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TEMPORAL PACING IN VISUAL ATTENTION (U)

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FOR THE COMMANDER

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Viewers engaged in a continuous letter classification task involving selective attending to one of two information streams (relevant and irrelevant). Temporal and spatial relations were systematically varied between the two streams to address hypotheses about external control of attention in dynamic environments. Relative event timing was varied both within and between the two streams. Spatial relationships for relevant and irrelvant events was the same for experiments 1 & 3, but different for experiment 2. Contrary to predictions from either spatial or object oriented approaches, attending and hence, performance, to relevant events in all three experiments was dependent on the integrated rhythmic patterns that obtained between the two streams, rather than spatial location and event features. Several alternative hypotheses addressed the issue of non-spatial control of attending to dynamic displays, The best account assumes viewer attending is "paced" by rhythms emerging from an integration of relevant and irrelevant event streams.

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ABSTRACT

Viewers engaged in a continuous letter classification task involving selective attending to one of two information streams (relevant and irrelevant). Temporal and spatial relations obtaining between the two streams were systematically varied to address hypotheses about external control of attention in dynamic environments. Relative event timing was varied both within (regular, R, versus irregular, I) and between (phasing) streams. Spatial relationships placed relevant and irrelevant events in the same (experiments 1 and 3), or different (experiment 2) spatial locations. Contrary to predictions from spatial oriented (e.g., spotlight) and object oriented (e.g., feature integration) approaches, attending to relevant events (letter pairs) in three experiments indicated that whether speed (experiments 1,2) or accuracy (experiment 3) was emphasized, response times showed both facilitation and interference that depended upon stream timings. Of several alternative hypotheses addressed to the control of attending in dynamic displays, the best account assumes that viewers "pace" attending to the rhythm emerging from an integration of both relevant and irrelevant event streams. This was particularly true when relevant and irrelevant events occur in the same spatial locations (Experiments 1 and 3).

TEMPORAL PACING IN VISUAL SELECTIVE ATTENTION

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Our everyday environment consists largely of change over time, and to cope with it we must somehow allocate attention over time and space. How do we do this? What controls attention in dynamic environments? Can we assume that attention is entirely under voluntary control in such contexts? The gist of the present report suggests the answer to the last question is "No". Attention appears to be at least partially controlled by the dynamic properties of the context itself.

In a number of situations, attention seems to be voluntarily controlled such that people can even "shift attention" to some spatial location independently of concomitant eye movements. In fact, three classes of models, all spatially-oriented, assume that visual attention is voluntarily controlled within some limited resource system. One class of model rests on a "spotlight" metaphor. These assume that attending is voluntarily directed to certain spatial locations where stimulus events illuminated within an attentional beam receive favored processing (e.g. Broadbent, 1982; Posner, Snyder & Davidson, 1980). In a second class are "zoom lens" models (e.g. Eriksen & St. James, 1986; Eriksen & Yeh, 1985); here limited attentional resources can be directed to targets within bounded spatial regions where focal attention is expanded or contracted to correspondingly change "resolving power". Finally, the third class of models includes "gradient" models of attention (e.g., Downing & Pinker, 1985; La Berge & Brown, 1989; Shulman, Wilson, & Sheehy, 1985). These approaches also assume that attention can be directed to spatial areas of different sizes, but they differ from others in assuming that attentional resources fall off monotonically from the spatial center of focal attention (a peak). All of these models share the assumption that attention is voluntary and endogenously directed over spatial regions and all have received some experimental support. At the same time, all have relied heavily upon search tasks which embed targets within arrays of targets and nontargets that are static in nature.

Other contemporary approaches to attention are structurally oriented and allow for the possibility that attention is controlled by event structure (e.g. Duncan, 1984; Treisman, 1988). For example, attending can be limited by the number of separate, but simultaneous, objects presented rather than simply by spatial area. Some object oriented theories of attending involve two stages where the first stage (preattentive) involves parallel processing and segmentation of the visual field into separate objects based on Gestalt principles (e.g. proximity, continuity, common fate, etc.). The second stage (attentive) involves serial processing, and in feature integration theory it involves limits upon a viewer's ability to combine different, simultaneous, aspects of a display to form a single perceptual object (Treisman, Kahneman, & Burkell, 1983; Treisman & Gelade, 1980; Treisman, 1988).

The present research rests on a rationale that shares the emphasis of object oriented approaches that external structure can exert some control on attention. However, while manipulations described by Gestalt principles of object structure are known to eventually affect performance in visual attention tasks (e.g. Kahneman & Henik, 1981; Prinzmetal, 1981;

Duncan, 1984; Driver & Baylis, 1989), these principles tend to fall short in describing objects' time structure. Consequently, models encorporating these principles offer weak provisions for describing temporal structure as such. These may be serious weaknesses in modeling attending to dynamic events. Accordingly, we explore the possibility that attention is sensitive to temporal object structure. A temporal object is a temporally extended display that changes systematically over time. Here, viewers are presented with two extended and unbroken temporal sequences of discrete events which we refer to as streams , and we consider whether they treat them as one or two separate temporal objects.

In general, dynamic arrays can capture important aspects of our everyday world which consists of object motion and/or rhythmical changes of sets of objects. These aspects include continuous and/or discrete time relationships. In such displays, for people to respond appropriately, they must sustain attending over some period of time. With respect to attentional control, might such relationships have some potential for controlling attention over this time period? Some evidence suggests they do. Continuous time relationships, in the form of object motions, attract attention even over noncontiguous regions of a display (Baylis, Driver, & McLeod, 1990; Driver & Baylis,1989; McLeod, Driver, Diense, & Crisp, 1991). For example, using displays composed of both static and moving elements, Driver and Baylis (1989) found that distant nontargets (distractors) which share movement (or immobility) with a target produce more interference than near ones which do not (e.g., "common fate" effects). This finding poses problems for the idea of spatially localized attention. Other research suggests that temporally discrete stimulus changes can also "capture" attention. Either via abrupt onsets of visual stimuli (Jonides, Naveh-Benjamin, & Palmer, 1985; Jonides & Yantis, 1988; Yantis & Johnson, 1984; 1990; Yantis & Jonides, 1990), or via the consistency with which they appear (Shiffrin, 1988) attention can be automatically attracted to some event onset. Thus, if an attentional "spotlight" moves continuously through space toward some target region, its course can be disrupted by the abrupt appearance of a new display element whether that distractor is near or far from the expected target's spatial locus. In short, voluntary control of attention can be disrupted or usurped by external factors that are inherent in dynamic displays suggesting that certain aspects of changing visual displays "take over" attending.

In spite of such developments, there remains little research which explicitly manipulates time relationships in dynamic visual displays, as some recently observe (Moray, 1984; Marks, 1987; Warm, Stutz & Vassolo, 1988; Driver & Baylis, 1989; Adams, and Pew, 1989; and Tipper, Brehaut, & Driver, 1990). For example, Tipper et al. (1990) comment ... "research studying visual selective attention has largely examined filtering tasks in which stationary targets are selected from stationary distractors... these situations differ fundamentally from the ecological reality of how we respond selectively to individual objects in cluttered dynamic visual environments". Similarly others call for greater reliance upon time as an independent variable (Moray, 1984).

In this vein, the dynamic visual displays used in the present research systematically manipulate discretely timed changes in occurrences of both targets (relevant) and nontargets (irrelevant) that comprise event streams. The design combines strategies used in studies of auditory displays with a traditional attentional task using visual targets and distractors with the aim of examining the role of relative timing on attentional control. Perhaps because acoustic arrays necessarily unfold over time, experimental strategies that manipulate relative timing properties (i.e., rate, relative time i.e. rhythm) have developed more naturally in these contexts. In fact, with auditory events, the idea of "capture" operates at several levels. Not only do onsets os sounds capture attention, but depending upon the unfolding pitch and loudness structure of the temporal object, some onsets are more attention-getting (accents) than others (Boltz & Jones, 1986; Handel, 1989). The term "capture" here has also been used to describe emergent rhythmic grouping effects in auditory streams that arise from manipulations of spacelike (i.e. pitch space) and temporal relations: perceptually a target tone groups with (i.e., is "captured by") one or another string of distractor tones depending upon relationships among targets and distractors in pitch space and relative time (e.g., Bregman & Rudnicky, ; Jones, Kidd, & Wetzel, 1981).

Jones (1976) suggested that in dynamic contexts, event onsets, especially of accented events, are more attention getting than offsets; this view received recent support (Danenbring & Bregman, 1976). According to this perspective attending in dynamic contexts is externally controlled (in part) not merely by isolated onsets but by relationships among the succession of unfolding events, namely by the patterns in time onsets create. For example, attention may be "paced" by rhythmic properties of extended temporal objects.

Supporting evidence for the idea that attending can be controlled by temporal event structure comes largely from auditory research in which the relative timing of event sequences (including speech and musical sequences) is manipulated (Jones, in press). In various tasks, the time structure of dynamic patterns also affects how listeners respond to constituent elements at certain positions in time, especially accented elements (Culter, 1976; Dowling, Lung & Herbold, 1987; Jones, Kidd & Wetzel, 1981; Jones, Boltz, & Kidd, 1982; Shields, McHugh & Martin, 1974; Pitt & Samuel, 1990). For instance, when the relative time structure (e.g. isochrony versus anisochrony) is manipulated, listeners are more accurate at detecting target sounds that coincide with temporally regular occurrences of accents (Cutler, 1976; Jones, Boltz, & Kidd, 1982). Dovetailing with this is evidence that modality differences (auditory versus visual) do not drastically alter the way people judge temporal patterns (Marks 1987).

Less research explicitly addresses the role of temporal structure of visual displays, although there are indications that relative timing may be generally important in such contexts.

For example, Garner and his colleagues found that the temporal arrangements of events in binary light patterns (e.g., run-gap rhythms) affected overall sequence perception especially with respect to events occurring at certain temporal locations (Garner and Gottwald, 1967;1968; Garner, 1974). Restle (1972) found that spatial and temporal regularities in serial light patterns determined viewers' abilities to anticipate the "when" and "where" of individual elements. Similarly, Skelly and her colleagues (Skelly, Hahn, & Jones, note 1) found that temporal and spatial aspects of light sequences determined viewers' detection of embedded deviant elements. While none of these tasks conform to classically defined "visual attention" tasks, we suggest that nonetheless attention must have been systematically timed to facilitate perception of certain elements. In fact, converging evidence of Skelly, Rizzuto & Wilson (1984) showed that attentional activity, as indexed by event-related potentials (ERPs) to deviant spatial changes, was sensitive to manipulations of a pattern's relative time structure (i.e., its rhythm). Both latencies and amplitudes of the N_2P_3 ERP associated with a target event (held constant) varied systematically with manipulations of rhythmic structure within its surrounding context.

Finally, some research which involves multiple event streams more directly implicates timing factors in attending to visual displays. For example, a two stream situation was used by Sperling and his colleagues who manipulated stream rate to examine an absolute attentional switching time between two streams (e.g., Reeves & Sperling, 1986; Sperling, 1984; Sperling & Melchner, 1978; Sperling & Reeves, 1980). More relevant are studies that directly manipulate relative timing among streams (e.g. Klapp, Hill, Tyler, Martin, Jagacinski, & Jones, 1985; Scerbo, Warm & Fisk, 1987). Scerbo et al. used a vigilance task in which viewers monitored two concurrent streams of visual information where targets (relevant stream) were temporally interleaved with nontargets (irrelevant stream). Viewers were best when time constraints in the two streams were similar (i.e., both regularly timed or both irregularly timed), suggesting that temporal compatibility of streams is important in pacing attending in two stream contexts. We return to the compatibility hypothesis shortly.

In summary, a majority of research concerned with voluntary control of attention relies on static rather than dynamic visual arrays. Yet, as Adams and Pew (1989) observed that in dynamic environments, information rarely arrives neatly packaged in task-by-task bundles. Instead, multiple, temporally interleaved, streams of information exist and attention must somehow be allocated among them. While indirect evidence suggests that allocation of visual attention in such contexts may be sensitive to (controlled by) relative time properties among multiple event streams, little research directly manipulates such variables. The present research relies on a two stream task to do so. Using relevant and irrelevant event streams, we consider whether the rhythm of one or both streams systematically affects attention to a succession of target events. We are especially interested in the role of extended temporal structure (within and between streams) and the way this may direct focal attending in time. If attention is amodally and externally driven by time patterns associated with one or both of two visual streams, then will certain aspects of these patterns temporally "prime" viewers promoting selective and anticipatory attending to events at certain temporal positions?

Experimental Rationale

Three experiments assess the influence of dynamic context (vis temporal and spatial relationships) on selective attending using a continuous version of a Posner type classification task with consistent mapping of relevant and irrelevant events. In the main part of each experiment (experimental conditions), viewers saw two interleaved information streams, one relevant and one irrelevant to the classification task. Preliminary to the main part of each study, viewers received and responded to the relevant letter stream alone (baseline conditions). In all experiments, relevant stream events were letter pairs whose members could be the same or different with respect to a physical match. Events within the irrelevant stream were shapes, namely squares to which no response was required, i.e., viewers were specifically told to ignore this information. Figure 1 presents examples of a baseline stream as well as relevant and irrelevant streams in two experimental conditions.

Insert Figure 1 here

The general rationale focused upon the ways in which the time structure of either or both streams of information might affect selective attending to relevant events as measured by errors and reaction times in the letter classification task. In both baseline and experimental conditions the time structure created by the succession of events within streams was manipulated: in relevant streams (of baseline and experimental conditions), letter pairs followed either a regular, R, (isochronous) or irregular (anisochronous), I, time schedule; similarly in irrelevant streams (of experimental conditions), squares occurred either regularly or irregularly in time (e.g. see Figure 1). In experimental conditions, between stream timing was also varied (i.e. via phasing relations). Performance in the two stream (i.e., experimental) context was gauged against performance in the single stream (baseline) case.

The three experiments differ with respect to instructions and/or spatial formatting of irrelevant events. Subjects in Experiments 1 and 2 received speeded classification instructions in which both speed and accuracy were emphasized; subjects in Experiment 3 were told to emphasize only accuracy. All experiments displayed relevant letter pairs centrally but only Experiments 1 and 3 also displayed irrelevant squares centrally (see Figure 2).

EXPERIMENT 1

Several hypotheses relating to possible influences of time structure on attending govern our approach to experiment 1 (and other experiments). They concern, respectively, comparisons between one versus two stream conditions (baseline versus experimental), and comparisons among experimental variables that distinguish the two stream conditions.

Insert Figure 2 here

One Versus Two Stream Hypotheses

Perhaps the most straightforward hypothesis about the effects of adding a second (irrelevant) event stream to the relevant stream is one which ignores specific timing manipulations to focuses upon the general potential of the two stream task for creating interference:

Hypothesis 1. The Overload Hypothesis states that baseline performance should be superior to that in experimental conditions. Regardless of stream timing, the addition of an irrelevant stream (in experimental conditions) should hurt primary performance either because it: 1. diverts attention to distractor items that occur within the spatial focus of attention (i.e spatially oriented attention theories), or 2. introduces multiple objects (object oriented models). Thus, on average, responses in experimental conditions should be less accurate and/or slower (i.e. reflect interference) than in baseline. Furthermore, apart from simultaneities of relevant with irrelevant events, time relationships of events within and between streams should not matter. Essentially, with respect to timing manipulatios the Overload hypothesis functions as a null hypothesis.

Two Stream Hypotheses

Alternative hypotheses directly address the possibility that dynamic aspects of the context control attending. One assumes that viewers treat the two streams independently but that certain timing properties within one or both streams can modulate the interference potential irrelevant events. Others assume that viewers combine the two streams and that the nature of this combination determines how they attend to relevant events.

