2	5.61E-2	3.49	0.0989	
AL	3.19E-2	1	3.19E-2	4.76	0.1172	
XD	3.99E-1	9	4.44E-2			
FD	4.86E-2	6	8.11E-3	1.00	0.4571	
SD	7.28E-2	6	1.21E-2	1.35	0.2883	
AD	1.67E-2	3	5.56E-3	1.57	0.2636	
LD	1.67E-1	3	5.57E-2	13.09	0.0012	
XFS	2.36E-1	12	1.97E-2			
XFA	5.78E-2	6	9.63E-3			
XSA	3.12E-2	6	5.20E-3			
FSA	3.72E-2	4	9.32E-3	1.37	0.3006	
XFL	7.34E-2	6	1.22E-3			
XSL	9.65E-2	6	1.60E-2			
FSL	7.36E-2	4	1.84E-2	3.14	0.0554	
XAL	2.01E-2	3	6.71E-2			
FAL	1.31E-2	2	6.58E-3	2.10	0.2038	
SAL	3.70E-3	2	1.85E-3	2.76	0.1411	
XFD	1.46E-1	18	8.13E-3			
XSD	1.62E-1	18	9.02E-3			
FSD	2.29E-1	12	1.91E-2	1.85	0.0758	
XAD	3.19E-2	9	3.54E-3			
FAD	3.09E-2	6	5.15E-3	0.62	0.7157	
SAD	5.08E-2	6	8.47E-3	0.89	0.5228	
XLD	3.83E-2	9	4.25E-3			
FLD	4.50E-2	6	7.51E-3	0.51	0.7937	
SLD	6.070E-2	6	1.01E-2	0.55	0.7668	
ALD	8.21E-4	3	2.73E-4	0.04	0.9904	XFSA
	8.148E-2	12	6.79E-3			
XFSL	7.04E-2	12	5.86E-3			
XFAL	1.88E-2	6	3.13E-3			
XSAL	4.02E-3	6	6.70E-4			
FSAL	3.37E-2	4	8.42E-3	0.81	0.5415	XFSD
	3.71E-1	36	1.03E-2			
XFAD	1.50E-1	18	8.38E-3			
XSAD	1.71E-1	18	9.52E-3			
FSAD	2.84E-2	12	2.37E-3	0.61	0.8165	XFLD
	2.65E-1	18	1.47E-2			
XSLD	3.33E-1	8	1.85E-2			
FSLD	8.57E-2	12	7.14E-3	1.43	0.1961	

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A.8 continued

XALD	6.95E-2	9	7.72E-3		
FALD	7.74E-3	6	1.29E-3	0.23	0.9628
SALD	3.60E-2	6	6.01E-3	0.34	0.0070
XFSAL	1.24E-1	12	1.03E-2		
XFSAD	1.39E-1	36	3.86E-3		
XFSLD	1.79E-1	36	4.98E-3		
XFALD	1.02E-1	18	5.70E-3		
XSALD	2.49E-2	18	1.38E-3		
FSALD	1.06E-1	12	8.86E-3	1.03	0.4424
XFSALD	3.09E-1	36	8.59E-3		

Appendix A.9

Source	SS	DF	SS	F	Prob.
MEAN	2.29E+13	1	2.29E+13	23.81	0.0082
X	3.84E+7	4	9.61E+6		
Z	2.10E+7	4	5.26E+6	9.97	0.0003
F	1.10E+6	2	5.48E+5	3.71	0.0725
S	7.52E+5	2	3.76E+5	2.64	0.1318
XZ	8.44E+6	16	5.28E+5		
XF	1.18E+6	8	1.48E+5		
ZF	1.12E+6	8	1.40E+5	1.52	0.1894
XS	1.14E+6	8	1.43E+5		
ZS	3.11E+5	8	3.89E+4	0.65	0.7311
FS	1.25E+6	4	3.11E+5	1.65	0.2106
XZF	2.95E+6	32	9.23E+4		
XZS	1.92E+6	32	5.99E+4		
XFS	3.02E+6	16	1.89E+5		
ZFS	2.05E+6	16	1.28E+5	1.67	0.0758
XZFS	4.90E+6	64	7.66E+4		

Appendix A.10

Source	SS	df	MS	F	Prob.
MEAN	5.02E+0	1	5.02E+0	442.63	0.0000
X	4.54E-2	4	1.13E-2		
F	1.13E-1	2	5.66E-2	21.60	0.0006
S	9.82E-4	2	4.91E-4	0.21	0.8111
T	5.67E-2	1	5.67E-2	207.56	0.0001
D	6.78E-2	2	3.39E-2	22.47	0.0005
XF	2.10E-2	8	2.62E-3		
XS	1.83E-2	8	2.28E-3		
FS	1.78E-2	4	4.44E-3	4.72	0.0105
XT	1.09E-3	4	2.73E-4		
FT	3.22E-2	2	1.61E-2	7.70	0.0137
ST	4.66E-3	2	2.33E-3	0.84	0.4679
XD	1.21E-2	8	1.51E-3		
FD	3.45E-2	4	8.62E-3	11.71	0.0001
SD	6.66E-2	4	1.66E-2	8.36	0.0008
TD	8.77E-2	2	4.39E-2	21.84	0.0006
XFS	1.51E-2	16	9.42E-4		
XFT	1.68E-2	8	2.09E-3		
XST	2.23E-2	8	2.79E-3		
FST	4.31E-2	4	1.08E-2	21.05	0.0000
XFD	1.18E-2	16	7.36E-4		
XSD	3.19E-2	16	1.99E-3		
FSD	2.98E-2	8	3.72E-3	4.88	0.0005
XTD	1.61E-2	8	2.01E-3		
FTD	3.26E-2	4	8.15E-3	11.67	0.0001
STD	6.23E-2	4	1.56E-2	13.46	0.0001
XFST	8.20E-3	16	5.12E-4		
XFSD	2.44E-2	32	7.63E-4		
XFTD	1.12E-2	16	7.00E-4		
XSTD	1.85E-2	16	1.16E-3		
FSTD	1.74E-2	8	2.17E-3	3.89	0.0027
XFSTD	1.79E-2	32	5.59E-4		

Appendix A.11

CONDITIONS	S1	S2	S3	S4	S5
150 x 150	17	37	13	36	25
150 x 200	8	23	10	13	14
150 x 400	19	37	12	35	24
200 x 150	17	15	11	24	25
200 x 200	17	30	33	32	35
200 x 400	17	31	15	26	17
400 x 150	25	34	17	30	31
400 x 200	25	38	17	33	22
400 x 400	39	39	18	36	38

