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AN APPLICATION OF SERIAL, PARALLEL, AND INTEGRALITY MODELS TO THE ENCODING AND DISCRIMINATION PROCESSES

by

Larry Raymond Decker

A Dissertation Submitted to the Faculty of the

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GRADUATE COLLEGE

I hereby recommend that this dissertation prepared under my direction by Larry Raymond Decker entitled An Application of Serial, Parallel, and Integrality Models to the Encoding and Discrimination Processes be accepted as fulfilling the dissertation requirement of the degree of Doctor of Philosophy

Neil R. Bartlett — Dissertation Director

April 18, 1972 — Date

After inspection of the final copy of the dissertation, the following members of the Final Examination Committee concur in its approval and recommend its acceptance:*

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SIGNED: Larry R. Dobson

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ABSTRACT

Stimulus complexity was varied instructionally in two experiments and the results were interpreted in terms of the serial, parallel, and integrality models of information-processing. Experiment 1 focused on three different methods of presentation (MOP): (1) simultaneous, (2) sequential S_1 present, and (3) sequential S_1 absent. The conditions of Set and No Set were also included in the experiment. Some evidence was found for parallel encoding and two mechanisms were hypothesized to exist within the comparison mechanism (one a serial/self-terminating/constant processor and the other either a serial or a parallel/exhaustive/constant processor).

The second experiment attempted to further test for the effect of the temporal intervals and of the same variables that were present in the first experiment. Evidence was found for a shift in processing strategies that appeared to be determined by task demands.

An information-processing model of discrimination was proposed as a result of the two experiments.

INTRODUCTION

Reaction time (RT) tasks have been used since the middle of the nineteenth century for the purpose of timing mental processes. Research of this type has increased during the last twenty years due to new experimental procedures which appear to avoid the criticisms made of the earlier techniques.

One of these new procedures employs a "binary-classification task" in which a stimulus may be classified either "same" or "different" in comparison to another stimulus. That is, two stimuli are presented, either sequentially or simultaneously and S must respond "same" or "different" depending on the relevant decision rule. The decision rules are usually concerned with either the physical (shape of stimuli) or the abstract (name, meaning of words, living or non-living) qualities of the stimulus. The stimuli employed in past studies have been multi-dimensional and usually involved differences in either shape, size, or hue (Hawkins, 1969; Egeth, 1966).

Of course, researchers in this area are not interested in RT per se but regard it as only a measure of underlying information-processing stages. One of the main questions asked in previous research concerns the amount of information that can be processed at one time. The amounts are usually determined by the number of dimensions that are processed simultaneously (in parallel). However, some research has indicated that dimensions are processed one at at time (in serial) (Egeth, 1966). The direction that the most recent research has taken (Grill, 1971) is to specify the conditions under which parallel and serial processing occur. It does not seem likely that the human organism is solely a serial processor or a parallel processor but that either mode of processing may occur depending on the relevant conditions. If one conceives of the human information-processing system as operating in stages with component processes operating at each stage (a component process may be defined as that which generates the parameters of the stage) the information-processing system may then be said to be operating in parallel if those component processes occur simultaneously. It is said to operate serially if the component processes occur one at a time in sequence. However, evidence of a great variety has arisen which supports both the serial and parallel interpretations. Previous research has also shown that the serial-parallel distinction is oversimplified, that there are supplementary variables that are necessary in order to actually differentiate the modes of processing. Egeth (1966) has proposed information-processing models which are differentiated according to the serial-parallel distinction but also incorporate the necessary supplementary variables. The supplementary variables within the parallel model are as follows: the comparisons may either be self-terminating (they may cease upon the detection of sufficient information) or they may be exhaustive (continuing until all relevant information has been analyzed); the amount of time taken to analyze a given dimension may either be constant across trials or may be distributed as a random variable across trials. The supplementary variables within the serial model include all of those in the parallel model with the addition of: the order in which the dimensions are analyzed may either be fixed (S may always compare in the order-form, shape, hue) or they may proceed in a random order across trials.

As mentioned previously the models presented have been tested in several studies and no clear evidence arose to support one or the other. It appears reasonable to assume that processing is flexible enough to permit both modes to operate at various times. The most profitable direction for research is to discover the conditions necessary for any particular mode of processing.