Hypothesis 2: The Entrainment Hypothesis maintains that isochrony in the relevant and/or the irrelevant stream will entrain a rhythmically senstive attender, leading the viewer to "tune in" to an isochronous stream. Thus, if isochrony associated with the regular, R, timing manipulation obtains in the relevant stream, this hypothesis predicts that interference will be reduced. Letting RR and RI refer respectively to experimental conditions with regularity of relevant events in conjunction with regularity of irrelevant ones (RR) and in conjunction with irregularity of irrelevant events (RI), one form of this hypothesis implies that viewers will perform better in these conditions than in others (i.e. IR, II). On the other hand, if entrainment effects apply primarily to irrelevant events, then when isochrony occurs among successive squares, this will heightened their distracting potential and increase interference in conditions with regular square timing (i.e. RR and IR). Thus, the entrainment hypothesis predicts certain patterns of additive main effects due to letter and square timing manipulations. Because it addresses modulation of interference effects, the Entrainment hypothesis can be viewed as a sophisticated version of the Overload hypothesis which addresses within stream timing manipulations.

The remaining hypotheses consider the possibility that the time structure of the two streams are not treated separately by the viewer, but rather they combine in certain ways to influence attending. In these, the mulitiple stream situation is postulated to form an inherently different configurations (or temporal objects) from the single (baseline) stream situation. Thus, certain stream combinations (relevant plus irrelevant) may actually facilitate performance on the relevant stream relative to baseline performance.

Hypothesis 3. Temporal Compatibility Hypothesis. This hypothesis builds on the idea of temporal isomorphism between two streams. It was inspired by the finding of Scerbo, Warm & Fisk (1986) that timing compatibility affected performance in a visual vigilance task. According to this hypothesis, an interaction of letter and square timing levels should occur such that performance is best when both streams are regular (compatible) or when both are irregular (compatible): RR = II >

RI = IR. Furthermore, such isomorphism may not merely reduce interference effects due to irrelevant events; in principle greater temporal redundancy leads to attentional "pacing" and this may be manifest in response times to relevant events that are faster than observed in baseline.

Hypothesis 4. Integrated Temporal Pattern Hypothesis. This hypothesis assumes that the two experimental streams combine (integrate) to form a single temporal object whose temporal structure in turn determines performance. Specifically, depending on the emergent rhythmic properties of the combined stream viewers may respond to certain "well timed" events within it at least as quickly as they did in comparable baseline conditions. Thus, as with the Compatibility hypothesis, this hypothesis assumes that addition of an irrelevant event stream to a relevant one can facilitate performance. It differs from that hypothesis in predicting effects of: 1. Both within and between stream timing manipulations in the form of emergent rhythmic patterns based on stream integration; and 2. Temporal position of a relevant event (letter pair) within the integrated time pattern; i.e. in some rhythms viewers will anticipate occurrences of certain (i.e."well-timed") relevant events better than others. Predictions consistent with this hypothesis rely upon development of metrics that assess rhythmic structure which are considered in more detail in the results section.

METHOD

Task. The task was continuous letter classification task in which pairs of letters were presented in an unbroken series of trials and viewers had to make "same" or "different" judgments based on a physical match between the two letters. It consisted of two phases: a baseline phase involving a single stream of relevant letter pairs; and a subsequent experimental phase in which letter pairs, the relevant stream events, occurred in conjunction with a concurrent stream of squares (irrelevant information). Events in both relevant and irrelevant streams always appeared centrally on a CRT display (see Figure 2).

Design. The design for experimental conditions was a 4x2x2x2 repeated measures factorial with four factors. The first factor, Timing, had four levels: RR, RI, IR, and II where the first and second letters refer respectively to letter and square timing manipulations (Regularity versus Irregularity). Other factors were Phase (In Phase, Out-of-Phase), Response Mode (Same, Different), and Temporal Position of a relevant event within a cycle (Position 1, 2).

Conditions. The four levels of within stream Timing derive from crossing Regular versus Irregular timing on relevant and irrelvant streams. With all R conditions, successive events in a stream were separated by a fixed onset-to-onset (SOAs) times of 1800 ms; with I condition SOAs of 1300 ms alternated with ones of 2300 ms. This yields the same average SOA (1800 ms) and cycle time (3600 ms) for R and I conditions. A cycle always included two relevant event occurrences but could involve more irrelevant ones (see Figure 1).

In Experimental conditions, a Phasing variable expressed between stream time relations; the two streams either began simultaneously (In Phase) or not (Out-of-Phase). In the latter, the first irrelevant event was delayed such that it occurred midway within the first SOA of the relevant stream. For example, RR(1) denotes a condition in which both streams are regularly timed and occur in phase whereas RR(2) denotes a condition where the same two streams occur out-of-phase. In conjunction with the four timing conditions above the phasing variable resulted in eight distinct combinations of relevant and irrelevant event streams. A ninth pattern was added to this set. Because the irregular timing pattern permitted combining the two I streams in several ways, two (II(1) and II'(1)) were employed. In the former, both streams started with the same SOA (e.g. 2300 ms); in the latter, while they started simultaneously, the first SOA differed (e.g. 2300ms and 1300ms). All nine patterns are shown in Figure 3 where cycles are also depicted. The final condition, Position, variable refers to the temporal location of a relevant event (letter pair) within a cycle, namely whether it was the first (Position 1) or second (Position 2) pair.

Insert Figure 3 here

Events. The relevant stream consisted of letter pairs that were created from combinations of four upper case letters, A,B,C,E, and four lower case letters, a,b,c,e. The irrelevant stream consisted of single squares. In all cases the stimulus duration for both letters and squares was 400 ms.

The phasing variable created experimental patterns in which letters and squares occurred simultaneously yielding coupled events, and/or in which the two events were separated in time yielding uncoupled events. For example, when in-phase (Phase 1) the two streams yielded sequences of letters and squares in which some or all of the discrete event occurrences were simultaneous (i.e letter pair and square coupling). In the present experiment where both events occurred centrally, a coupled event is a letter pair enclosed by an irrelevant square. An uncoupled event is any isolated occurrence of a centrally located letter pair or square (see Figure 1).

Subjects. Eleven subjects with normal or corrected visual acuity acuity were recruited from The Armstrong Laboratory's subject pool. Subjects from this pool are local university students between ages 18 and 34 years. One subject's data was excluded from the data analysis for failure to meet the performance criterion regarding error rates of 10% or less; the final number of Ss used was ten.

Apparatus. Timing of stimuli was controlled by a Commodore 64 computer and stimuli were presented on a standard video monitor. The luminance values were recorded and calibrated by a Minolta Luminance Meter. Luminance values ranged from 44.7 ftL. (square alone) to 33.2 ft.L. (letter pair with square) and 5.85 ft.L. (letter pair alone) Background luminance was 5.2 ft.L. Screen background was a medium gray with letters black and the squares appearing as a light gray.

Procedure. Subjects were seated in a low luminance sound attenuated experimental booth 60cm in front of the CRT. Stimulus events subtended visual angles of .5733° to 1.43°. A response panel, mounted with two response buttons labeled "Same" (left button) and "Different" (right button), was in front of the S. Subjects were instructed to respond to letter pairs as quickly and accurately as possible by pressing the appropriate button with the index finger of the preferred hand. They were told to ignore the squares. Each S received four practice trials on relevant stream events (i.e. letter pairs only).

In the Baseline condition, all subjects received 8 randomized blocks of 64 letter pairs alone (without the square stimuli), 4 blocks each of regularly and irregularly timed letters respectively. Equal numbers of Same and Different letter pairs appeared in random order in each block. They were required to make only one type of response per block of trials, i.e., they were instructed to withhold either responses to "same" letter events or those to "different" ones.

After a five minute break, Ss received 18 randomized blocks of 64 trials of Experimental conditions. Again, each trial block contained equal numbers of Same and Different letter pairs appeared, randomly ordered. Two blocks occurred for each of nine different (Phase x Timing) experimental conditions.

RESULTS AND DISCUSSION

Preliminary baseline data are considered first and that from experimental conditions next. Figure 4a presents averages of median reaction times (RT) for both baseline and the four primary Timing (experimental) conditions (RR, RI, IR and II) averaged over phase, "same" and "different" responses, and position (1,2) in experiment 1. In all conditions, errors rates were less than 2%; hence primary dependent measures involve response time, both median (RT) and median deviation from baseline (DRT).

Insert Figure 4 here

Baseline Conditions

Single Stream Performance: When viewers experience only the relevant event stream, the R-Base and I-Base conditions in Experiment 1 and Experiment 2 are identical (see Figure 4a and b). In both studies I-Base produced longer median reaction times than R-Base, on average; these differences were marginally significant in experiment 1, and clearly so for the combined (and more powerful) analysis based on 20 Ss, $F(1,19) = 10.68$, $p < .004$.

Single versus Two Stream Peformance: The Overload hypothesis predicts that the combined mean of the four Two Stream (experimental) timing conditions, RR, RI, IR, and II should be significantly greater than the combined baseline (R-base plus I-base) performance. It receives no support in Experiment 1 either in terms of accuracy or speed of responding in baseline versus experimental conditions. Differences between median reaction times in baseline conditions and others are not significant, $F(1,45) = .58$ (ns). Overall, experimental conditions differed from average baseline response times by 3.11 ms.

We can focus more narrowly upon versions of the Overload hypothesis that seem to apply to simultaneity of relevant and irrelevant stimuli i.e. coupled events. In this case, both spatially oriented attentional models (e.g. spotlight, zoom lens) and object oriented approaches (e.g. feature integration) imply that viewers should respond more slowly to all coupled events. Here deviation response times, DRTs, are useful: Positive DRT's are taken to index interference due to addition of the irrelevant stream relative to baseline and negative DRT scores to reflect facilitation. According to these hypotheses, DRTs to coupled events should show interference in experimental conditions relative to uncoupled events in experimental and baseline conditions. To examine this prediction, there are seven occasions across the nine conditions that involve coupled events (see Figure 3).

Overall, responses to these events are indeed slower than to uncoupled events relative to uncoupled baseline events (i.e. mean DRTs were 15.7 ms versus -.87 ms for coupled and uncoupled events respectively) and this difference was significant, $F(1, 9) = 14.23$, $p < .005$. Thus, while little interference appears with uncoupled events, the prediction of interference associated with coupled events is supported.

Finally, however, the Overload hypothesis and versions of it that do not incorporate provisions for timing effects all imply that interference effects should be unchanged by manipulations of stream timing. Thus, such hypotheses have difficulty with the finding that interference due to coupling does in fact vary signficantly with timing: it is much greater with regular letter timing than with irregular letter timing, $F(1,9) = 16.09$, $p < .005$.

Experimental Conditions

In experimental conditions where viewers had to attend to relevant letter pairs and ignore the concurrent stream of squares, analyses continued to rely upon DRTs.

Preliminary analyses of median DRT's indicated that response (Same versus Different) had predictably significant effects with same responses faster than different ones, $F(1,9) = 8.57$, $p < .017$. This common disparity is not surprising. However, since it does not interact with any other variable, the remaining analyses are collapsed over this variable. In the remaining discussion, results are considered jointly with hypotheses outlined in the introduction.

Hypothesis 2. The Entrainment hypothesis finds little support in the experimental data. In spite of the fact that viewers were faster in R-base than in I-base conditions during the baseline phase, they did not reveal significant modulations in interference levels due to isochrony in relevant and/or irrelevant streams within the experimental conditions. No main effects of Timing emeged.

Hypothesis 3. The Temporal Compatibility Hypothesis also finds no support in these data. It predicts that interference (or less facilitation) from irrelevant streams should appear only when they are incompatible with relevant streams i.e. in RI and IR conditions. On average less interference occurs with II and RR (DRT mean is 2.068 ms) than with RI and IR (DRT mean is 4.238 ms), but this difference is slight and not statistically significant. Furthermore, this averaging masks the fact that RR conditions produce more interference than either II or IR conditions.

Hypothesis 4. The Temporal Pattern Integration Hypothesis, which assumes that people respond to rhythmic groupings of letters and squares, does garner some support from the profile of DRT's across the nine experimental conditions. These data are presented in Figures 5 and 6. Significant effects of both Phase, $F(1,9) = 42.06$ $p < .0001$, and Timing by Position, $F(3,27) = 4.31$, $p < .0132$, are consistent with predictions of this hypothesis between and within stream time relations, respectively, should influence performance. They also suggest that viewers integrate information from both streams and that this has differential impact on their responses to events at certain temporal locations.

Insert Figures 5 and 6 here

Consider first the phasing effect. When the two streams were In phase (Phase 1), this yielded sizeable interference; people were slower than baseline, on average, by 13.06 ms (mean median DRT). However, when the two streams were out of phase (Phase 2), people were slightly faster than baseline (median DRT's = -6.76 ms). This phasing effect suggests that the time relationships obtaining between the two streams is an important determinant of interference. However, it is also the case that Phase 1 conditions contain more coupled events and so the interference that these differences arise solely from timing constraints may be unjustified.

The more interesting finding pertains to the interaction between Timing with Position (i.e. the temporal position of a letter pair within a cycle). Figure 5 shows this interaction in terms of interference and facilitation effects (i.e. relative to baseline RTs). People respond more slowly to the first letter pair in a cycle when the combined stream involves regular letter timing (RR and RI) and this creates substantial interference. Parallel differences as a function of temporal location of the relevant event do not occur in streams with irregular letter timing (IR and II); indeed in these stream combinations, people are slightly slower to the second letter pair in a cycle, and there is facilitation to the first letter pair. Within this overall pattern, significant pairwise differences are those associated with the first target in a cycle within the RI condition; these differed signficantly from those of II and IR (error rate $p < .10$). Phase, which exerts a significant overall effect on performance, also modulates these positions by timing effects as Figure 6 shows. However, the three way interaction of Phase with Timing and Position does not attain statistical significance, $F(3,27) = 2.02$, $p < .13$.

In short, these data are generally consistent with hypothesis 4. However, while this hypothesis implies that people respond to rhythmic groupings of letters with squares and that they do so differentially over time, it is not specifically formulated to predict the particular nature of the interaction of Timing x Position. To pursue the gist of this hypothesis, an ad hoc metric was developed to capture salient rhythmic aspects of combined streams. The data themselves yielded some clues in this respect. In the first place, overall there was a wide range in the average (over position) response times to the nine patterns (from 407 ms to 440 ms) with the II(2) condition evoking fastest responding and II(1) evoking slowest responding (see Figure 6). One feature associated with simpler (i.e. faster) patterns was the degree of temporal uniformity within a rhythmic group composed of both letters and squares. For example, Figure 6 shows that II(2) is the simplest pattern, and Figure 3 shows that this pattern is characterized by distinct rhythmic groups with uniform within group time spans (i.e. 650 ms). In the second place, as Figures 5 and 6 indicate, substantial differences in response time occur as a function of position and condition; factors that may influence this involve the location of a letter within a temporally uniform rhythmic group and/or the degree to which the group itself is segmented by a distinctive time interval or pause. In short, the data suggested that temporal pattern integration involved (at least) two salient features within combined streams: 1. the relative magnitude of the pause segmenting rhythmic groups, i.e. between groups time; and 2. the uniformity (e.g. isochrony) of time periods within rhythmic groups themselves, i.e. within groups time.