Appendix A.12

Source	SS	df	MS	F	Prob.
MEAN	1.47E+7	1	1.47E+7	5146.47	0.0000
X	1.14E+4	4	2.8E+3		
F	7.61E+5	2	3.80E+5	166.62	0.0000
S	2.81E+5	2	1.40E+5	244.74	0.0000
L	4.40E+3	1	4.40E+3	6.08	0.0693
D	1.39E+4	2	6.97E+3	16.99	0.0013
XF	1.82E+4	8	2.28E+3		
XS	4.59E+3	8	5.74E+2		
FS	7.59E+3	4	1.89E+3	3.87	0.0220
XL	2.90E+3	4	7.25E+2		
FL	6.30E+4	2	1.81E+5	220.07	0.0000
SL	3.79E+5	2	1.89E+5	213.01	0.0000
XD	2.86E+2	8	4.10E+2		
FD	7.90E+4	4	1.97E+4	71.46	0.0000
SD	6.18E+4	4	1.54E+4	17.90	0.0000
LD	3.03E+4	2	1.51E+4	100.09	0.0000
XFS	7.84E+3	16	4.90E+2		
XFL	6.59E+3	8	8.24E+2		
XSL	7.13E+3	8	8.91E+2		
FSL	8.40E+3	4	2.10E+3	4.92	0.0089
XFD	4.42E+3	16	2.76E+2		
XSD	1.38E+4	16	8.63E+2		
FSD	9.08E+3	8	1.13E+3	4.78	0.0006
XLD	1.21E+3	8	1.51E+2		
FLD	7.15E+4	4	1.78E+4	50.92	0.0000
SLD	5.74E+4	4	1.43E+4	17.26	0.0000
XFSL	6.83E+4	16	4.27E+2		
XFSD	7.60E+3	32	2.37E+2		
XFLD	5.62E+3	16	3.51E+2		
XSLD	1.33E+4	16	8.31E+2		
FSLD	1.01E+4	8	1.26E+3	7.58	0.0000
XFSLD	5.35E+3	32	1.67E+2		

Appendix A.13

CONDITIONS	S1	S2	S3	S4	S5
150/150	17	37	13	36	25
150/200	6	6	6	6	3
150/400	4	26	7	24	2
200/150	3	7	0	1	7
200/200	17	30	18	32	35
200/400	2	0	6	25	2
400/150	3	26	1	1	29
400/200	0	15	1	1	20
400/400	39	39	33	36	38

Appendix A.14

Source	SS	df	MS	F	Prob.
MEAN	1.53E+4	1	1.53E+4	4582.73	0.0000
X	1.34E+1	4	3.35E+0		
Z	3.80E+0	4	9.51E-1	0.40	0.8078
F	1.78E+1	2	8.93E+0	12.49	0.0035
S	1.58E+0	2	7.93E-1	1.12	0.3732
T	3.64E+0	1	3.64E+0	3.15	0.1505
D	2.02E+0	2	1.01E+0	3.59	0.0771
XZ	3.83E+1	16	2.39E+0		
XF	5.71E+0	8	7.14E-1		
ZF	7.83E+0	8	9.80E-1	1.94	0.0875
XS	5.68E+0	8	7.10E-1		
ZS	5.07E+0	8	6.33E-1	1.44	0.2176
FS	1.38E+1	4	3.46E+0	4.44	0.0133
XT	4.62E+0	4	1.15E+0		
ZT	1.16E+0	4	2.91E-1	1.54	0.2383
FT	2.04E+1	2	1.02E+1	24.77	0.0004
ST	7.06E+0	2	3.53E+0	6.14	0.0242
XD	2.25E+0	8	2.81E-1		
ZD	3.12E+0	8	3.91E-1	1.71	0.1334
FD	7.17E-1	4	1.79E-1	0.57	0.6908
SD	3.23E+0	4	8.08E-1	1.53	0.2413
TD	9.55E+0	2	4.77E+0	6.83	0.0186
XZF	1.61E+1	32	5.04E-1		
XZS	1.40E+1	32	4.39E-1		
XFS	1.24E+1	16	7.81E-1		
ZFS	4.95E+0	16	3.09E-1	0.66	0.8224
XZT	3.03E+0	16	1.89E-1		
XFT	3.30E+0	8	4.12E-1		
ZFT	5.28E+0	8	6.60E-1	2.48	0.0321
XST	4.60E+0	8	5.75E-1		
ZST	2.51E+0	8	3.13E-1	1.87	0.1001
FST	1.24E+1	4	3.11E+0	11.07	0.0002
XZD	7.30E+0	32	2.28E-1		
XFD	5.06E+0	16	2.16E-1		
ZFD	2.55E+0	16	1.59E-1	0.84	0.6370
XSD	8.46E+0	16	5.29		
ZSD	3.17E+0	16	1.98E-1	0.97	0.4969
FSD	5.50E+0	8	6.88E-1	4.06	0.0020
XTD	5.60E+0	8	7.00E-1		
ZTD	1.02E+0	8	1.28E-1	0.54	0.8139
FTD	3.53E+0	4	8.84E-1	4.36	0.0142
STD	8.13E-1	4	2.03E-1	0.89	0.4925
XZFS	3.00E+1	64	4.70E-1		
XZFT	8.50E+0	32	2.65E-1		
XZST	5.37E+0	32	1.67E-1		
XFST	4.50E+0	16	2.81E-1		
ZFST	2.30E+0	16	1.43E-1	0.54	0.9128
XZFD	1.21E+1	64	1.90E-1		
XZSD	1.30E+1	64	2.04E-1		
XFSD	5.41E+0	32	1.69E-1		
ZFSD	8.14E+0	32	2.54E-1	1.54	0.0495
XZTD	7.55E+0	32	2.36E-1		
XFTD	3.24E+0	16	2.02E-1		
ZFTD	3.60E+0	16	2.25E-1	1.52	0.1203

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A.14 continued

XSTD	3.65E+0	16	2.28E-1		
ZSTD	2.31E+0	16	1.44E-1	0.94	0.5321
FSTD	1.90E+0	8	2.38E-1	1.47	0.2057
XZFST	1.69E+1	64	2.64E-1		
XZFSD	2.11E+1	128	1.65E-1		
XZFTD	9.48E+0	64	1.48E-1		
XZSTD	9.87E+0	64	1.54E-1		
XFSTD	5.17E+0	32	1.61E-1		
ZFSTD	5.82E+0	32	1.81E-1	0.86	0.6840
XZFSTD	2.71E+1	128	2.11E-1		

Appendix A.15

Source	SS	df	MS	F	Prob.
MEAN	2.83E+3	1	2.83E+3	3264.38	0.0000
X	3.47E+0	4	8.69E-1		
F	2.18E+0	2	1.09E+0	8.30	0.0112
S	1.97E+0	2	9.88E-1	4.50	0.0490
L	1.89E+0	1	1.89E+0	7.60	0.0510
D	2.54E+0	2	1.27E+0	12.39	0.0035
XF	1.05E+0	8	1.31E-1		
XS	1.75E+0	8	2.19E-1		
FS	8.39E-1	4	2.09E-1	2.04	0.1365
XL	9.97E-1	4	2.49E-1		
FL	1.63E+0	2	8.15E-1	5.10	0.0374
SL	2.51E+0	2	1.25E+0	7.88	0.0129
XD	8.20E-1	8	1.02E-1		
FD	2.03E-1	4	5.07E-2	1.09	0.3967
SD	3.11E-1	4	7.79E-2	0.56	0.6976
LD	5.10E+0	2	2.55E+0	26.42	0.0003
XFS	1.64E+0	16	1.02E-1		
XFL	1.27E+0	8	1.59E-1		
XSL	1.27E+0	8	1.59E-1		
FSL	2.56E+0	4	6.41E-1	7.94	0.0010
XFD	7.48E-1	16	4.67E-2		
XSD	2.24E+0	16	1.40E-1		
FSD	1.36E+0	8	1.70E-1	3.67	0.0039
XLD	7.72E-1	8	9.66E-2		
FLD	2.44E-1	4	6.12E-2	0.84	0.5187
SLD	1.94E-1	4	4.86E-2	0.56	0.6957
XFSL	1.29E+0	16	8.07E-2		
XFSD	1.48E+0	32	4.65E-2		
XFLD	1.16E+0	16	7.27E-2		
XSLD	1.39E+0	16	8.70E-2		
FSLD	3.96E-1	8	4.96E-2	1.57	0.1721
XFSLD	1.00E+0	32	3.15E-2		

Appendix A.16

Source	SS	df	MS	F	Prob.
MEAN	3.81E+1	1	3.81E+1	216.41	0.0001
X	7.05E-1	4	1.76E-1		
Z	2.20E-1	4	5.50E-2	1.06	0.4095
F	1.52E+0	2	7.64E-1	24.23	0.0004
S	4.59E-1	2	2.29E-1	4.63	0.0462
T	3.48E-2	1	3.48E-2	0.84	0.4114
D	2.38E-3	2	1.19E-3	0.10	0.9093
XZ	8.32E-1	16	5.20E-2		
XF	2.52E-1	8	3.15E-2		
ZF	3.59E-1	8	4.49E-2	2.02	0.0752
XS	3.97E-1	8	4.96E-2		
ZS	2.01E-1	8	2.51E-2	1.41	0.2290
FS	1.41E-1	4	3.52E-2	1.87	0.1647
XT	1.66E-1	4	4.15E-2		
ZT	8.64E-2	4	2.16E-2	1.36	0.2925
FT	8.42E-1	2	4.21E-1	44.45	0.0000
ST	3.26E-1	2	1.63E-1	5.88	0.0269
XD	9.93E-2	8	1.24E-2		
ZD	1.48E-1	8	1.85E-2	1.48	0.2047
FD	8.33E-2	4	2.08E-2	1.35	0.2932
SD	3.29E-1	4	8.24E-2	6.09	0.0036
TD	5.61E-2	2	2.80E-2	0.85	0.4621
XZF	7.10E-1	32	2.21E-2		
XZS	5.56E-1	32	1.77E-2		
XFS	3.01E-1	16	1.88E-2		
ZFS	2.39E-1	16	1.49E-2	0.71	0.7728
XZT	2.49E-1	16	1.59E-2		
XFT	7.57E-2	8	9.47E-3		
ZFT	2.05E-1	8	2.56E-2	1.35	0.2549
XST	2.22E-1	8	2.77E-2		
ZST	6.72E-2	8	8.40E-3	0.68	0.2349
FST	2.39E-1	4	5.98E-2	5.18	0.0072
XZD	4.01E-1	32	1.25E-2		
XFD	2.46E-1	16	1.53E-2		
ZFD	1.32E-1	16	8.25E-3	0.70	0.7799
XSD	2.16E-1	16	1.35E-2		
ZSD	1.86E-1	16	1.16E-2	1.12	0.3557
FSD	1.73E-1	8	2.16E-2	2.51	0.0105
XTD	2.63E-1	8	3.29E-2		
ZTD	6.14E-2	8	7.68E-3	0.55	0.8121
FTD	1.29E-1	4	3.23E-2	3.14	0.0437
STD	1.88E-1	4	4.71E-2	4.39	0.0139
XZFS	1.34E+0	64	2.10E-2		
XZFT	6.07E-1	32	1.89E-2		
XZST	3.94E-1	32	1.23E-2		
XFST	1.85E-1	16	1.15E-2		
ZFST	1.50E-1	16	9.38E-3	0.64	0.8353
XZFD	7.50E-1	64	1.17E-2		
XZSD	6.64E-1	64	1.03E-2		
XFSD	2.76E-1	32	8.63E-3		
ZFSD	3.22E-1	32	1.00E-2	1.09	0.3539
XZTD	4.49E-1	32	1.40E-2		
XFTD	1.64E-1	16	1.02E-2		
ZFTD	2.10E-1	16	1.31E-2	1.31	0.2195

Continued, next page

A.16 continued

XSTD	1.72E-1	16	1.07E-2		
ZSTD	1.63E-1	16	1.02E-2	1.13	0.3497
FSTD	9.53E-2	8	1.19E-2	1.45	0.2157
XZFST	9.32E-1	64	1.45E-2		
XZFSD	1.81E+0	128	9.23E-3		
XZFTD	6.42E-1	64	1.00E-2		
XZSTD	5.78E-1	64	9.04E-3		
XFSTD	2.63E-1	32	8.23E-3		
ZFSTD	3.43E-1	32	1.07E-2	1.05	0.4063
XZFSTD	1.30E+0	128	1.02E-2		

Appendix A.17

Source	SS	df	MS	F	Prob.
MEAN	4.46E+0	1	4.46E+0	412.10	0.0000
X	4.33E-2	4	1.08E-2		
F	6.51E-2	2	3.25E-2	16.73	0.0014
S	6.69E-3	2	3.34E-3	0.84	0.4681
L	2.67E-2	1	2.67E-2	9.49	0.0369
D	3.68E-2	2	1.84E-2	14.23	0.0023
XF	1.55E-2	8	1.94E-3		
XS	3.20E-2	8	4.00E-3		
FS	1.28E-2	4	3.21E-3	1.91	0.1580
XL	1.12E-2	4	2.81E-3		
FL	5.52E-2	2	2.76E-2	13.44	0.0028
SL	1.68E-2	2	8.40E-3	3.34	0.0880
XD	1.03E-2	8	1.29E-3		
FD	2.02E-2	4	5.06E-3	6.28	0.0031
SD	3.27E-2	4	8.18E-3	3.46	0.0323
LD	5.51E-2	2	2.75E-2	22.04	0.0006
XFS	2.69E-2	16	1.68E-3		
XFL	1.64E-2	8	2.05E-3		
XSL	2.01E-2	8	2.51E-3		
FSL	2.78E-2	4	6.96E-3	6.03	0.0037
XFD	1.29E-2	16	8.06E-4		
XSD	3.79E-2	16	2.36E-3		
FSD	1.78E-2	8	2.23E-3	2.65	0.0238
XLD	1.00E-2	8	1.25E-3		
FLD	1.77E-2	4	4.43E-3	3.91	0.0211
SLD	2.76E-2	4	6.90E-3	4.42	0.0135
XFSL	1.84E-2	16	1.15E-3		
XFSD	2.70E-2	32	8.44E-4		
XFLD	1.81E-2	16	1.13E-3		
XSLD	2.50E-2	16	1.56E-3		
FSLD	4.73E-3	8	5.91E-4	0.88	0.5470
XFSLD	2.16E-2	32	6.75E-4		

Appendix A.18

Source	SS	df	MS	F	Prob.
MEAN	2.96E+8	1	2.96E+8	34.16	0.0043
G	2.06E+7	3	6.87E+6	0.79	0.5590
H	1.85E+4	1	1.85E+4	1.55	0.2806
F	1.93E+5	2	9.68E+4	0.97	0.4210
S	4.35E+5	2	2.17E+5	8.18	0.0116
X(G)	3.47E+7	4	8.69E+6		
GH	3.42E+4	3	1.14E+4	0.96	0.4938
GF	2.42E+5	6	4.03E+4	0.40	0.8578
HF	5.20E+4	2	2.60E+4	1.02	0.4029
GS	5.06E+5	6	8.43E+4	3.17	0.0673
HS	4.40E+4	2	2.20E+4	1.02	0.4028
FS	7.61E+5	4	1.90E+5	4.45	0.0132
XH(G)	4.76E+4	4	1.19E+4		
XF(G)	8.01E+5	8	1.00E+5		
XS(G)	2.12E+5	8	2.65E+4		
GHF	1.43E+5	6	2.39E+4	0.94	0.5166
GHS	1.55E+5	6	2.59E+4	1.20	0.3927
GFS	5.56E+5	12	4.63E+4	1.08	0.4323
HFS	5.14E+4	4	1.28E+4	0.58	0.6803
XHF(G)	2.03E+5	8	2.54E+4		
XHS(G)	1.72E+5	8	2.15E+4		
XFS(G)	6.84E+5	16	4.28E+4		
GHFS	1.89E+5	12	1.57E+4	0.71	0.7201
XHFS(G)	3.53E+5	16	2.21E+4		