Two metrics, both couched in terms of temporal contrast, were devised to reflect respecting between and within groups time relations. A temporal contrast is a time difference between an expected time period (ET) and an observed one (OT). The rationale is simply that patterns which embed many and/or large deviations in time from an expected time span, i.e. many temporal contrasts, will lead to slow responding. However, we distinguish Between Groups Contrast, and the metric reflecting this, Bg, from Within Groups Contrast, and its, Wg. To derive these metrics, we determine C, a an simple index of temporal contrast that can apply to either between (Bg) or within (Wg) groups time intervals. This C simply registers the relative (absolute) magnitude of a discrepancy between certain expected and observed time spans:

$$C = \frac{w_i OT_i - ET}{ET} \qquad (1)$$

$$w_i = 0 \text{ if } OT_i = ET$$

$$= 1 \text{ if } OT_i = ET$$

The expected time period, ET, is the modal time span of a cycle if one exists; if not, ET is the most salient time span within a group, usually one that stands out as the largest or smallest within a segmented group. The observed time spans, OTi (i indexes cycle time spans), are either segmenters of rhythmic groups (i.e. segmenters) and hence contribute to Bg, or they are time spans within a segmented rhythmic group and so contribute to Wg. These distinctions imply that viewers will "reorganize" events within a cycle according to between and within groups time relations. Finally, the binary weight, w_i, permits an individual contrast of either Bg or Wg to assume a value of 1.00 whenever ET = OT_i; this occurs with isochronous patterns which fall out as a special case in this algorhithm.

The between groups metric, Bg, is computed first because the segmenting interval defines a group. This OT_i is usually taken to be the largest time span within a cycle. Once the group is identified, ET can be identified. Finally, from equation 1:

$$Bg = C \qquad (2)$$

As the absolute difference between OT_i and ET increases, so does the between groups contrast, Bg. Large Bgs reflects greater, i.e. more distinctive, separation between rhythmic groupings of letters and squares. Figure 3 shows Bg values for all nine pattern conditions. Note that Bg is larger in patterns with relatively long segmenting time spans and/or which juxtapose very small with fairly large time spans. Patterns with large Bg are II(2) and RI(1) while those with small Bg values are IR(1) and II(1').

Adapting equation 1 to within groups contrast, Wg, is similar except that Wg is weighted by the strength of an expected interval i.e., its modal value, n:

$$Wg = C/n \qquad (3)$$

ET has the same value for Wg and Bg. What differs is the value of OT_i. With Wg, OT_i is taken from within the segmented rhythmic group; specifically it is the "most disruptive" within group time span, namely that which is most deviant from the expected one, ET. Thus, Wg increases with the magnitude of the most deviant time span within a rhythmic group. If all observed time intervals are alike (i.e. isochrony) within a rhythmic group (e.g. II(2) in Figure 3), then no deviant OT_i exists and in this case OT_i = ET but has a zero weight ($w_i = 0$). As rhythmic uniformity, in terms of isochrony, increases, the modal value, n, increases and Wg decreases. Figure 3 shows Wg values associated with each of the nine pattern conditions. Note that II(2) and RI(2) have small Wg values and RI(1) has a large Wg value.

Together, these metrics permit an assessment of the extent to which rhythmical distinctiveness (Bg) and within group uniformity (Wg) may combine to determine simpler rhythmical patterns. To shed light on this and on the way one or both metrics may determine the response times to specific temporal locations within these patterns, both Bg and Wg are combined as weighted predictor variables in a canonical regression analysis where the criteria variables are median response times to the first and second letter pairs in the viewer's reorganized rhythmic group: i.e. RT1 and RT2. Median response times rather than DRT's were used in the canonical analysis because analysis of variance on experimental patterns imply that experimental patterns are not simple transformations of baseline sequences (in any case, canonical fits of DRT's and RT's are extremely similar). The general rationale is that together Bg and Wg will describe differential response times to letter pairs occurring at certain temporal positions in reorganized rhythmic groups.

Insert Figure 7 and Table 1 about here

Figure 7 shows the weighted combination of RT1 - RT2 as a function of the combined weights of predictor variables (Bg + Wg) produced by the canonical regression analysis. Two significant canonical variates were found ($R^2_1 = .94$, approximate $F(4,10) = 17.15$, $p < .001$; $R^2_2 = .71$, approximate $F(1,6) = 14.82$, $p < .01$); both are shown in Figure 7. Table 1 shows standardized coefficients, correlations, and reduncancies for each variate. Because both variates. The first variate is strongly characterzied by a positive relationship between Wg and RT1. As Wg increases, responding to the first letter pair within a rhythmic group slows down. In other words, as a rhythmic group becomes less uniform, the response time to the first letter pair within it gets longer. While accounting for less variance, the second variate isolates an inverse relationship between Bg and RT2: as the time between groups increases, people respond more quickly to the second letter pair within a group; this is especially pronounced when Bg exceeds Wg, suggesting that when a combined stream has both uniform rhythmic groups and these groups are distinctly segregated in time by salient pauses (as in II(2)) people become faster in responding to the second letter pair within these groups. In sum, it appears that people respond more quickly to the first letter pair within a rhythmic cluster of letters and squares when that cluster forms a uniform rhythmic group; in addition when a uniform group is also set off by distinctive pauses, viewers become quicker in responding to the second target in the group as well.

In summary, the first experiment indicates that: 1. Addition of irrelevant information (squares) does not always interfere with selective attending to relevant events (letter pairs); 2. Little support exists for hypotheses that two streams function as separate sources of information; 3. Phasing, Timing and Position all exert significant effects on response times, implying that viewers respond to time relationships in combined streams; 4. The hypothesis which most adequately explains performance assumes that people respond differentially in time to relevant elements as a function of rhythmic grouping properties of temporally integrated patterns formed from both streams.

EXPERIMENT 2

Experiment 2 examines the same hypotheses as in Experiment 1, however it does so in a different context where irrelevant stream events (squares) appear eccentrically (rather than centrally as in Experiment 1). Over time, the succession of squares formed a circular array about the central location of the letter pairs (Figure 2).

In addition to hypotheses already advanced regarding time relationships, specific versions of Overload hypothesis take on greater meaning in experiment 2. Spatial oriented approaches to attention suggest a version of the Overload hypothesis which assumes that displacements of irrelevant events will reduce interference effects observed in experimental conditions of experiment 1 because viewers will more readily ignore squares. For example, Eriksen and Eriksen (1974) found that viewers are quicker in responding to a target letter as the distance between it and a distractor increases implying that displaced distractors are less interfering. This has been interpreted in terms of a "attentional spotlight" of fixed size (cf. Reintz, 1990). This line of reasoning implies that whereas the Overload hypothesis may be tenable in experiment 1, where both letter pairs and squares occur centrally, it is not in experiment 2 where the two are spatially segregated. We refer to this version of the Overload hypothesis as the Spotlight hypothesis.

A different version of the Overload hypothesis and spatial displacements is associated with object oriented attentional theories (e.g. Kahneman & Treisman, 1983; Treisman & Kahneman, 1983). Here coincidence of events in both space and time (as in experiment 1) leads to the creation of single object file in memory thus determining the percept of one object (i.e., letters enclosed by a square). This failure to "filter" out irrelevant features led to the correct prediction of slower response times to coupled than to uncoupled events in experiment 1. When extended to Experiment 2, this view predicts an even greater difference between coupled and uncoupled events, where coupled events cannot be conceived in terms of a single "object file". That is, when two simultaneous features are spatially separated, attentional conflict arises and two separate object files (e.g., letter pair, square) must be formed, leading to longer response times. We refer to this as the Object File Hypothesis. In contrast to the Spotlight hypothesis, the Object File hypothesis again predicts that the Overload Hypothesis will obtain for coupled events and, moreover, it implies that in experiment 2 response times for these events should show significantly more interference than in experiment 1.

METHOD

Subjects. Twelve subjects with normal vision were recruited from The Armstrong Research Laboratory's subject pool; two were eliminated, one for failure to meet criterion. None of the ten remaining subjects had participated in experiment 1.

Apparatus, Design, Procedure. Experiment 2 was identical to Experiment 1 in all respects except spatial formatting of irrelevant events. In particular, instructions to viewers in experiment 2 paralleled those in experiment 1 in emphasizing both speed and accuracy.

With respect to spatial separation of relevant and irrelevant events, horizontal and vertical distances from the center of a letter pair to the outside edge of the distractor square subtended visual angles of 3.0° and 2.19°. Figure 2 indicates the order in which squares appeared at horizontal and vertical locations over time.

RESULTS AND DISCUSSION

Again, we consider baseline and experimental data separately. Error rates in all conditions were less than 2%, hence only RT's and DRT's are analyzed.

Baseline Conditions

Data from the single stream (baseline) condition of these Ss were considered in experiment 1. Figure 4b presents median RT's in both baseline and experimental conditions for experiment 2.

Single versus Two Stream Conditions. A test of the general Overload hypothesis compares average baseline performance with that on experimental patterns. Statistically, this comparison yields no support for the general Overload hypothesis, $F(1,45) = 1.45$ (ns).

The two versions of the Overload hypothesis summarized by the Spotlight hypothesis and the Object File hypothesis also fare poorly. The relevant analyses focus upon coupled events, namely those where squares and letters are simultaneous. Some support for the Spotlight model is suggested by the finding that differences in interference due to coupling within this study were not statistically significant, $F(1,9) = 2.68$, $p < .14$ suggesting that interferenc is lessen (relative to experiment 1). On the other hand, this apparent decline in interference with spatial displacement of distractors was not remarkable enough to warrant statistical significance in an analysis that compared DRTs of coupled events in experiment 1 versus experiment 2. No statisitically significant change occurred in the magnitude of interference associated with these events as a function of spatial displacement $F(1,18) = .67$ ns. Finally, there is no conclusive support for either the Spotlight or the Object File version of the Overload hypothesis.

Experimental Conditions

Figure 8 shows median response times as a function of Timing (RR, RI, IR, II), Phase and Temporal position (1,2). The profile of these data differs from that found in experiment 1. The

DRT data (collapsed over response mode) indicate that the only significant change from baseline involved the main effect of Timing, $F(3,27) = 3.87$, $p < .04$. While the Entrainment Hypothesis predicts difference as a function of letter timing, the pattern of observed effects are not consistent with this hypothesis. Contrary to expectations from this hypothesis, regularly timed letters showed more not less interference than those with irregular timing (which showed facilitation!). These effects are largely due to the fact that baseline levels for I and R conditions differ. In fact, median RT's in experiment 2 show no statistically remarkable influence of Timing nor of any of the other variables manipulated.

Insert Figure 8 here

In fact, neither DRTs nor RTs support any of the three hypotheses developed to address timing variables. At the same time, it is evident, from the profile of RTs in Figure 8, that there is a good deal of systematic variability associated with different experimental combinations in this experiment. Thus, because hypothesis 4, the Temporal Pattern Integration hypothesis, received support in experiment 1, a parallel canonical analysis using contrast metrics was undertaken for experiment 2 RT's. The same values of contrast metrics (Bg and Wg) used in experiment 1 were used for predictor variables; RT1 and RT2 again were criteria variables.

Insert Figure 9 here

Results from the canonical analysis are shown in Figure 9 and Table 1. Neither of the two canonical variates is significant; the first and second variates, plotted in Figure 10, yield R^2 values of .57 and .12 respectively [$F(4,10) = 1.59$ $p < .25$; $F(1,6) = .83$, $p < .39$]. These negative findings are consistent with the failure to find interactions of temporal position with other independent variables, and they suggest that temporal pattern structure, as summarized by the Bg and Wg metrics, does not determine the observed pattern of reaction times.

In spite of this, there is evidence that emergent temporal properties exert some effects on performance in this experiment. The range of RTs observed over experimental conditions is great, with very fast responses occuring in some rhythmically simple conditions (Figure 8). For example, in conditions with regular letter timing, the only condition which produced facilitation was an isochronous one wherein letter pairs and squares regularly alternated in time (RR(2)). In addition, in irregularly timed letter pairs two experimental conditions showed marked facilitation, and signficantly both have characteristic rhythmic structures: one displayed distinctive, but ischronous, rhythmic groups (II(2)), while the other involved a simple subdivision of cycle time by the regularly timed squares (IR(1)). However, the profile of reaction times over experimental conditions differs in experiment 1 and experiment 2; the product moment correlation of mean median RT's between the two studies is $r = .46$ $p < .21$.

What does all this mean? The most reasonable explanation rests on the notion that spatial displacements selectively <u>disrupt</u> rhythmic coherence. That is, adding spatially displaced squares to a relevant letter sequence doesn't uniformly render experimental conditions in experiment 2 more difficult than those in experiment 1, it simply makes them <u>different.</u>

In sum, these findings provide little support for a number of hypotheses that address the potential influence of temporal and spatial relationships on attending to visual displays. They indicate that: 1. Advantages conferred by isochrony in the one stream (baseline) conditions, disappear in two stream (experimental) conditions; 3. Interference does arise with the introduction of spatially segregated irrelevant events but so does facilitation and, on average, the hypothesis that simply adding distractors to a relevant event stream (i.e. the Overload hypothesis) finds no support; 4. Nor, is greater interference specific to coupled events; spatially separated distractors do not signficantly change the overall level of interference observed relative to experiment 1, a finding equally difficult for theories which assume that irrelevant events which fall outside a spotlight beam should be less interfering (Spotlight model) and for theories which assume that such events create a need for two (potentially conflicting) object files (Object File model) and so should be more interfering. 5. The degree of interference depends on stream timing, with greater interference associated with streams based on regular letter timing; 6. As in experiment 1, both interference and facilitation effects vary with experimental condition, and the nature of these effects appears to depend upon the way the two streams combine. However, as currently formulated, none of the hypotheses designed to address timing effects (Entrainment, Temporal Compatibility, Temporal Pattern Integration) explain these data.

EXPERIMENT 3

A final experiment varied instructions to viewers responding to streams presented in the spatial format of experiment 1. In that study both letters and squares occurred centrally and viewers' responses to relevant events suggested that they were using the relative time structure between these streams to make speeded classification responses. One interpretation of these data is that an integrated temporal pattern, based on letter pairs plus squares, controlled, i.e. "paced", attending and facilitated responding to certain relevant events at highly predictable temporal locations.

However, another view is that instructions to respond accurately and quickly inherently change the nature of an attending task, biasing viewers to rely on immediately preceding and/or temporal aspects of the sequence to anticipate targets. Thus, perhaps effects observed in experiment 1 are specific to attentional sets where viewers feel pressured to respond quickly[2]. Accordingly, in experiment 3, subjects were told to respond accurately regardless of response time.

METHOD

Subjects. Ten subjects with normal or corrected vision were recruited from the Armstrong Laboratory's subject pool. None participated in earlier experiments.

Apparatus, Design, Procedure. Experiment 3 was identical to Experiment 1 in all respects except one: Subjects were instructed that judgment accuracy, not response speed, was most important.

RESULTS AND DISCUSSION

Figure 4c presents median RT's for baseline and experimental conditions (RR, RI, IR and II) averaged over phase and "same" and "different" responses and position (1,2) in experiment 1. As in speeded classification tasks, here all conditions continued to produce errors rates less than 2%.

Baseline Conditions

Single Stream Performance. When viewers experience only the relevant event stream, they respond much more quickly to regularly timed letter pairs than to irregular ones, $F(1,9) = 12.31$, $p < .007$. Overall, these subjects were slower than than in earlier experiments indicating that instructions were taken seriously. However, neither differences due to instructional set (experiment 1 versus 2) nor those associated with any interactions of set attained statistical significance ($p > .20$ in all cases). Thus, generally the pattern of baseline performance is similar to that found in experiment 1, merely slowed down a bit.

Single versus Two Stream Performance. The Overload hypothesis prediction that the combined mean of RR, RI, IR, and II should be significantly greater than that of R-base with I-base again finds no support in these data. In fact, experiment 3 reveals that on average experimental conditions significantly facilitated performance relative to baseline, $F(1,45) = 5.45$, $p < .025$. Facilitation was evident in virtually all four timing conditions. These findings are very difficult for a general Overload Hypothesis.