Appendix A.19

Source	SS	df	MS	F	Prob.
MEAN	4.61E+7	1	4.611E+7	3505.82	0.0000
G	8.89E+4	3	2.96E+4	2.25	0.2244
F	2.97E+6	2	1.49E+6	156.68	0.0000
S	4.27E+5	2	2.14E+5	21.75	0.0006
H	8.78E+1	1	8.78E+1	0.05	0.8351
L	6.55E+4	1	6.55E+4	13.82	0.0205
X(G)	5.26E+4	4	1.32E+4		
GF	1.65E+4	6	2.75E+3	0.29	0.0257
GS	1.82E+4	6	3.04E+3	0.31	0.9149
FS	4.08E+4	4	1.02E+4	7.68	0.0012
GH	3.87E+3	3	1.29E+3	0.72	0.5879
FH	3.45E+3	2	1.73E+3	9.47	0.0078
SH	1.55E+3	2	7.77E+2	1.63	0.2554
GL	2.86E+4	3	9.93E+3	2.01	0.2549
FL	6.51E+5	2	3.26E+5	29.43	0.0002
SL	4.01E+5	2	2.01E+5	20.99	0.0007
HL	2.12E+2	1	2.12E+2	0.47	0.5305
XF(G)	7.58E+4	8	9.48E+3		
XS(G)	7.86E+4	8	9.82E+3		
XH(G)	7.11E+3	4	1.78E+3		
XL(G)	1.90E+4	4	4.74E+3		
GFS	2.36E+4	12	1.97E+3	1.48	0.2274
GFH	1.45E+3	6	2.41E+2	1.32	0.3470
GSH	2.32E+3	6	3.87E+2	0.81	0.5896
FSH	9.06E+2	4	2.27E+2	0.78	0.5530
GFL	1.90E+4	6	3.16E+3	0.29	0.9277
GSL	1.86E+4	6	3.10E+6	0.32	0.9063
FSL	2.38E+4	4	5.94E+6	6.21	0.0033
GHL	1.27E+3	3	4.21E+2	0.94	0.5020
FHL	2.12E+3	2	1.06E+3	3.43	0.0839
SHL	3.17E+3	2	1.59E+3	9.39	0.0080
XFS(G)	2.12E+4	16	1.33E+3		
XFH(G)	1.46E+3	8	1.82E+2		
XSH(G)	3.82E+3	8	4.78E+2		
XFL(G)	8.85E+4	8	1.11E+4		
XSL(G)	7.65E+4	8	9.56E+3		
XHL(G)	1.80E+3	4	4.50E+2		
GFSH	8.77E+3	12	7.31E+2	2.52	0.0430
GFSL	1.79E+4	12	1.49E+3	1.56	0.2008
GFHL	1.29E+3	6	2.15E+2	0.70	0.6611
GSHL	2.57E+3	6	4.28E+2	2.54	0.1115
FSHL	2.17E+3	4	5.43E+2	3.82	0.0231
XFSH(G)	4.63E+3	16	2.90E+2		
XFSL(G)	1.53E+4	16	9.57E+2		
XFHL(G)	2.48E+3	8	3.09E+2		
XSHL(G)	1.35E+3	8	1.69E+2		
GFSHL	1.87E+3	12	1.56E+2	1.09	0.4253
XFSHL(G)	2.28E+3	16	1.42E+2		

Appendix A.20.

Source	SS	df	MS	F	Prob.
MEAN	1.76E+8	1	1.76E+8	3857.29	0.0000
X	3.19E+5	7	4.56E+4		
F	6.70E+6	2	3.35E+6	552.43	0.0000
S	4.42E+6	2	2.21E+6	304.86	0.0000
H	1.89E+3	1	1.89E+3	1.70	0.2330
L	5.24E+4	1	5.24E+4	8.31	0.0236
D	3.38E+4	3	1.12E+4	2.86	0.0614
XF	8.49E+4	14	6.06E+3		
XS	1.01E+5	14	7.25E+3		
FS	1.67E+5	4	4.18E+4	13.51	0.0000
XH	7.78E+3	7	1.11E+3		
FH	2.46E+2	2	1.23E+2	0.17	0.0000
SH	4.93E+3	2	2.46E+3	6.98	0.0079
XL	4.41E+4	7	6.30E+3		
FL	5.97E+6	2	2.98E+6	369.64	0.0000
SL	4.72E+6	2	2.36E+6	434.09	0.0000
HL	4.00E+3	1	4.00E+3	5.37	0.0536
XD	8.29E+4	21	3.94E+3		
FD	1.33E+5	6	2.22E+4	11.98	0.0000
SD	1.75E+5	6	2.92E+4	13.23	0.0000
HD	1.24E+4	3	4.15E+3	10.83	0.0002
LD	3.79E+3	3	1.26E+3	0.36	0.7805
XFS	8.68E+4	28	3.10E+3		
XFH	9.99E+3	14	7.13E+2		
XSH	4.94E+3	14	3.53E+2		
FSH	3.25E+3	4	8.12E+2	1.10	0.3780
XFL	1.13E+5	14	8.07E+3		
XSL	7.62E+4	14	5.44E+3		
FSL	2.06E+5	4	5.16E+4	20.57	0.0000
XHL	5.22E+3	7	7.45E+2		
FHL	3.80E+3	2	1.90E+3	2.34	0.1333
SHL	8.84E+3	2	4.42E+3	9.83	0.0022
XFD	7.78E+4	42	1.85E+3		
XSD	9.29E+4	42	2.21E+3		
FSD	2.45E+4	12	2.04E+3	3.82	0.0001
XHD	8.05E+3	21	3.83E+2		
FHD	2.07E+3	6	3.45E+2	1.00	0.4411
SHD	2.13E+3	6	3.55E+2	1.33	0.2645
XLD	7.31E+4	21	3.48E+3		
FLD	1.54E+5	6	2.57E+4	13.91	0.0000
SLD	2.13E+5	6	3.56E+4	16.74	0.0000
HLD	7.27E+3	3	2.42E+3	6.36	0.0031
XFSH	2.07E+4	28	7.41E+2		
XFSL	7.02E+4	28	2.50E+3		
XFHL	1.14E+4	14	8.15E+2		
XSHL	6.29E+3	14	4.49E+2		
FSHL	2.51E+3	4	6.29E+2	3.01	0.0348
XFSD	4.49E+4	84	5.35E+2		
XFHD	1.45E+4	42	3.46E+2		
XSHD	1.11E+4	42	2.66E+2		
FSHD	5.29E+2	12	4.40E+1	0.23	0.9964
XFLD	7.78E+4	42	1.85E+3		
XSLD	8.94E+4	42	2.12E+3		
FSLD	2.08E+4	12	1.74E+3	3.88	0.0001

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A.20 continued

XHLD	8.00E+3	21	3.81E+2		
FHLD	2.26E+3	6	3.77E+2	1.40	0.2360
SHLD	3.57E+3	6	5.95E+2	2.16	0.0665
XFSHL	5.85E+3	28	2.09E+3		
XFSHD	1.61E+4	84	1.91E+2		
XFSLD	3.77E+4	84	4.48E+2		
XFHLD	1.13E+4	42	2.69E+1		
XSHLD	1.15E+4	42	2.75E+2		
FSHLD	1.14E+3	12	9.50E+2	0.47	0.9252
XFSHLD	1.68E+4	84	2.00E+2		