The fact that general facilitation is observed with experimental conditions in experiment 3 is also problematic for Spotlight and Object File versions of the Overload hypothesis. Neither predicts such facilitation effects. On the average, coupled events did not produce signficant amounts of interference in this study (mean DRT was 2.4 ms) and in fact interference was largely observed in only one condition (i.e. RI(1)); in most conditions coupled events too yielded facilitation! Accordingly, detailed analyses of DRT data with respect to predictions of the latter two hypotheses regarding coupled event response times seem unwarranted. Finally, because neither of these hypotheses readily accounts for: 1. facilitation or 2. dependence of interference on temporal structure, the data from experiment 3 are difficult not only for the Overload hypothesis but also for Spotlight and Object File versions of it.

Experimental Conditions

Insert Figure 10 here

Figure 10 presents median RT's as a function of Timing, Phase and Position. Analysis of variance on DRT's indicated that all three of these timing variables exerted significant influences on performance, and because of this various versions of the Entrainment and Temporal Compatibility hypotheses, which do not address these variables, are ruled out. Again, the data suggest that the most viable hypothesis is the Temporal Pattern Integration hypothesis. Furthermore, they imply that the results of experiment 1 are not specific to attentional sets engendered by instructions to respond both quickly and accurately. Indeed, with the exception of a few conditions (i.e. RI(1), RR(1), RR(2), the profile of median RTs in Figure 10 (experiment 3) is quite similar to that in Figure 6 (experiment 1); an analysis of variance with experiment as a factor confirms that this profile does not differ signficantly across the the two studies.

Considering briefly the main effects of interest in experiment 3: Timing yielded an $F(3,27) = 7.45$, $p < .0009$, reflecting the fact that less interference obtained with irregular than with regular timing of letter pairs; Phase yielded an $F(1,9) = 34.76$, $p < .0002$ which again indicated that phase 1 conditions were slower than phase 2 (although neither generated remarkable interference); and finally, target Postion yielded a significant effect [$F(1,9) = 9.96$, $p < .011$] which indicated that viewers tend to respond more slowly to targets in the first position within a cycle. However, since these main effects are qualified by three interactions, we move to consider these.

The most important findings in this study concern interactions. The first is an interaction of Timing with temporal Position, $F(3,27) = 8.15$, $p < .0005$, which shows that responses to initial targets are subtantially slower in conditions with regular letter timing than in ones with irregular letter timing. Differences in response times to first and second targets in a cycle also depended on Phase, yielding a second significant interaction of Postion with Phase, $F(3, 27) = 5.65$; in this case, in phase conditions produced a greater slowing of RT's to targets in the first postion. However, both of these two-way interactions are qualified by the three way interaction of Timing with Phase and Position (also shown in Figure 10). Together the two-way interactions suggest that facilitation to targets in position 2 should be greatest when they occur with out-of-phase and irregularly timed letter sequences, the three way interaction reflects that this facilitation is disproportionately great in two such conditions: II(2) position 2 (mean = - 51.03 ms) and to IR(2) position 2 (mean = -34.58 ms). In addition, the degree of facilitation/interference on position 1 changes dramatically with condition with sizeable facilitation and interference in conditions IR(2) and RI(1) respectively. While a number of pairwise comparisons among the sixteen conditions entering into this complex interaction are signficant, the best way to understand to it involves regression analyses that accomodate salient structural aspects of two stream combinations.

Canonical regression analysis was again applied using Bg and Wg metrics. Figure 11 shows the weighted combination of criterial variates RT1 - RT2 as a function of the combined weights of the two predictor variables (Bg, Wg).

Insert Figure 11 Here

Two significant variates were found [$R^2_1 = .78$, approximate $F(4,10) = 6.74$, $p < .007$; and $R^2_2 = .67$, approximate $F(1,6) = 12.42$, $p < .02$]. Table 1 shows standardized coefficients, correlations, and redundancies for each variate. The finding that both variates are significant implies that there are two independent relationships among these sets of variates. However, in contrast to experiment 1 where a significant inverse relation emerged between Bg and response time to the second target within a rhythmic group (RT2), in this experiment that inverse relation, while present, was weak and insignificant. Instead the first variate describes a strong positive relationship between Bg and RT1: as the segmenting pause increases so does response time to the first letter pair within a rhythmic group. Although the second variate accounts for less variability, it demonstrates that the two experiments are in greater accord with respect to the role of Wg. As uniformity of timing within a rhythmic group declines (Wg increases), increments appear in RT2 and to a lesser degree in RT1. Conversely, this means as rhythmic uniformity increases so does response speed. These analyses suggest that instructions to emphasize accuracy attenuate viewers' tendencies to use the segmenting time interval to "plan ahead" and speed RT2 as they did in experiment 1.

Overall there is greater variability in this canonical analysis than in that of experiment 1 and this seems surprising because other aspects of the data are quite comparable across the two studies. One possibility is that accuracy instructions in experiment 3 encouraged certain viewers to de-emphasize temporal patterning; if so, poorer fits should characterize the data of these viewers. It turns out that unlike experiment 1, the data of viewers in experiment 3 fell into two clearly identifiable categories: Four Ss were fast responders and six were slow responders. Although it seems reasonable to assume that fast responders are less inclined to follow accuracy instructions and so should mimic experiment 1 viewers, this is not the case. Fast responders Ss turned out to yield poor canonical fits (both R^2 were non significant). It is the slow responders, presumably those following accuracy instructions more closely, who yield a good fit, indeed a fit that is better than that of the entire group (significant R^2's of .84 and .68 for first and second variates respectively).

Slow responders performed more like those in experiment 1 in that: increments in Bg both increased RT1 and decreased RT2 and increments in group uniformity continued to speed both responses. This suggests that in viewers who actually succeeded in following instructions to emphasize accuracy the Temporal Integration Hypothesis finds stronger support.

Canonical analyses focus upon a fine level of temporal detail in that they describe differential responding over time to a pattern's microstructure and so address interactions of position with other temporal variables. They suggest how viewers in the two experiments differentially use certain aspects of rhythmic patterns. However, at a more molar time level, a substantial similarity exists between the data from the two experiments. For example, if we average over response times at the two temporal positions within each pattern condition, and use this mean response time as a gross index of pattern difficulty, then the easiest (i.e. fastest) and hardest (i.e. slowest) patterns are the same in both studies, namely II(2) and II(1) respectively. The average median RT's across the nine patterns are significantly correlated over the two experiments [$r = .89$, $df = 7$, $p < .002$], confirming that at this level, rhythmic structure has consistent effects. This raises the question of whether one or both contrast metrics can function as a molar simplicity gauge, one that predicts overall performance across both expeiments. Because rhythmic coherence within groups (Wg) had similar influences on response times at both positions in both experiments, whereas between groups contrast (Bg) had somewhat different influences across position and experiment, it is likely that Wg will emerge as the more dominant or consistent factor in such a gauge. To assess this, a stepwise regression was performed on mean RTs (averaged over position) from both experiments (separately normalized) with Bg and Wg as predictor variables (see Figure 12). The results confirm that Wg correlates most highly with mean RT [$R^2 = .57$, $F(1,17) = 22.68$, $p < .002$]; however Bg accounts for significant additional variability so that the combined regression equation yields an $R^2 = .77$ [$F(2,16) = 26.28$]. Standardized beta weights for Bg and Wg are -.59 and 1.14 respectively. This provides some rationale for an overall simplicity metric based on rhythmic properties, although it should be stressed that averaging over temporal position masks some of the real influences of temporal patterning on performance. In sum, taken together both canonical and stepwise regression analyses imply that at a molar level while viewers in both instructional conditions show generally similar patterns of average response times, this is largely the result of their common response to within group rhythmic coherence.

Insert Figure 12 here

In sum, when viewers follow instructions to weigh accuracy rather than speed in this task, they continue to rely heavily upon rhythmic properties of combined streams. These data suggest that: 1. Relative time properties between relevant and irrelevant streams guide attending differentially to certain temporal locations within combined stream patterns; 2. Instructions to emphasize accuracy generally produce slow responding and incline viewers to rely less on the segmenting rhythmic pause to speed responding to future targets; 3. A gross measure of pattern simplicity based on average response times to rhythmic patterns indicates that conditions with coherent temporal groupings of letters and squares produce faster mean response times than ones which lack temporal coherence.

GENERAL DISCUSSION

When people selectively attend to dynamically changing visual arrays involving two event streams (relevant, irrelevant), their attention is at least partly controlled by temporal and spatial relationships among the streams. Temporal relationships among events within and between streams have pronouned effects on average response times to relevant events and they also modulate the speed of responding to letter pairs (relevant events) that occur at particular temporal locations within a sequence. The influence of temporal variables (Timing, Phase) is most simply explained in terms of the way temporal properties of emergent rhythmic groups within combined streams pace attending over time. These effects are most evident when relevant and irrelevant events occur at the same spatial location and they characterize performance of viewers told to emphasize both speed and accuracy (experiment 1) as well as those told to emphasize only accuracy (experiment 3). Spatial segregation of streams (experiment 2) does not yield overall improvement of performance in responding to relevant events; instead it appears to change viewers' use of rhythmic grouping properties within combined stream patterns.

At first glance, the most striking and counter-intuitive effects surround the discovery that addition of distracting or irrelevant information does not automatically interfere with performance on the relevant event stream as measured by both error rates and response times. The Overload hypothesis, which captures the conventional intuition that experimental conditions should be more difficult than baseline ones, received no support. In fact, performance in two stream (experimental) conditions actually benefited from addition of irrelevant information (relative to baseline levels) in experiment 3!

Specific versions of the Overload hypothesis that focus upon special circumstances which should maximize interference also received limited support. Indicative of this is performance with coupled events in experiment 1 (not spatially segregated) and experiment 2 (spatially segregated). In the former, squares form a frame surrounding relevant letter pairs when they co-occur, while in the latter squares are spatially displaced from letter pairs. Spatial oriented models, embodied in the Spotlight hypothesis, suggest that spatial displacements should reduce interference. If an attentional spotlight in involved this prediction derives from the fact that distractors would be outside the spotlight beam. On the other hand, object oriented approaches, embodied in the Object File hypothesis, suggest that spatial displacements should should increase interference due to attentional competition associated with multiple object files. In fact, although viewers tended to respond more slowly to coupled than to comparable uncoupled events, the decline in interference effects which occurs with spatial segregation of distractors was modest and not significant (experiment 1 versus 2).

These findings are generally difficult for both spatially oriented and object oriented attentional approaches, although they appear to be more troublesome for the latter.

In spite of this, an object oriented approach to attending does receive apparent support. One premise of the Object File hypothesis (Kahneman & Treisman, 1984) is that formation of a single object file involves integrating features of visual display (e.g. square surrounding letters) and the formation of a single object file should require less encoding time when the object involves fewer features (e.g. letters alone). Consistent with this idea is the finding that phase 1 conditions, in which more coupled events appear, yielded significantly slower response times than phase 2 conditions, in which no coupled events appear. Follow up analyses on interference effects to coupled events alone confirmed these findings. Thus, one interpretation of the phase variable is that it affords a basis for squares to "frame" letter pairs and create perceptually integral spatial objects although this takes time.

Unfortunately, this support for the Object File interpretation may be more apparent than real. Three problems relate to the application of this hypothesis over the present set of findings. First, in experiment 3, while differences in response times to coupled events are much slower than to uncoupled events as in experiment 1 (phase is also a significant influence here), these response times do not reflect interference. In the majority of experimental conditions in experiment 3 there are no interference effects associated with with coupled events. The only condition which does not show facilitation relative to uncoupled baseline events is RI(1). Secondly, also in experiment 3 there are two experimental conditions which differ in phase (hence coupling) and which have identical two stream time patterns in that both are isochronous (RR(1) versus RR(2)). The Object File hypothesis predicts that RR(2) which consists only of uncoupled events should produce faster response times than RR(1) which consists only of coupled events; in fact, the reverse is true: RR(2) response times are slightly longer than are RR(1). Finally, it is not clear that the Object File hypotheis can easily account for the finding that extent of interference effects associated with coupled events in experiments 1 and 2 is significantly influenced by contextual timing. When taken together with the fact that the Object File hypothesis incorrectly predicts an increase in interference effects in experiment 2 relative to experiment 1, these problems cast doubt on the adaptability of this hypothesis to dynamic arrays.

In spite of difficulties encountered here for the Object File hypothesis, the orientation of object-based attending theories toward event structure and toward the possibility of competition among different structural descriptions may eventually be useful. In particular, the idea that a breakdown of "object integrality" leads to attentional conflict and, hence, to poor performance may have applicability in the present context if integrality incorporates time as a part of object structure. In this case, it is possible that the rhythmic integrality of temporal objects based on combined streams is threatened by the insertion of spatial displacements in experiment 2. Here attentional conflict would refer to competing temporal patterns based on certain configurations of space and time relationships. Perhaps ill-timed spatial displacements are responsible for the finding that temporal pattern integration did not occur in experiment 2. This interpretation is speculative and owes some of its inspiration to arguments of Kahneman and Treisman (1984) and Garner (1974). While the specific determinants of conflicting temporal structures require more investigation, this sort of approach builds upon the basic idea that the relationships which define an object of attention are not simply static spatial relationships among parts of an array but they also include temporal relationships.

When spatial changes are eliminated (as in experiments 1 and 3), the deterrents to temporal pattern integration reside primarily in the relative timing properties associated with various combinations of timing variables manipulated in these studies (Timing, Phase, Position). Explicit manipulation of these properties not only permit assessment of simple and complex rhythmic properties, but provided for a preliminary elimination of plausible alternative hypotheses addressed to the role of time relationships in multiple stream displays. For example, we can rule out various versions of the Entrainment hypothesis and the Temporal Compatibility hypothesis because the relevant main effects of Timing and/or specified interactions were not statistically signficant in any of the experiments. These findings confirm that viewers treat the two streams neither as separate information sources, nor as coordinated temporal isomorphs. Instead, the patterns of facilitation and interference which emerge in various combinations of Timing, Phase and/or Position suggest that viewers are attempting to temporally integrate events within the two streams to form one coherent combined stream. More detailed examinations of these conditions indicates that certain kinds of rhythmic properties are more likely to promote temporal pattern integrality than others.

In summarizing key rhythmic determinants of temporal pattern integrality we consider evidence from three sources: baseline data, overall differences in performance as a result of pattern structure; and contrast metric analyses. First, with respect to baseline performance, the fact that regularity of letter pairs produced significantly faster response times than irregularity suggests that viewers are sensitive to and can indeed exploit isochrony in temporally extended event streams when it occurs. Secondly, special combinations of Timing and Phase in experimental patterns (in experiments 1,3) produced systematic performance changes; depending upon the emergent rhythmic structure, attending to targets at certain temporal locations could be facilitated or inhibited. In addition, averaging over temporal position, performance over the nine experimental conditions indicated that certain simple rhythmic patterns produce fastest response times while less simple ones produced very slow responses and these profiles were very similar in experiments 1 and 3. Both within and between group time properties contributed to predicting this rhythmic simplicity (i.e. rhythmic coherence). For example, the three simplest patterns, all yielding average response times of 417 ms or less (II(2), RI(2), and IR(2)), were distinguished by the presence of rhythmic groups which were set apart by distinctive pauses of moderate length and which exhibited high degrees of within group isochrony. Conditions of intermediate difficulty included combined streams that were entirely isochronous (e.g. RR(1)). On the other hand, the most difficult patterns were those in conditions (e.g. II(1)) which exhibited neither isochrony nor clear cut rhythmic groupings of letter pairs with squares. In general, patterns are simpler when they exhibit only a few well placed (i.e. rhythmic segmenters) temporal contrasts.