Appendix A.21

CONDITIONS	S1	S2	S3	S4	S5	S6	S7	S8
200 x 200 1 HAND	44	44	13	17	31	42	32	23
200 x 200 2 HANDS	30	51	9	12	17	42	30	26
200 x 400 1 HAND	39	42	9	0	4	38	31	22
200 x 400 2 HANDS	35	49	19	0	1	36	28	23
200 x 600 1HAND	46	49	25	9	26	35	31	26
200 x 600 2 HANDS	45	51	19	15	9	44	29	29
400 x 200 1 HAND	38	44	7	0	13	40	32	16
400 x 200 2 HANS	36	50	11	0	8	41	33	16
400 x 400 1 HAND	48	55	45	0	32	51	45	36
400 x 400 2 HANDS	50	53	46	0	28	44	45	35
400 x 600 1 HAND	49	44	41	1	25	47	39	28
400 x 600 2 HANDS	49	51	41	4	23	45	39	29
600 x 200 1 HAND	34	34	20	11	6	36	38	29
600 x 200 2 HANDS	28	39	21	2	6	33	39	28
600 x 400 1 HAND	38	40	25	1	22	45	27	19
600 x 400 2 HANDS	43	48	30	2	29	38	28	21
600 x 600 1 HAND	49	55	48	2	33	48	46	36
600 x 600 2 HANDS	50	55	48	12	30	47	45	37

Appendix A.22

Source	SS	df	MS	F	Prob.
MEAN	1.50E+8	1	1.50E+8	18056.34	0.0000
X	5.00E+4	6	8.34E+3		
F	6.49E+6	2	3.24E+6	612.98	0.0000
S	4.08E+6	2	2.04E+6	193.05	0.0000
H	1.72E+3	1	1.72E+3	2.30	0.1798
L	1.89E+4	1	1.89E+4	4.41	0.0805
D	4.07E+4	3	1.35E+4	4.23	0.0198
XF	6.35E+4	12	5.29E+3		
XS	1.26E+5	12	1.05E+4		
FS	1.70E+5	4	4.26E+4	14.93	0.0000
XH	4.48E+3	6	7.47E+2		
FH	1.21E+3	2	6.09E+2	1.64	0.2355
SH	1.95E+4	2	9.76E+3	3.15	0.0796
XL	2.57E+4	6	4.29E+3		
FL	5.28E+6	2	2.64E+6	430.39	0.0000
SL	4.16E+6	2	2.08E+6	236.58	0.0000
HL	2.61E+1	1	2.61E+1	0.08	0.7917
XD	5.78E+4	18	3.21E+3		
FD	1.72E+5	6	2.87E+4	18.48	0.0000
SD	2.28E+5	6	3.80E+4	21.30	0.0000
HD	6.68E+2	3	2.22E+2	0.74	0.5414
LD	2.69E+4	3	8.97E+3	3.23	0.0471
XFS	6.85E+4	24	2.85E+3		
XFH	4.47E+3	12	3.724E+2		
XSH	3.72E+4	12	3.10E+3		
FSH	7.21E+3	4	1.80E+3	0.50	0.7376
XFL	7.36E+4	12	6.14E+3		
XSL	1.05E+5	12	8.81E+3		
FSL	1.32E+5	4	3.30E+4	6.15	0.0015
XHL	2.05E+3	6	3.42E+2		
FHL	1.37E+3	2	6.87E+2	1.40	0.2836
SHL	2.80E+4	2	1.40E+4	4.88	0.0282
XFD	5.59E+4	36	1.55E+3		
XSD	6.43E+4	36	1.7E+3		
FSD	3.03E+4	12	2.53E+3	3.59	0.0003
XHD	5.41E+3	18	3.00E+2		
FHD	2.42E+3	6	4.04E+2	3.58	0.0070
SHD	5.44E+2	6	9.06E+1	0.31	0.9278
XLD	5.00E+4	18	2.78E+3		
FLD	1.85E+5	6	3.08E+4	16.26	0.0000
SLD	2.60E+5	6	4.33E+4	25.28	0.0000
HLD	1.49E+2	3	4.97E+1	0.53	0.6644
XFSH	8.69E+4	24	3.62E+3		
XFSL	1.28E+5	24	5.36E+3		
XFHL	5.88E+3	12	4.90E+2		
XSHL	3.45E+4	12	2.87E+3		
FSHL	9.84E+3	4	2.46E+3	0.78	0.5510
XFSD	5.07E+4	72	7.04E+2		
XFHD	4.07E+3	36	1.13E+2		
XSHD	1.05E+4	36	2.92E+2		
FSHD	2.46E+3	12	2.05E+2	1.12	0.3585
XFLD	6.83E+4	36	1.89E+3		
XSLD	6.17E+4	36	1.71E+3		
FSLD	1.95E+4	12	1.62E+3	2.90	0.0025

Continued, next page

A.22 continued

XHLD	1.67E+3	18	9.31E+1		
FHLD	1.17E+3	6	1.95E+2	2.00	0.0909
SHLD	5.68E+2	6	9.47E+1	0.34	0.9105
XFSHL	7.60E+4	24	3.16E+3		
XFSHD	1.32E+4	72	1.83E+2		
XFSLD	4.04E+4	72	5.61E+2		
XFHLD	3.51E+3	36	9.77E+1		
XSHLD	1.00E+4	36	2.78E+2		
FSHLD	3.14E+3	12	2.61E+2	1.21	0.2919
XFSHLD	1.55E+4	72	2.16E+2		

Appendix A.23

CONDITIONS	S1	S2	S3	S4	S5	S6	S7	S8
200 x 200 1 HAND	44	44	13	0	2	42	32	23
200 x 200 2 HANDS	30	51	9	0	2	42	30	26
200 x 400 1 HAND	11	42	9	0	5	38	28	20
200 x 400 2 HANDS	13	49	19	0	6	36	28	22
200 x 600 1HAND	10	49	25	0	48	35	30	25
200 x 600 2 HANDS	19	51	19	0	48	44	29	29
400 x 200 1 HAND	2	43	0	0	1	40	0	5
400 x 200 2 HANS	3	48	2	0	0	35	1	4
400 x 400 1 HAND	48	55	45	0	32	51	45	36
400 x 400 2 HANDS	50	53	46	0	28	44	45	35
400 x 600 1 HAND	5	15	18	0	12	32	24	13
400 x 600 2 HANDS	2	9	5	0	6	16	21	3
600 x 200 1 HAND	7	32	2	0	1	35	3	1
600 x 200 2 HANDS	8	38	2	0	3	30	2	13
600 x 400 1 HAND	3	30	5	0	5	34	0	0
600 x 400 2 HANDS	5	38	6	0	4	30	0	1
600 x 600 1 HAND	49	55	48	0	33	48	46	36
600 x 600 2 HANDS	50	55	48	12	30	47	45	37