One criticism of the rhythmic structure interpretation focuses merely upon interference steming from temporal adjacencies e.g. masking. That is, some difficult conditions (RI(1)) contain a very short onset-to-onset time span (e.g. 500 ms between a letter pair and a square). Could slower response time simply be a function of temporal masking with briefer time spans creating more difficult patterns? This is most unlikely for several reasons: 1. The briefest onset-to-onset span (400 ms) occurs in one of the simplest patterns (RI(2)); 2. In one of the most difficult conditions, RI(1), the response which is slowed is not the one predicted to be so by a masking interpretation of the embedded 500 ms span; 3. The most difficult experimental condition is one in which fairly long time spans occur and in which no question of masking can arise; 4. A masking interpretation suggests improved performance when squares are spatially displaced (experiment 2 vs experiment 1), however the three conditions which contain relatively short onset-to-onset time spans exhibit average response time to those letters in spatially segregated displays that is not less but is 5 ms greater than in displays where the two events occur in the same spatial locus. Finally, a more likely explanation for greater difficulty of a condition with a brief time span is found in the temporal integration hypothesis. It assumes that temporal contrasts arising from juxtapositions of very short and very long time spans within a sequence contribute to rhythmic incoherence.

Finally, the third source of information about rhythmic determinants of integrality derives from regression analyses (canonical, multiple) using contrast metrics Bg and Wg as predictor variables. The canonical regression addresses a fine level of temporal structure in which interactions of timing variables with temporal position of letter pairs transpire. It describes how a viewer uses temporal structure to respond more or less quickly at certain points in time. The multiple regression analysis addresses a more molar level of time structure and considers determinants of overall pattern simplicity/difficulty. Both analyses converge in suggesting that rhythmic structure involves grouping that has within and between groups temporal contrast aspects. The canonical analysis suggests that regardless of whether viewers are emphasizing speed or accuracy, increments in Bg and Wg (i.e. heightened temporal contrast) can differentially affect responding to one or both temporal locations of targets. Instructions (speed versus accuracy) appear to influence the way in which viewers weight these two aspects of rhythmic structure to anticipate future targets. When viewers are told to emphasize speed as well as accuracy (experiment 1) increasing within group contrasts slows responding to the first letter pair in a rhythmic group, while increasing the pause between groups seems to help views "get a jump" on the second target in a group and so it speeds responding to it. On the other hand, when told to emphasize accuracy (experiment 3), the need to "get a jump" on future targets seems to decrease and these viewers use the longer pause to slow down their response to the first letter pair in a group. Within group contrasts for these subjects continue to have similar effects as in experiment 1: as the structure of the rhythmic group approaches isochrony, responding to both target positions, but especially to the second, gets faster. At a more molar level, the multiple regression analysis suggests that this within group rhythmic property is more critical than the between group property in determining overall pattern simplicity.

Although the contrast metrics find some internal validation in these studies, caution is in order for several reasons: 1. The experiments were originally designed to factorially vary separate stream properties, not properties of the rhythms which emerge from combined streams; hence the metrics were developed ad hoc to evaluate the applicability of the Temporal Pattern Integration hypothesis; 2. While cross validated here with an independent group of viewers (and instructional set), the Bg and Wg metrics nonetheless should also be cross validated with new and different patterns; 3. The metrics themselves reflect joint influences of several sorts of time relationships (e.g. modal time period, ET, versus tempo, 1/n), and factorial manipulation of these emergent combined stream properties is necessary in the future; 4. In conditions where no modal time spans obtained, the expected time span, ET, was taken as the "most salient" interval, a subjective decision that could prove wrong in the long run. 5. The metrics are crude in that only two deviant time intervals (in addition to ET) are involved in their computation. We think it is most prudent to assume that contrast metrics and their evaluation represent a theoretical interpretation of the combined and interactive effects of Timing, Phase and Position variables. In this sense, they suggest new ways to conceive of extended temporal objects in multiple stream contexts and they offer some support for the proposition that viewers do respond differentially over time as a function of rhythmical aspects of this temporal structure.

The metrics are helpful in suggesting differences in strategies used by viewers given different instructions. Instructions to emphasize accuracy modulate, but do not eliminate, the influence of rhythmic structure. People tend to be somewhat slower in experiment 3 than in experiment 1 and in addition they may rely less on the segmenting pause to "plan ahead". Even so, the response times of these viewers continue to show pronounced sensitivities to timing variables (Timing, Phase, Position), and overall their response to experimental patterns is highly correlated with that of viewers in experiment 1. However, a singular difference between the two studies is consistent with the idea that subjects in the two experiments may weight longer time spans differently. This involves the two isochronous patterns (RR(1) and RR(2): viewers in experiment 3 performed slightly better on the slower of the two (RR(1) whereas those told to emphasize speed as well as accuracy (experiment 1) were better on the faster paced sequence. If we assume that instructions biased the former group toward slower responding then their attention would be more readily paced by the slower of the two sequences. But apart from this disparity and a few others, a remarkably similar profile of average response times (over temporal location) arises as a function of pattern structure. Such findings argue against the idea that viewers exploit time relationships only in situations where a premium is placed on fast responding. Indeed, if we can assume that viewers in experiment 3 were in some sense also granted greater voluntary control over their attentional strategies, it is clear from the performance of slow responders in experiment 3 that their behavior is still shaped in great measure by similar structural properties of combined streams.

These data illustrate the potential that various time relationships hold for controlling attending. The data suggest that we can go beyond assertions about isolated event onsets to consider hypotheses about time spans that relate successive onsets. In fact, when taken together with other research involving auditory sequences, there is some basis for suggesting that particular event onsets within a sequence may be more effective at "capturing" attention than others and that the time intervals between these onsets are especially potent in controlling attending. For example, onsets of rhythmic groups were especially important in experiments 1 and 3; so also were onsets of coupled events. It is quite possible that if an integrated (combined) stream is conceived as a temporally extended object, then within this object we may be able to identify several different levels of temporal structure that exert control over attending: the time span from the beginning of a session to the end is clearly the most global time level, but nested within this are others time spans namely those marked by segmenting pauses which cover intact rhythmic groups and those marked by elements within rhythmic groups such as onsets of coupled, uncoupled events, relevant events, and so on. All may contribute to differntial markings of various recurrent time levels that are embedded within a combined steam of letter pairs and squares.

We are suggesting that to some degree attention is externally controlled by rhythmic properties of temporally extended objects. If this is so, what must we assume about attending itself? In the first place, just as the attended object has extension in time, so too must attending. Attending is not an activity that is over within an instant. Secondly, if attending is controlled by such object relationships, then these relationships must include time. Time relationships can be of various sorts: ordinal (before, after), interval (onset-to-onset), or ratio (onset-to-onset/onset-to-onset). The present data suggest that relationships involving at least an interval level of description is involved since viewers demonstrated sensitivities to patterns involving invariant time intervals (e.g. isochrony).

Finally, we have been careful to preface any discussion of external control of attention with words such a "partly controlled by" and "controlled to some degree"...etc. This is because dynamic attending is also an acquired skill that is refined with experience and so can reflect internal control as well (Jones & Boltz, 1989). In the present circumnstances, where there is consistency of both relevant events and of the recurrent rhythmic structure within which they occur, this internal control reflects a viewer's abstraction and "use" of certain invariant relational properties of the rhythmic object in ways that lead to automatic targeting of attending in time. In this respect, attending can become "automated" (Shiffrin, 1988). However, in a dynamic context such automation resides in the use of a refined sense of temporal structure which promotes anticipatory attending. Abstraction of relative time properties means that viewers can begin the act of attending to future events within an unfolding sequence literally before those events occur. This anticipatory aspect is most evident behaviorally in experimental conditions which promote synchrony between time spans marked in the external pattern and abstracted time spans of the attender. Assuming that time relationships involving distinctive rhythmic (e.g ischronous) groups are most readily abstracted, the present studies suggest that attentional synchronicity and its sequitur, faster response times, is more likely to occur when the external "object" structure (i.e. a combined stream) is characterized by pauses of moderate size which distinguish simple rhythmic subsets of embedded events. This synchrony of attending with the external time structure of events is finally what we mean by the "pacing of attention".

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Notes

1. Skelly, J. Hahn, J.I. & Jones, M.R. (1983) Effects of spatio-temporal context on duration detections. (Unpublished manuscript).

Figure Captions

Figure 1. A baseline (panel a) and two experimental conditions (panels b,c). a: Relevant events (letter pairs) form a regularly timed (R) stream; b: Addition of a regularly timed irrelevant event stream (squares) to a regular relevant stream (letter pairs) yields RR(2) when the two streams start at different times (i.e. are out-of-phase); c: Addition of an irregularly timed irrelevant stream to a regular relevant one yields RI(2) when out-of-phase. Thickened lines outline a single cycle.

Figure 2. Spatial formats in experiments 1 and 2 with centered and displaced irrelevant events respectively. Note the distinction between coupled and uncoupled events in both formats.

Figure 3. Nine pattern conditions used in experiments 1,2, and 3 listed in rank order of average response time [fastest = (1)] from experiment 1. The thickened lines outline a single cycle. Segmenting time interval (seg) and brackets below group, together denote the emergent rhythmic group used to compute values of two metrics (Bg and Wg values shown here) that are described in the text.

Figure 4. Means of median response times for the four experimental timing conditions (RR, RI, IR, II) along with two baseline conditions for experiment 1 (panel a), experiment 2 (panel b) and experiment 3 (panel c).

Figure 5. Mean of median DRTs for the four experimental timing conditions as a function of the temporal position of the two relevant letter pairs. Positive DRTs reflect response slower than baseline (i.e. interference); negative ones reflect faster than baseline responding (i.e. facilitation).

Figure 6. Mean of median RTs as a function of Timing, Phase and Position (Timing Combination) for both baseline and experimental conditions in experiment 1.

Figure 7. Results of canonical regression analysis on RT's in experiment 1. Standardized criteria (RT1,RT2) variables as a function of standardized predictor variables (Bg, Wg) and two independent variates: variate 1 (top) and variate 2 (bottom).

Figure 8. Mean of median RTs as a function of Timing, Phase and Position (Timing Combination) for both baseline and experimental conditions in experiment 2.

Figure 9. Results of canonical regression analysis on RT's in experiment 2. Standardized criteria (RT1, RT2) variables as a function of standardized predictor variables (Bg, Wg) and two non significant variates: variate 1 (top) and variate 2 (bottom).

Figure 10. Mean of median RT's as a function of Timing, Phase and Position (Timing Combination) for both baseline and experimental conditions in experiment 3

Figure 11. Results of canonical regression analysis on RTs for experiment 3. Standardized criteria (RT1, RT2) variables as a function of standardized predictor variables (Bg, Wg) and two independent variates: variate 1 (top) and variate 2 (bottom).

Figure 12. Stepwise regression plot of means of median response times over position (ordinate) for experiment 1 (□) and experiment 3 (●) as a function of $\widehat{STRT}$, the predicted standardized mean reaction time.

TABLE 1

Canonical Regression Results

EXPERIMENT 1

	FIRST VARIATE		SECOND VARIATE	
	CORRELATION	STANDARDIZED COEFFICIENT	CORRELATION	STANDARDIZED COEFFICIENT
RT1	.99	1.06	.14	−.35
RT2	.31	−.16	.95	1.10
% VARIANCE	.59		.41	
REDUNDANCY	.56		.29	
Bg	.70	.08	−.71	−1.33
Wg	1.00	.95	.06	.93
% VARIANCE	.62		.38	
REDUNDANCY	.59		.27	
CANONICAL R^2	.94		.71	

EXPERIMENT 2

	FIRST VARIATE		SECOND VARIATE	
	CORRELATION	STANDARDIZED COEFFICIENT	CORRELATION	STANDARDIZED COEFFICIENT
RT1	.42	−.27	.91	1.23
RT2	.98	1.14	.21	−.53
% VARIANCE	.75		.25	
REDUNDANCY	.43		.03	
Bg	−.75	−1.33	.66	.01
Wg	.01	.88	1.00	.99
% VARIANCE	.41		.59	
REDUNDANCY	.24		.07	
CANONICAL R^2	.57		.12	

EXPERIMENT 3

	FIRST VARIATE		SECOND VARIATE	
	CORRELATION	STANDARDIZED COEFFICIENT	CORRELATION	STANDARDIZED COEFFICIENT
RT1	.67	1.11	.74	.34
RT2	−.29	−.86	.96	.78
% VARIANCE	.30		.70	
REDUNDANCY	.23		.47	
Bg	1.00	.91	−.09	−.96
Wg	.73	.12	.69	1.32
% VARIANCE	.87		.13	
REDUNDANCY	.67		.09	
CANONICAL R^2	.78		.67	

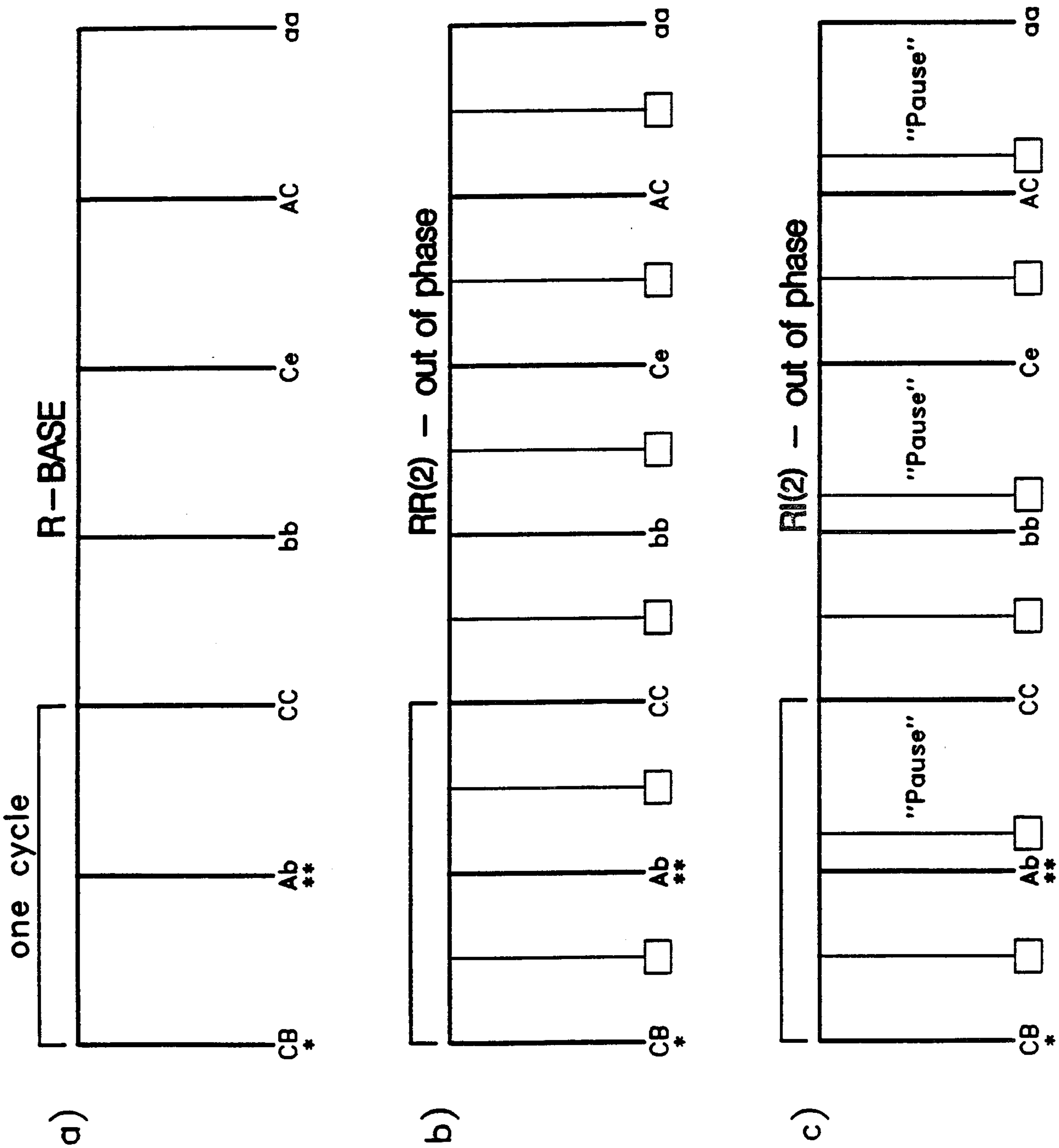
a)
R – BASE
one cycle
CB *
Ab **
CC
bb
Ce
AC
aa
b)
RR(2) – out of phase
CB *
Ab **
CC
bb
Ce
AC
aa
c)
RI(2) – out of phase
"Pause"
"Pause"
"Pause"
CB *
Ab **
CC
bb
Ce
AC
aa