Appendix A.24

Source	SS	dF	MS	F	Prob.
MEAN	4.49E+3	1	4.49E+3	2.53E+3	0.0000
G	2.71E+0	3	9.05E-1	0.51	0.6968
F	5.79E+0	2	2.90E+0	16.06	0.0016
S	7.67E-1	2	3.83E-1	1.65	0.2503
H	1.88E+0	1	1.88E+0	6.87	0.0587
L	1.48E+1	1	1.48E+1	78.80	0.0009
X(G)	7.10E+0	4	1.78E+0		
GF	1.94E+0	6	3.23E-1	1.79	0.2177
GS	3.36E-1	6	5.61E-2	0.24	0.9496
FS	4.90E+0	4	1.22E+0	16.28	0.0000
GH	9.15E-1	3	3.05E-1	1.12	0.4407
FH	1.19E+0	2	5.93E-1	10.66	0.0055
SH	2.96E-1	2	1.48E-1	0.91	0.4402
GL	6.06E-1	3	2.02E-1	1.08	0.4536
FL	4.28E+0	3	2.14E+0	21.71	0.0006
SL	4.66E-1	2	2.33E-1	2.26	0.1667
HL	8.64E-2	1	8.64E-2	3.45	0.1367
XF(G)	1.44E+0	8	1.80E-1		
XS(G)	1.85E+0	8	2.32E-1		
XH(G)	1.09E+0	4	2.73E-1		
XL(G)	7.50E-1	4	1.88E-1		
GFS	1.14E+0	12	9.53E-2	1.27	0.3230
GFH	4.17E-1	6	6.96E-2	1.25	0.3743
GSH	6.58E-1	6	1.10E-1	0.67	0.6757
FSH	2.21E-1	4	5.53E-2	0.60	0.6685
GFL	8.12E-2	6	1.35E-2	0.14	0.9869
GSL	1.24E+0	6	2.07E-1	2.01	0.1773
FSL	4.83E-1	4	1.21E-1	1.35	0.2955
GHL	5.72E-2	3	1.91E-2	0.76	0.5717
FHL	8.06E-2	2	4.03E-2	0.52	0.6150
SHL	2.89E-1	2	1.44E-1	2.67	0.1294
XFS(G)	1.20E+0	16	7.52E-2		
XFH(G)	4.45E-1	8	5.56E-2		
XSH(G)	1.30E+0	8	1.63E-1		
XFL(G)	7.89E-1	8	9.86E-2		
XSL(G)	8.25E-1	8	1.03E-1		
XHL(G)	1.00E-1	4	2.50E-2		
GFSH	1.91E+0	12	1.61E-1	1.74	0.1481
GFSL	9.45E-1	12	7.88E-2	0.88	0.5826
GFHL	2.14E-1	6	3.57E-2	0.46	0.8215
GSHL	6.84E-1	6	1.14E-1	2.11	0.1625
FSHL	4.49E-1	4	1.12E-1	4.10	0.0179
XFSH(G)	1.48E+0	16	9.23E-2		
XFSL(G)	1.43E+0	16	8.97E-2		
XFHL(G)	6.24E-1	8	7.79E-2		
XSHL(G)	4.33E-1	8	5.41E-2		
GFSHL	5.48E-1	12	4.57E-2	1.67	0.1677
XFSHL(G)	4.38E-1	16	2.74E-2		

Appendix A.25

Source	SS	df	MS	F	Prob.
MEAN	1.85E+4	1	1.85E+4	1514.04	0.0000
X	8.59E+1	6	1.22E+1		
F	4.36E+0	2	2.18E+0	3.02	0.0814
S	3.57E+0	2	1.78E+0	3.35	0.0648
H	0.21E+0	1	0.21E+0	0.93	0.2369
L	3.65E+1	1	3.65E+1	92.93	0.0000
D	1.07E+1	3	3.57E+0	12.93	0.0001
XF	1.01E+1	12	0.72E+0		
XS	7.48E+0	12	0.53E+0		
FS	2.38E+1	4	5.96E+0	14.17	0.0000
XH	1.65E+0	6	0.23E+0		
FH	1.02E+0	2	0.51E+0	1.99	0.1740
SH	0.15E+0	2	0.77E-1	0.35	0.7123
XL	2.75E+0	6	0.39E+0		
FL	3.59E+0	2	1.79E+0	7.44	0.0063
SL	0.98E+0	2	0.49E+0	1.19	0.3340
HL	0.39E+0	1	0.39E+0	7.31	0.0305
XD	5.80E+0	18	0.27E+0		
FD	0.53E+0	6	0.88E-1	0.79	0.5845
SD	1.13E+0	6	0.18E+0	1.03	0.4210
HD	5.48E+0	3	1.82E+0	20.16	0.0000
LD	7.59E+0	3	2.53E+0	17.85	0.0000
XFS	1.17E+1	24	0.42E+0		
XFH	3.61E+0	12	0.25E+0		
XSH	3.12E+0	12	0.22E+0		
FSH	0.86E+0	4	0.21E+0	1.36	0.2741
XFL	3.38E+0	12	0.24E+0		
XSL	5.81E+0	12	0.41E+0		
FSL	0.42E-1	4	0.10E-1	0.05	0.9944
XHL	0.37E+0	6	0.53E-1		
FHL	0.12E+0	2	0.64E-1	0.71	0.5096
SHL	0.65E-1	2	0.32E-1	0.40	0.6757
XFD	4.73E+0	36	0.11E+0		
XSD	7.72E+0	36	0.18E+0		
FSD	2.98E+0	12	0.24E+0	2.55	0.0064
XHD	1.90E+0	18	0.90E-1		
FHD	0.57E+0	6	0.95E-1	1.08	0.3886
SHD	0.25E+0	6	0.42E-1	0.40	0.8728
XLD	2.97E+0	18	0.14E+0		
FLD	0.16E+0	6	0.27E-1	0.25	0.9548
SLD	1.04E+0	6	0.17E+0	1.03	0.4216
HLD	4.61E+0	3	1.53E+0	15.39	0.0000
XFSH	4.43E+0	24	0.16E+0		
XFSL	5.61E+0	24	0.20E+0		
XFHL	1.28E+0	12	0.91E-1		
XSHL	1.13E+0	12	0.81E-1		
FSHL	0.20E+0	4	0.51E-1	0.40	0.8104
XFSD	3.19E+0	72	0.97E-1		
XFHD	3.70E+0	36	0.88E-1		
XSHD	4.40E+0	36	0.10E+0		
FSHD	0.70E+0	12	0.59E-1	0.86	0.5888
XFLD	4.53E+0	36	0.10E+0		
XSLD	7.10E+0	36	0.16E+0		
FSLD	1.83E+0	12	0.15E+0	1.41	0.1766

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A.25 continued

XHLD	2.10E+0	18	0.10E+0		
FHLD	0.68E+0	6	0.11E+0	1.15	0.3528
SHLD	0.94E+0	6	0.15E+0	1.36	0.2549
XFSHL	3.62E+0	28	0.12E+0		
XFSHD	5.77E+0	84	0.68E-1		
XFSLD	9.32E+0	84	0.11E+0		
XFHLD	4.15E+0	42	0.98E-1		
XSHLD	4.90E+0	42	0.11E+0		
FSHLD	0.61E+0	12	0.51E-1	0.50	0.9084
XFSHLD	8.59E+0	84	0.10E+0		

Appendix A.26

Source	SS	df	MS	F	Prob.
MEAN	1.37E+4	1	1.37E+4	3759.44	0.0000
X	2.19E+1	6	3.65E+0		
F	2.74E+1	2	1.37E+1	45.71	0.0000
S	2.04E+1	2	1.02E+1	21.08	0.0001
H	2.17E-1	1	2.17E-1	1.40	0.2819
L	8.62E+0	1	8.62E+0	33.59	0.0012
D	1.38E+1	3	4.61E+0	32.99	0.0000
XF	3.60E+0	12	3.00E-1		
XS	5.82E+0	12	4.85E-1		
FS	1.18E+1	4	2.96E+0	19.98	0.0000
XH	9.33E-1	6	1.55E-1		
FH	2.73E-1	2	1.36E-1	3.58	0.0604
SH	4.22E-1	2	2.11E-1	2.14	0.1609
XL	1.54E+0	6	2.56E-1		
FL	1.91E+1	2	9.57E+0	47.79	0.0000
SL	1.40E+1	2	7.01E+0	36.19	0.0000
HL	1.39E-1	1	1.39E-1	1.97	0.2105
XD	2.51E+0	18	1.39E-1		
FD	4.34E-1	6	7.23E-2	1.39	0.2448
SD	3.43E+0	6	5.73E-1	7.83	0.0000
HD	4.38E-1	3	1.46E-1	2.27	0.1154
LD	5.51E+0	3	1.83E+0	30.08	0.0000
XFS	3.56E+0	24	1.48E-1		
XFH	4.58E-1	12	3.82E-2		
XSH	1.18E+0	12	9.90E-2		
FSH	1.85E-1	4	4.63E-2	0.39	0.8168
XFL	2.40E+0	12	2.00E-1		
XSL	2.32E+0	12	1.93E-1		
FSL	2.19E-1	4	5.48E-2	0.57	0.6880
XHL	4.26E-1	6	7.11E-2		
FHL	3.16E-1	2	1.58E-1	2.11	0.1635
SHL	3.93E-1	2	1.96E-1	3.40	0.0676
XFD	1.87E+0	36	5.20E-2		
XSD	2.63E+0	36	7.32E-2		
FSD	1.39E+0	12	1.16E-1	3.67	0.0003
XHD	1.16E+0	18	6.44E-2		
FHD	5.39E-1	6	8.99E-2	2.98	0.0181
SHD	1.22E-1	6	2.03E-2	0.49	0.8111
XLD	1.09E+0	18	6.11E-2		
FLD	1.68E-1	6	2.80E-2	0.94	0.4817
SLD	2.46E+0	6	4.11E-1	8.89	0.0000
HLD	3.02E-2	3	1.00E-2	0.68	0.5782
XFSH	2.80E+0	24	1.20E-2		
XFSL	2.31E+0	24	9.65E-2		
XFHL	8.99E-1	12	7.49E-2		
XSHL	6.93E-1	12	5.78E-2		
FSHL	4.24E-1	4	1.06E-1	1.41	0.2615
XFSD	2.28E+0	72	3.17E-2		
XFHD	1.08E+0	36	3.01E-2		
XSHD	1.49E+0	36	4.14E-2		
FSHD	3.78E-1	12	3.15E-2	0.90	0.5510
XFLD	1.08E+0	36	3.00E-2		
XSLD	1.66E+0	36	4.62E-2		
FSLD	5.10E-1	12	4.25E-2	1.60	0.1097

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A.26 continued

XHLD	2.68E-1	18	1.49E-2		
FHLD	2.59E-1	6	4.31E-2	1.23	0.3137
SHLD	2.91E-1	6	4.85E-2	1.88	0.1104
XFSHL	1.81E+0	24	7.54E-2		
XFSHD	2.52E+0	72	3.50E-2		
XFSLD	1.90E+0	72	2.65E-2		
XFHLD	1.26E+0	36	3.50E-2		
XSHLD	0.92E+0	36	2.57E-2		
FSHLD	0.30E+0	12	2.52E-2	1.42	0.1748
XFSHLD	1.27E+0	72	1.77E-2		

Appendix A.27

Source	SS	df	MS	F	Prob.
MEAN	6.90	1	6.90	384.36	0.0000
G	3.21E-2	3	1.07E-2	0.60	0.6497
F	1.82E-1	2	9.11E-2	5.73	0.0286
S	2.57E-2	2	1.29E-2	1.21	0.3484
H	5.86E-2	1	5.86E-2	5.42	0.0805
L	2.13E-1	1	2.13E-1	50.62	0.0021
X(G)	7.18E-2	4	1.79E-2		
GF	4.20E-2	6	7.00E-3	0.44	0.8335
GS	9.03E-3	6	1.50E-3	0.14	0.9859
FS	5.40E-2	4	1.35E-2	6.54	0.0026
GH	2.26E-2	3	7.54E-3	0.70	0.6011
FH	5.48E-2	2	2.74E-2	5.87	0.0270
SH	4.31E-3	2	2.16E-3	0.55	0.5963
GL	1.09E-2	3	3.63E-3	0.87	0.5285
FL	1.21E-4	2	6.05E-5	0.01	0.9931
SL	5.25E-2	2	2.62E-2	4.76	0.0434
HL	1.98E-3	1	1.98E-3	2.87	0.1654
XF(G)	1.27E-1	8	1.59E-2		
XS(G)	8.52E-2	8	1.07E-2		
XH(G)	4.33E-2	4	1.08E-2		
XL(G)	1.68E-2	4	4.20E-2		
GFS	4.88E-2	12	4.07E-3	1.97	0.1025
GFH	2.73E-2	6	4.55E-3	0.97	0.4987
GSH	1.81E-2	6	3.02E-3	0.77	0.6118
FSH	4.78E-3	4	1.20E-3	0.45	0.7741
GFL	9.51E-3	6	1.58E-3	0.18	0.9742
GSL	5.05E-2	6	8.41E-3	1.53	0.2826
FSL	1.76E-2	4	4.39E-3	1.09	0.3929
GHL	2.60E-3	3	8.66E-4	1.26	0.4013
FHL	1.39E-3	2	6.96E-4	0.23	0.7987
SHL	1.35E-2	2	6.76E-3	2.86	0.1154
XFS(G)	3.30E-2	16	2.06E-3		
XFH(G)	3.74E-2	8	4.67E-3		
XSH(G)	3.12E-2	8	3.91E-3		
XFL(G)	7.0AE-2	8	8.76E-3		
XSL(G)	4.41E-2	8	5.51E-3		
XHL(G)	2.76E-3	4	6.89E-4		
GFSH	3.57E-2	12	2.98E-3	1.11	0.4150
GFSL	3.99E-2	12	3.32E-3	0.83	0.6238
GFHL	7.27E-3	6	1.21E-3	0.40	0.8581
GSHL	1.95E-2	6	3.25E-3	1.38	0.3286
FSHL	1.76E-2	4	4.40E-3	4.07	0.0184
XFSH(G)	4.29E-2	16	2.68E-3		
XFSL(G)	6.42E-2	16	4.01E-3		
XFHL(G)	2.41E-2	8	3.01E-3		
XSHL(G)	1.89E-2	8	2.36E-3		
GFSHL	1.53E-2	12	1.27E-3	1.18	0.3732
XFSHL(G)	1.73E-2	16	1.08E-3		