FIGURE 1

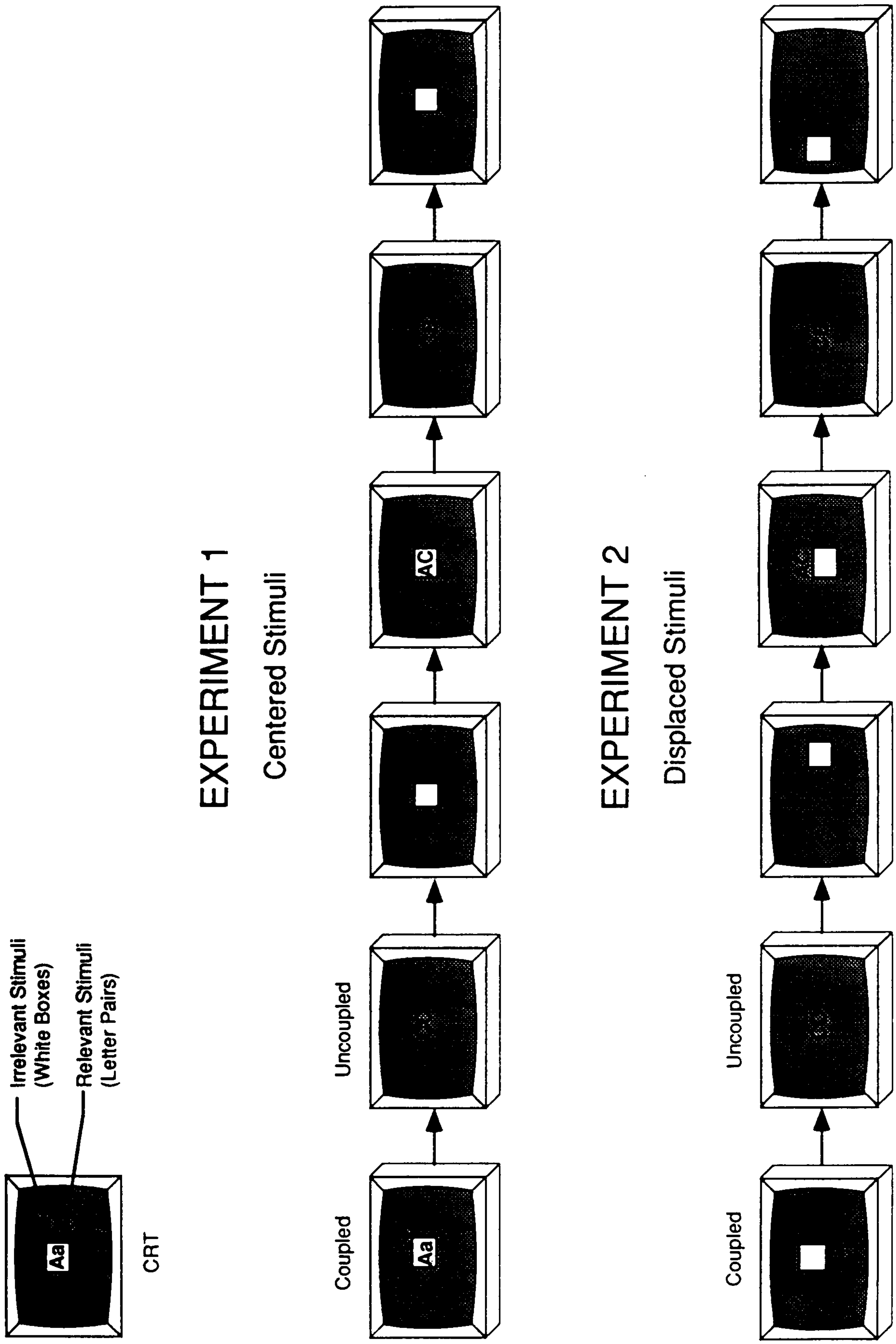
Aa
Irrelevant Stimuli
(White Boxes)
Relevant Stimuli
(Letter Pairs)
CRT
EXPERIMENT 1
Centered Stimuli
Coupled
Aa
Uncoupled
AC
EXPERIMENT 2
Displaced Stimuli
Coupled
Uncoupled

FIGURE 2

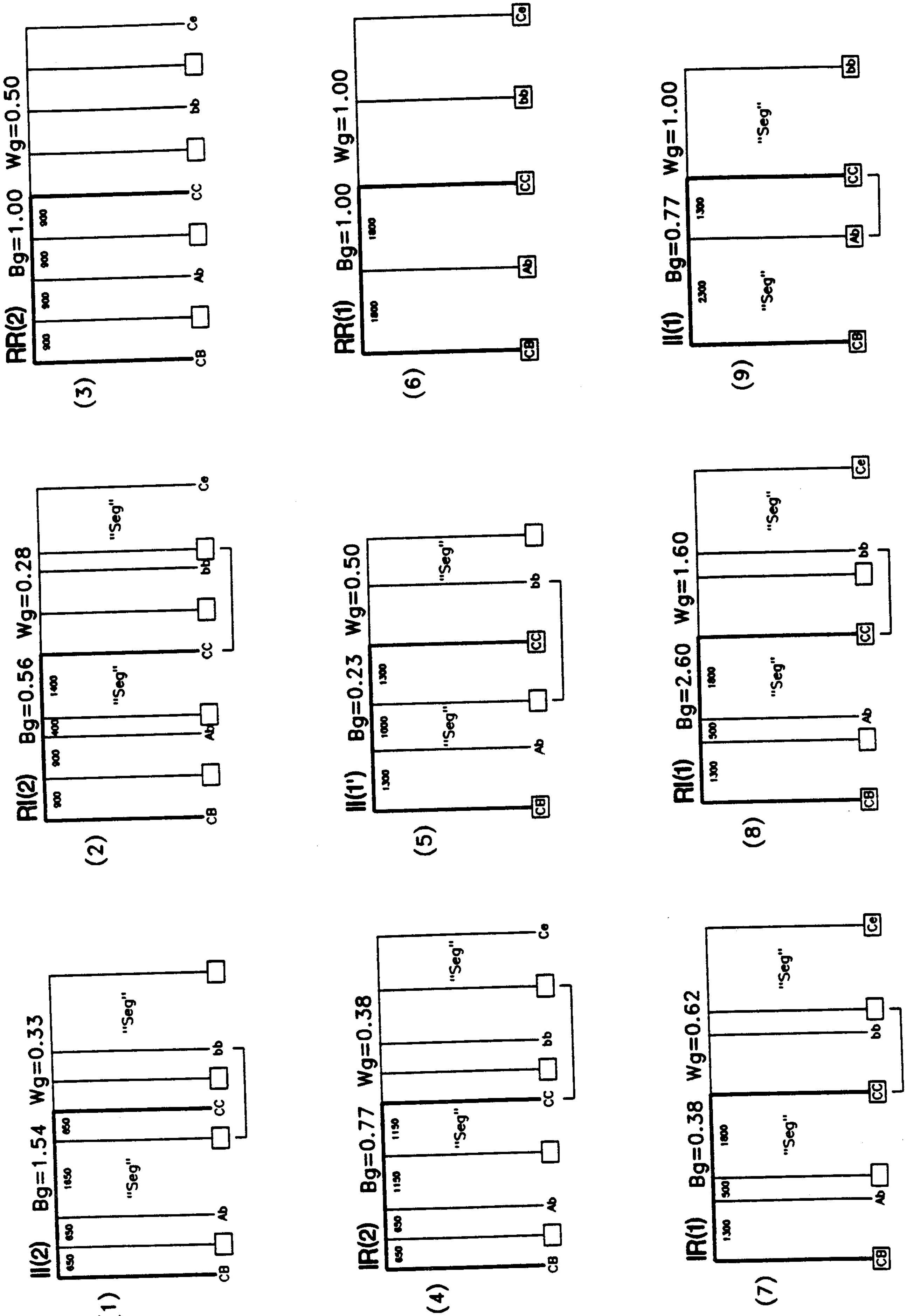
(1)
II(2) Bg=1.54 Wg=0.33
(2)
RI(2) Bg=0.56 Wg=0.28
(3)
RR(2) Bg=1.00 Wg=0.50
(4)
IR(2) Bg=0.77 Wg=0.38
(5)
II(1') Bg=0.23 Wg=0.50
(6)
RR(1) Bg=1.00 Wg=1.00
(7)
IR(1) Bg=0.38 Wg=0.62
(8)
RI(1) Bg=2.60 Wg=1.60
(9)
II(1) Bg=0.77 Wg=1.00
"Seg"
CB
Ab
CC
bb
Ce

FIGURE 3

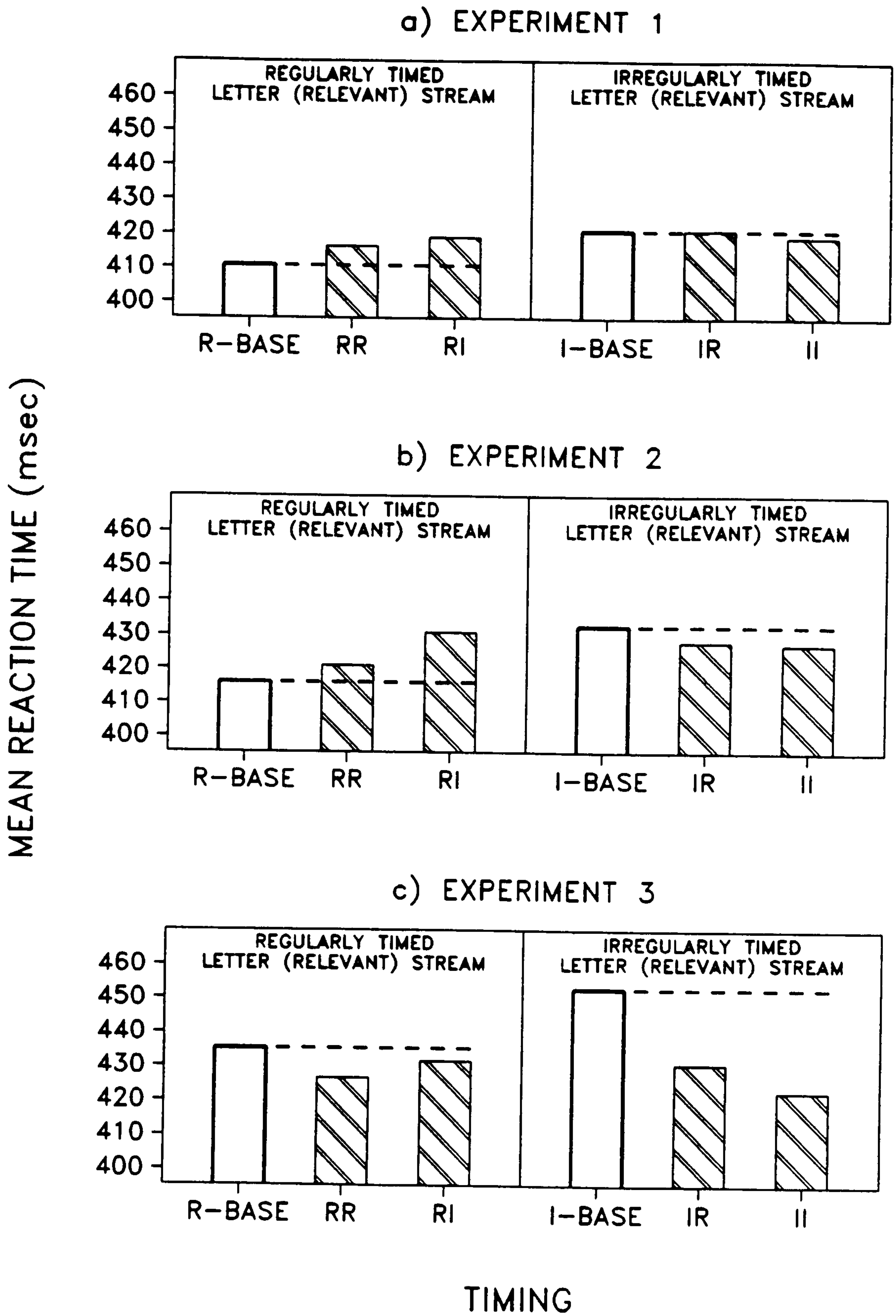
a) EXPERIMENT 1
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
460
450
440
430
420
410
400
R-BASE
RR
RI
I-BASE
IR
II
b) EXPERIMENT 2
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
460
450
440
430
420
410
400
R-BASE
RR
RI
I-BASE
IR
II
c) EXPERIMENT 3
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
460
450
440
430
420
410
400
R-BASE
RR
RI
I-BASE
IR
II
MEAN REACTION TIME (msec)
TIMING

FIGURE 4

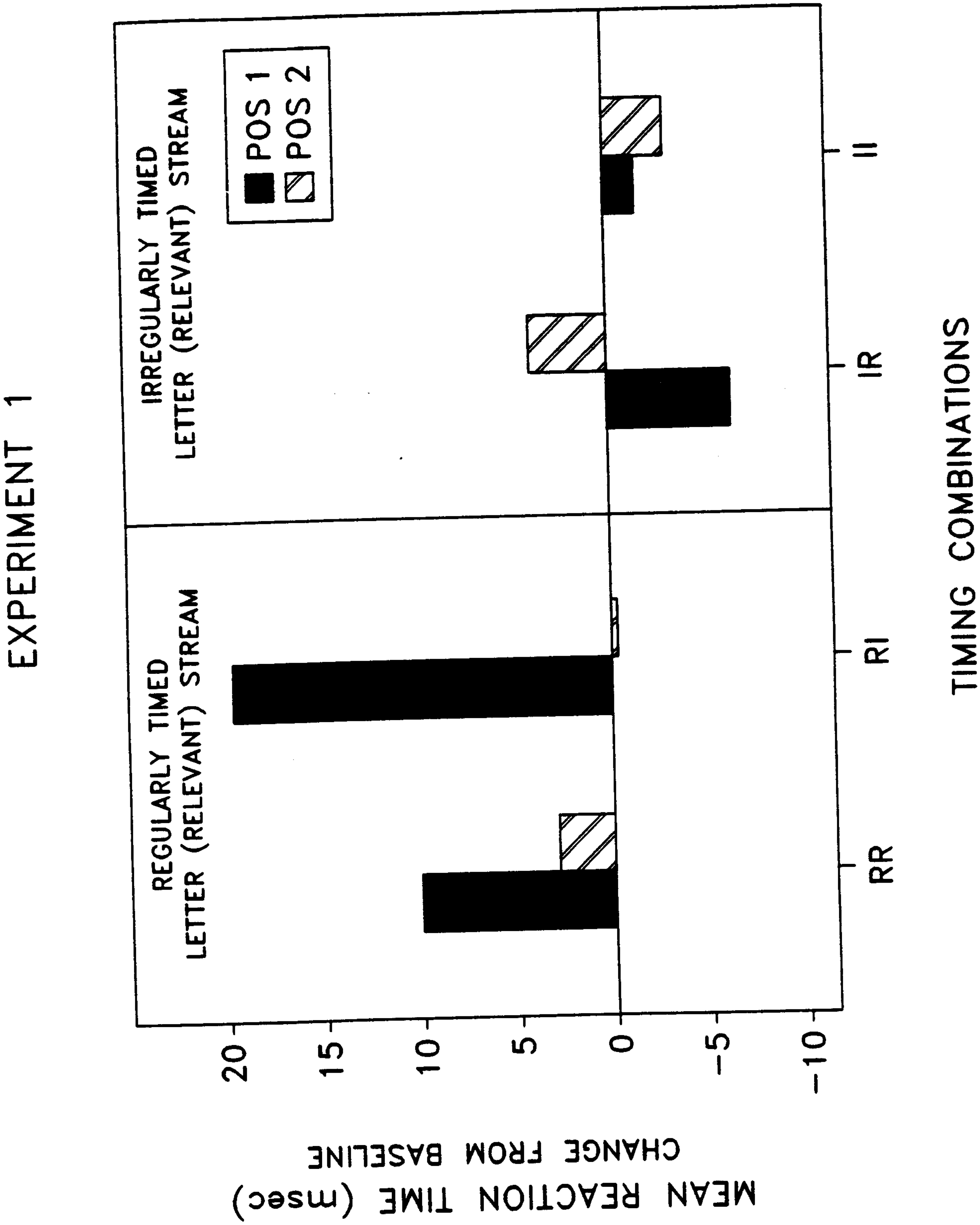
EXPERIMENT 1
REGULARLY TIMED
LETTER (RELEVANT) STREAM
IRREGULARLY TIMED
LETTER (RELEVANT) STREAM
POS 1
POS 2
MEAN REACTION TIME (msec)
CHANGE FROM BASELINE
20
15
10
5
0
-5
-10
RR
RI
IR
II
TIMING COMBINATIONS

FIGURE 5

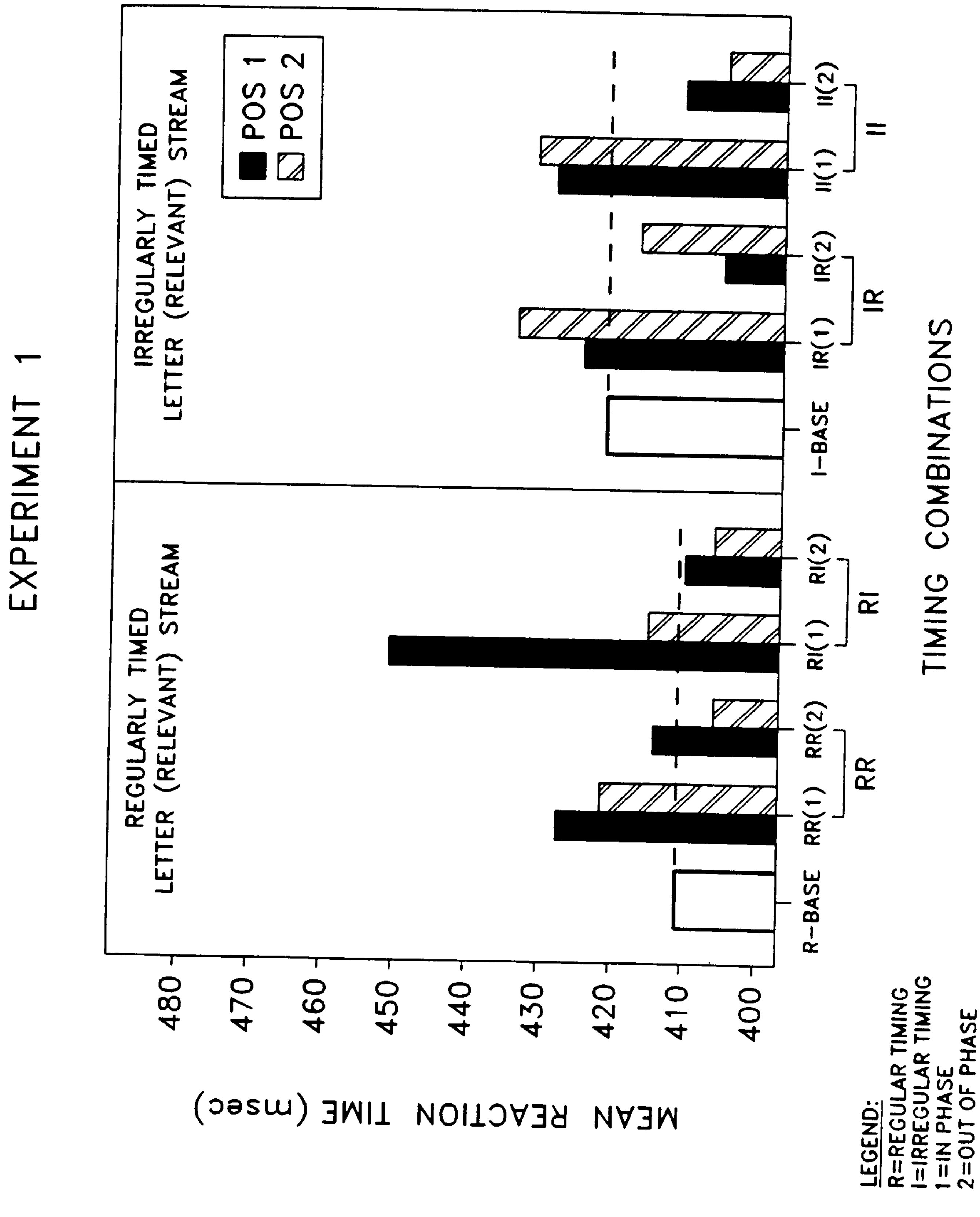
EXPERIMENT 1
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
POS 1
POS 2
MEAN REACTION TIME (msec)
480
470
460
450
440
430
420
410
400
R-BASE
RR(1)
RR(2)
RI(1)
RI(2)
I-BASE
IR(1)
IR(2)
II(1)
II(2)
RR
RI
IR
II
TIMING COMBINATIONS
LEGEND:
R=REGULAR TIMING
I=IRREGULAR TIMING
1=IN PHASE
2=OUT OF PHASE

FIGURE 6

EXPERIMENT 1

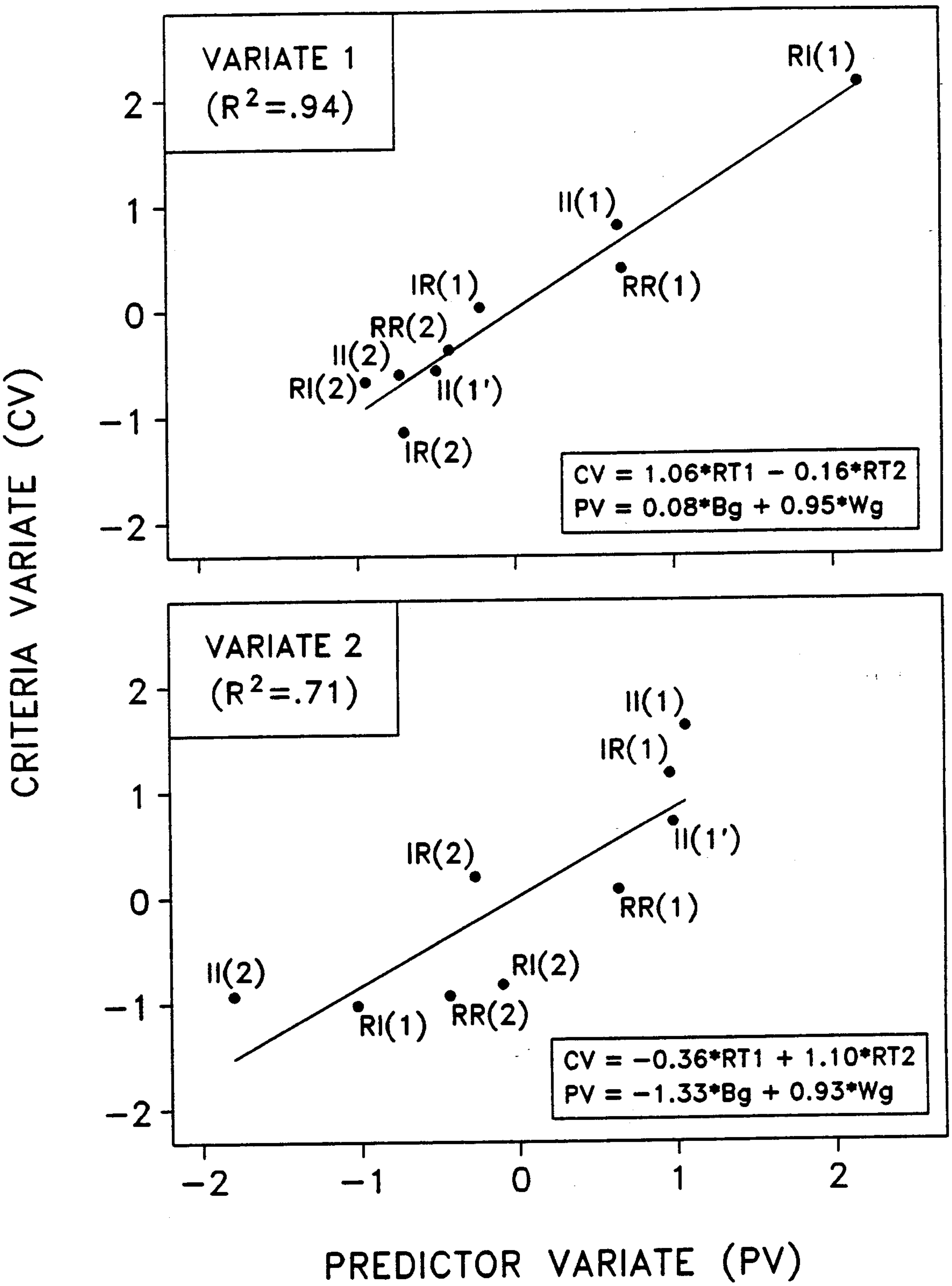

FIGURE 7

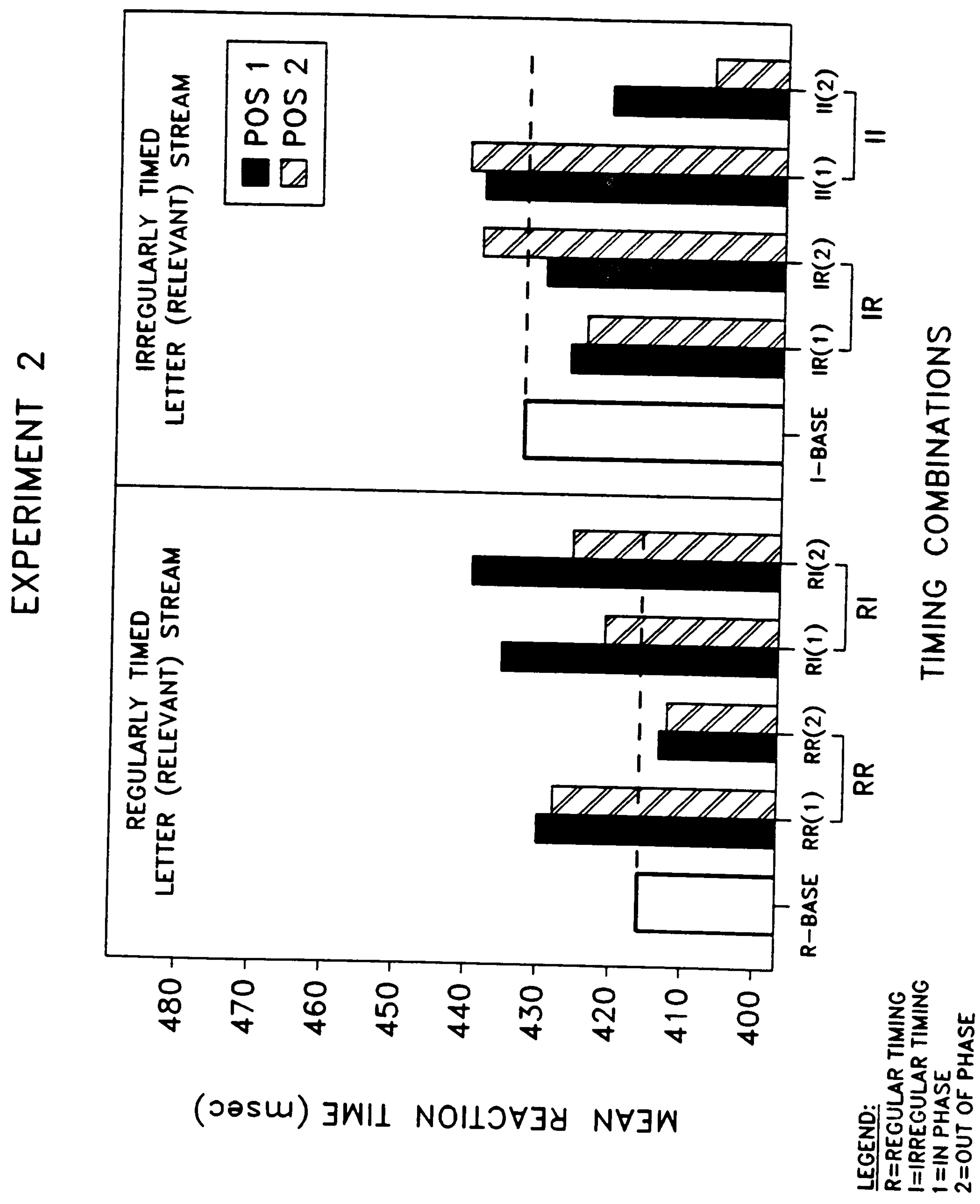
EXPERIMENT 2
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
POS 1
POS 2
MEAN REACTION TIME (msec)
400
410
420
430
440
450
460
470
480
R-BASE
RR(1)
RR(2)
RR
RI(1)
RI(2)
RI
I-BASE
IR(1)
IR(2)
IR
II(1)
II(2)
II
TIMING COMBINATIONS
LEGEND:
R=REGULAR TIMING
I=IRREGULAR TIMING
1=IN PHASE
2=OUT OF PHASE