Appendix A.28

Source	SS	df	MS	F	Prob.
MEAN	4.17E+1	1	4.17E+1	142.40	0.0000
X	2.05E+0	7	2.92E-1		
F	1.19E+0	2	5.97E-1	10.99	0.0014
S	1.23E+0	2	6.17E-1	9.32	0.0027
H	1.51E-1	1	1.51E-1	11.86	0.0108
L	7.07E+0	1	1.70E+0	39.73	0.0004
D	1.62E+0	3	5.40E-1	12.66	0.0001
XF	7.61E-1	14	5.44E-2		
XS	9.26E-1	14	6.61E-2		
FS	3.67E-1	4	9.18E-2	3.28	0.0205
XH	8.91E-2	7	1.27E-2		
FH	4.37E-2	2	2.18E-2	0.76	0.4868
SH	5.57E-2	2	2.78E-2	1.87	0.1908
XL	3.00E-1	7	4.29E-2		
FL	6.27E-1	2	3.13E-1	18.03	0.0001
SL	7.85E+0	2	8.92E-1	13.53	0.0005
HL	1.95E-1	1	1.95E-1	23.13	0.0019
XD	8.95E-1	21	4.26E-2		
FD	7.38E-2	6	1.23E-2	0.87	0.5233
SD	6.84E-1	6	1.14E-1	3.11	0.0103
HD	8.34E-1	3	2.78E-1	27.21	0.0000
LD	1.59E+0	3	5.30E-1	17.80	0.0000
XFS	7.84E-1	28	2.80E-2		
XFH	4.03E-1	14	2.88E-2		
XSH	2.08E-1	14	1.49E-2		
FSH	5.14E-2	4	1.28E-2	0.83	0.5176
XFL	2.43E-2	14	1.74E-2		
XSL	9.23E-1	14	6.59E-2		
FSL	1.83E-1	4	4.58E-2	1.98	0.1251
XHL	5.92E-2	7	8.46E-3		
FHL	8.34E-3	2	4.17E-3	0.21	0.8161
SHL	4.91E-2	2	2.45E-2	3.13	0.0750
XFD	5.92E-1	42	1.41E-2		
XSD	1.53E+0	42	3.66E-2		
FSD	2.46E-1	12	2.05E-2	1.46	0.1566
XHD	2.14E-1	21	1.02E-2		
FHD	2.52E-2	6	4.20E-3	0.22	0.9686
SHD	1.54E-1	6	2.57E-2	1.95	0.0944
XLD	6.26E-1	21	2.98E-2		
FLD	4.98E-2	6	8.30E-3	0.53	0.7799
SLD	6.56E-1	6	1.09E-1	3.28	0.0097
HLD	7.42E-1	3	2.47E-1	24.66	0.0000
XFSH	4.33E-1	28	1.54E-2		
XFSL	6.49E-1	28	2.31E-2		
XFHL	2.83E-1	14	2.02E-2		
XSHL	1.09E-1	14	7.84E-3		
FSHL	3.35E-2	4	8.39E-3	0.49	0.7438
XFSD	1.80E+0	84	1.40E-2		
XFHD	8.05E-1	42	1.91E-2		
XSHD	5.54E-1	42	1.31E-2		
FSHD	5.84E-2	12	4.87E-3	0.40	0.9581
XFLD	6.54E-1	42	1.55E-2		
XSLD	1.39E+0	42	3.33E-2		
FSLD	1.80E-1	12	1.50E-2	0.98	0.4714

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A.28 continued

XHLD	2.10E-1	21	1.00E-2		
FHLD	2.55E-2	6	4.25E-3	0.23	0.9645
SHLD	2.07E-1	6	3.45E-2	2.43	0.0418
XFSHL	4.80E-1	28	1.71E-2		
XFSHD	1.01E+0	84	1.20E-2		
XFSLD	1.28E+0	84	1.53E-2		
XFHLD	7.76E-1	42	1.84E-2		
XSHLD	5.97E-1	42	1.42E-2		
FSHLD	4.85E-2	12	4.04E-3	0.28	0.9912
XFSHLD	1.21E+0	84	1.45E-2		

Appendix A.29.

Source	SS	df	MS	F	Prob.
MEAN	1.48E+1	1	1.48E+1	401.47	0.0000
X	2.21E-1	6	3.69E-2		
F	7.85E-2	2	3.92E-2	7.10	0.0092
S	3.28E-2	2	1.64E-2	2.05	0.1710
H	6.76E-3	1	6.76E-3	1.56	0.2579
L	1.07E-1	1	1.07E-1	22.37	0.0032
D	2.28E-1	3	7.63E-2	37.41	0.0000
XF	6.63E-2	12	5.53E-3		
XS	9.61E-2	12	8.00E-3		
FS	9.03E-2	4	2.25E-2	10.21	0.0001
XH	2.59E-2	6	4.32E-3		
FH	9.19E-3	2	4.59E-3	2.93	0.0920
SH	4.36E-3	2	2.18E-3	0.84	0.4565
XL	2.88E-2	6	4.80E-3		
FL	6.36E-2	2	3.18E-2	7.02	0.0096
SL	7.84E-2	2	3.92E-2	5.96	0.0160
HL	1.23E-3	1	1.23E-3	0.80	0.4044
XD	3.67E-2	18	2.04E-3		
FD	3.95E-2	6	6.58E-3	2.49	0.0407
SD	8.24E-3	6	1.37E-3	0.79	0.5811
HD	1.45E-2	3	4.84E-3	2.73	0.0745
LD	9.21E-2	3	3.07E-2	31.95	0.0000
XFS	5.30E-2	24	2.21E-3		
XFH	1.88E-2	12	1.56E-3		
XSH	3.12E-2	12	2.60E-3		
FSH	3.44E-3	4	8.61E-4	0.41	0.8016
XFL	5.43E-2	12	4.53E-3		
XSL	7.89E-2	12	6.58E-3		
FSL	1.37E-2	4	3.43E-3	1.86	0.1500
XHL	9.20E-3	6	1.53E-3		
FHL	3.95E-3	2	1.97E-3	1.38	0.2898
SHL	2.56E-3	2	1.28E-3	1.07	0.3721
XFD	9.53E-2	36	2.64E-3		
XSD	6.23E-2	36	1.73E-3		
FSD	1.56E-2	12	1.30E-3	1.62	0.1054
XHD	3.19E-2	18	1.77E-3		
FHD	1.95E-2	6	3.25E-3	2.95	0.0191
SHD	5.26E-3	6	8.77E-4	1.07	0.3995
XLD	1.73E-2	8	9.61E-4		
FLD	1.96E-2	6	3.27E-3	2.05	0.0836
SLD	8.28E-3	6	1.38E-3	0.88	0.5180
HLD	1.52E-3	3	5.08E-4	1.78	0.1869
XFSH	5.07E-2	24	2.11E-3		
XFSL	4.42E-2	24	1.84E-3		
XFHL	1.72E-2	12	1.43E-3		
XSHL	1.43E-2	12	1.19E-3		
FSHL	7.30E-3	4	1.82E-3	1.69	0.1857
XFSD	5.78E-2	72	8.03E-4		
XFHD	3.97E-2	36	1.10E-3		
XSHD	2.95E-2	36	8.21E-4		
FSHD	6.18E-3	12	5.15E-4	0.80	0.6483
XFLD	5.73E-2	36	1.59E-3		
XSLD	5.63E-2	36	1.56E-3		
FSLD	9.07E-3	12	7.55E-4	0.88	0.5681

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A.29 continued

XHLD	5.13E-3	18	2.85E-4		
FHLD	3.44E-3	6	5.74E-4	0.93	0.4877
SHLD	1.14E-2	6	1.90E-3	2.95	0.0189
XFSHL	2.59E-2	24	1.08E-3		
XFSHD	4.63E-2	72	6.43E-4		
XFSLD	6.16E-2	72	8.56E-4		
XFHLD	2.23E-2	36	6.19E-4		
XSHLD	2.31E-2	36	6.43E-4		
FSHLD	6.44E-3	12	5.36E-4	1.64	0.1001
XFSHLD	2.35E-2	72	3.27E-4		

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