FIGURE 8

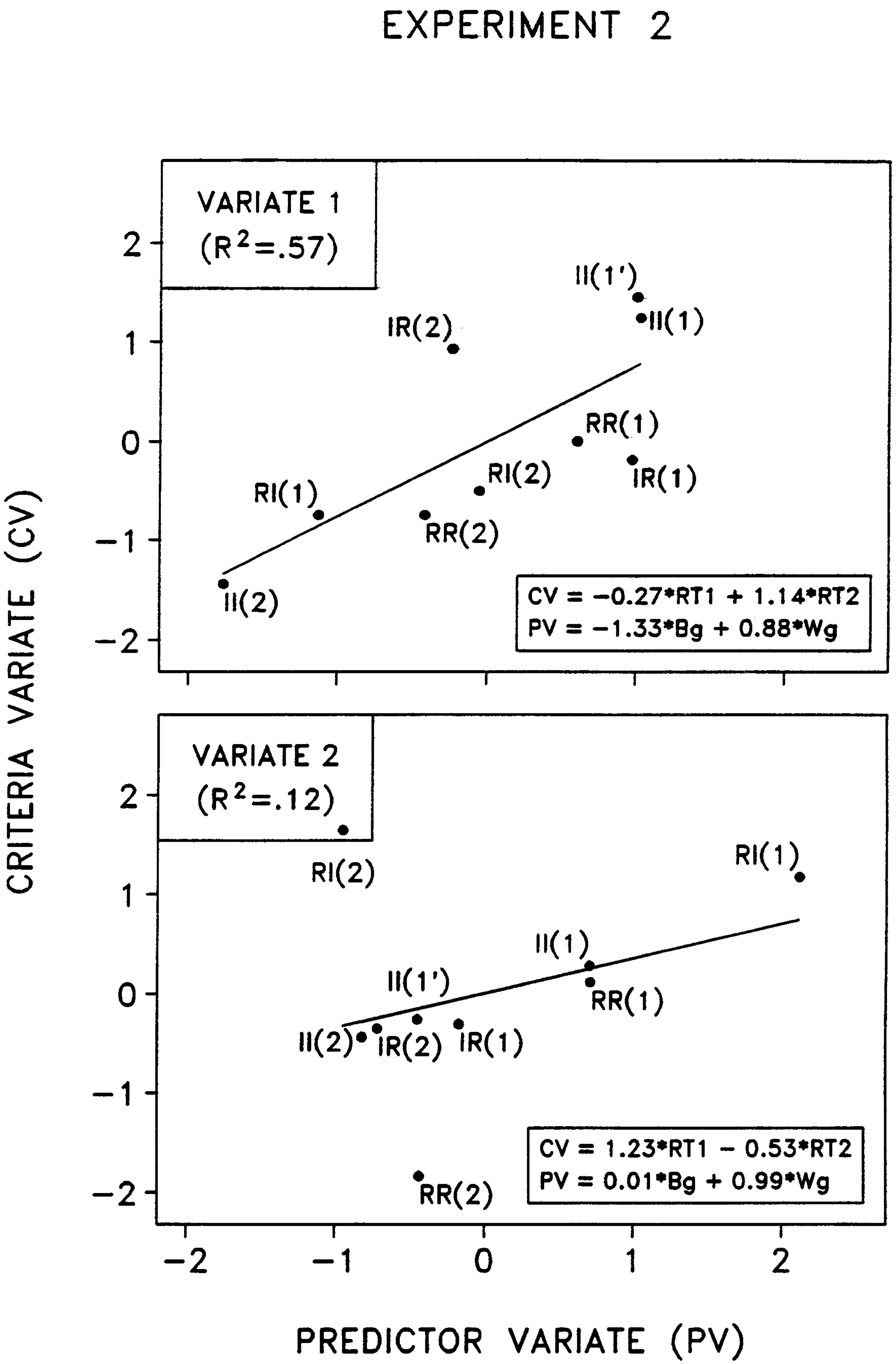
EXPERIMENT 2
VARIATE 1
(R^2=.57)
II(1')
II(1)
IR(2)
RR(1)
RI(2)
IR(1)
RI(1)
RR(2)
II(2)
CV = −0.27*RT1 + 1.14*RT2
PV = −1.33*Bg + 0.88*Wg
VARIATE 2
(R^2=.12)
RI(2)
RI(1)
II(1)
II(1')
RR(1)
II(2)
IR(2)
IR(1)
RR(2)
CV = 1.23*RT1 − 0.53*RT2
PV = 0.01*Bg + 0.99*Wg
CRITERIA VARIATE (CV)
PREDICTOR VARIATE (PV)
2
1
0
−1
−2
−2
−1
0
1
2

FIGURE 9

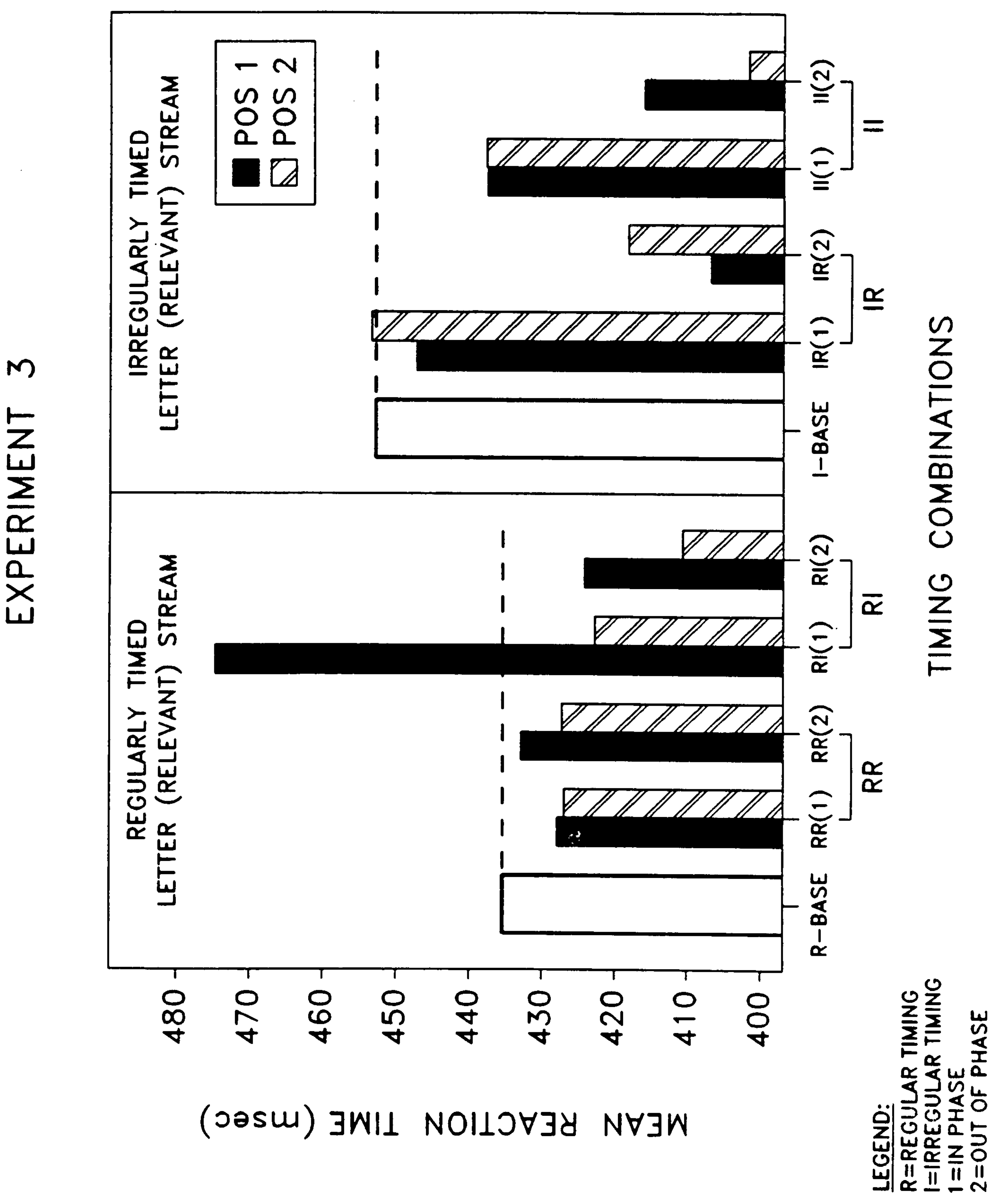
EXPERIMENT 3
REGULARLY TIMED LETTER (RELEVANT) STREAM
IRREGULARLY TIMED LETTER (RELEVANT) STREAM
POS 1
POS 2
MEAN REACTION TIME (msec)
400
410
420
430
440
450
460
470
480
R-BASE
RR(1)
RR(2)
RR
RI(1)
RI(2)
RI
I-BASE
IR(1)
IR(2)
IR
II(1)
II(2)
II
TIMING COMBINATIONS
LEGEND:
R=REGULAR TIMING
I=IRREGULAR TIMING
1=IN PHASE
2=OUT OF PHASE

FIGURE 10

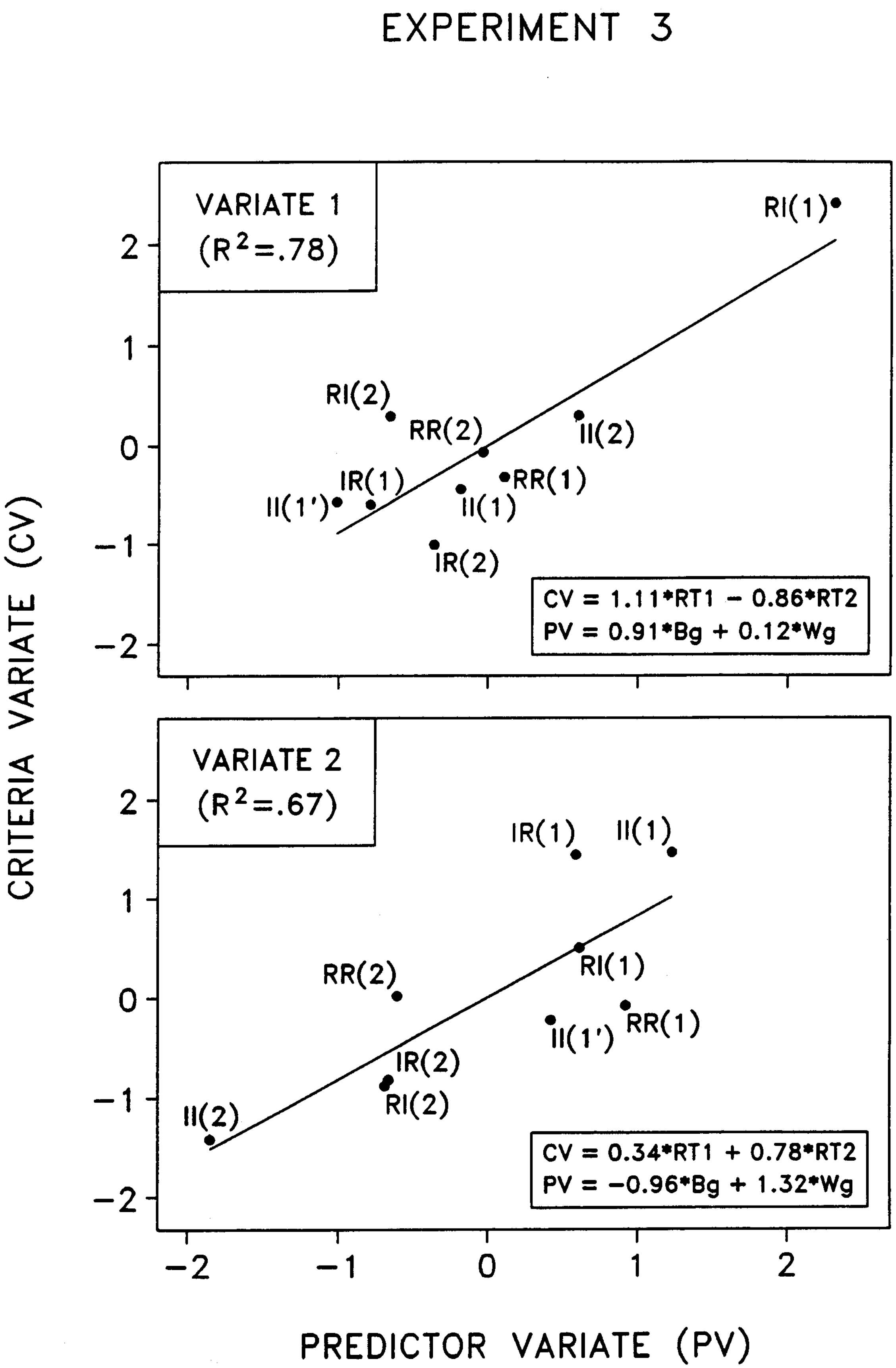
EXPERIMENT 3
VARIATE 1
(R^2=.78)
RI(1)
RI(2)
RR(2)
II(2)
IR(1)
RR(1)
II(1')
II(1)
IR(2)
CV = 1.11*RT1 – 0.86*RT2
PV = 0.91*Bg + 0.12*Wg
VARIATE 2
(R^2=.67)
IR(1)
II(1)
RR(2)
RI(1)
II(1')
RR(1)
IR(2)
RI(2)
II(2)
CV = 0.34*RT1 + 0.78*RT2
PV = –0.96*Bg + 1.32*Wg
2
1
0
–1
–2
CRITERIA VARIATE (CV)
PREDICTOR VARIATE (PV)

FIGURE 11

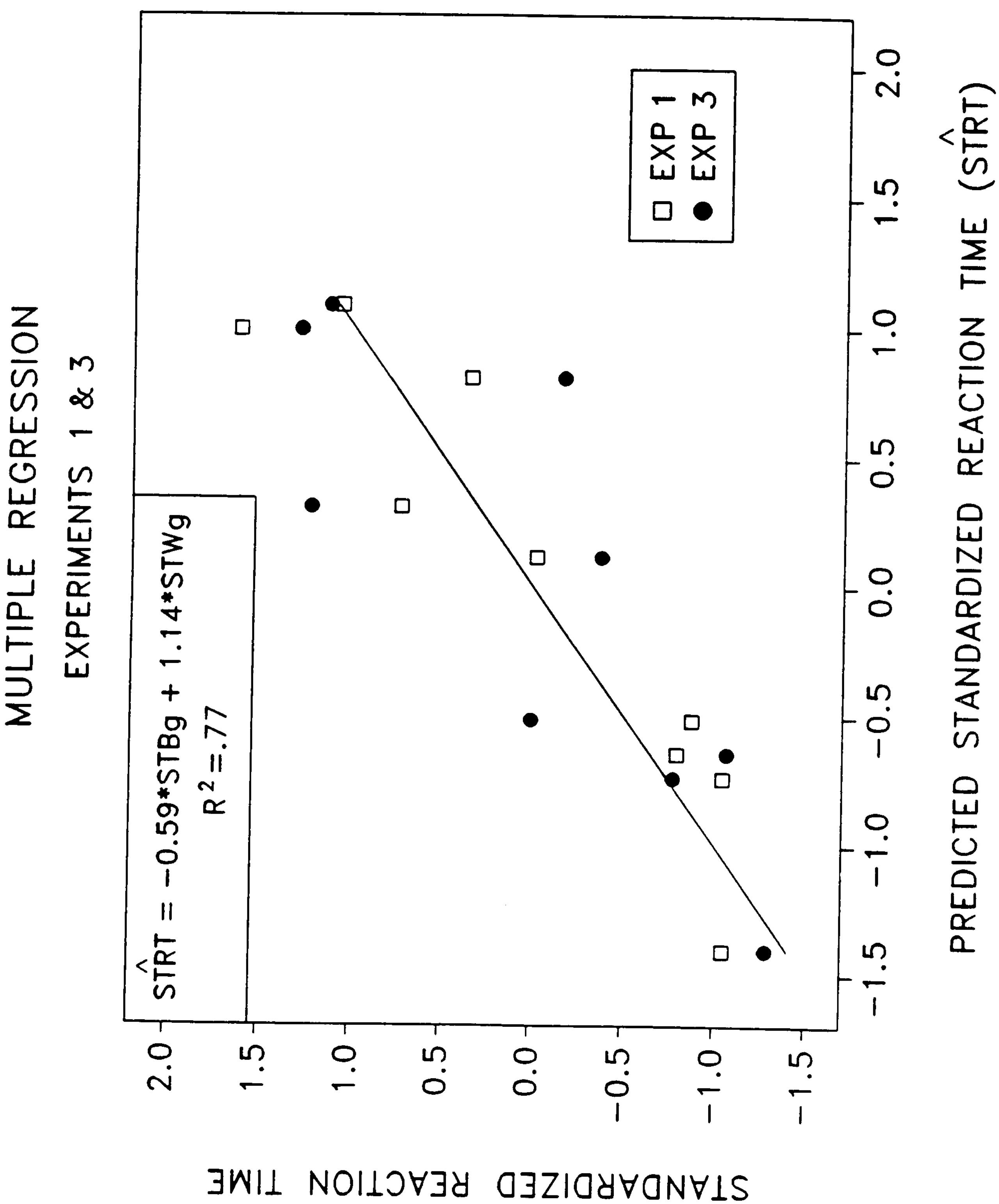
MULTIPLE REGRESSION
EXPERIMENTS 1 & 3
STRT = −0.59*STBg + 1.14*STWg
R 2 =.77
EXP 1
EXP 3
PREDICTED STANDARDIZED REACTION TIME (STRT)
STANDARDIZED REACTION TIME
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0

FIGURE 12