Hawkins (1969) presented stimuli which could differ in terms of form, size, and hue in a unidimensional, a bidimensional, and a tridimensional condition. The present paper is concerned only with one part of his tridimensional condition. That part consisted of only one dimension varying. However, it was possible that either all three, two, or one dimension could vary. Unfortunately, the dimensions that did not vary on a particular trial assumed different states than when they did vary. That is, when color varied the stimuli were either blue or green. But when color did not vary the stimuli were always gray. The size dimension was defined by the size of a circle that was contained within a square. The form dimension was defined by pairs of neutral gray trapezoids with the long base either up or down.

The point is that size was not integral to either form or hue. That is, the surrounding square could be taken away and size differentiation would still exist. Furthermore, size was not a property of the colored trapezoid but of the superimposed circle. Finally, the variability of the stimuli, depending on their relevancy, further confuses their integrality. There is no exact definition of integrality but dimensions are usually considered integral if the stimulus ceases to exist when one dimension is removed. For example, it is difficult to conceive of a visual stimulus without form, size, hue, brightness, and saturation. If a visual stimulus had no form it would not exist. In Hawkins' (1969) study the trapezoids had size but S did not decide "same" or "different" on the basis of the size of the trapezoids but rather on the basis of the superimposed circle which was not integral to the trapezoid.

The "integrality hypothesis" was proposed by Lockhead (1966) and may further define the conditions under which parallel and serial processing occur. This hypothesis assumes that dimensions integral to each other are processed as wholes. On the surface this appears to be the same as parallel processing but the parallel model entails the assumption that although the attributes of a stimulus are all tested at the same time they are treated as separate dimensions. Integrality assumes that the attributes are treated by S as a single dimension or stimulus.

One way of testing for the integrality notion would be to compare "same"-"different" RTs when only (1) one dimension varies and S is aware of the dimension before the stimuli are presented with (2) a situation where only one of three dimensions varies but with S unaware of the variable dimension before the stimuli are presented. The first condition may be labeled the "Set" (S) condition and the second condition the "No Set" (NS) condition. In this comparison one assumes the integrality hypothesis would predict no difference. The parallel and serial models would lead to several predictions depending on the supplementary assumptions involved. The situation admittedly is not a strong one for the differentiation of parallel and integrality. If "different" RTs in the NS group are faster than "different" RTs in the S group, and a parallel/self-terminating/distributed model is assumed, integrality and serial processing may be ruled out in this particular condition.

While the above attempts to explore some parameters of the comparison process most information theorists assume that a coding response is necessary before the stimuli can be compared. That is, stimuli must be transformed at the receptor surface according to a set of rules which govern the coding operation. The coding operation transforms the physical stimuli into some sort of perceptual code. The type of code has interested pattern-recognition researchers for some time. Dodwell (1961) proposed a hierarchy of coding principles and he suggests that some sort of stochastic processing of the coded stimulus properties seems plausible. The present paper is concerned with the actual parameters of the coding operation rather than with the type of code involved (images, symbols, auditory, etc.). That is, it seems as if the parallel-serial distinction that was applied earlier to the comparison process may also be applied to the coding operation. Nickerson (1967) investigated the effects of simultaneous and sequential presentation of multidimensional stimuli with the requirement of a response in the sequential condition upon presentation of the second stimulus (S_2). He found that the same basic relationships between RT and number of attributes varying existed between sequential and simultaneous but that mean RTs were much faster in the sequential presentation.

Nickerson did not discuss this effect in detail but in a later paper (1970) mentioned that there were two possible explanations of this faster RT in the sequential condition (1) perhaps S "reads" the items from the display a single one at a time (serial encoding) and (2) knowing the target S may have been able to do some preprocessing, to program the appropriate tests before the presentation of S_2. Thus if one were to establish independent probabilities of S_1 and S_2 so that S_1 could not give preknowledge of S_2 the only variable left is the encoding function. Thus the difference in RTs from the sequential to the simultaneous could reflect the time it takes to code a complex stimulus.

To continue along these same lines: if S_1 was turned off before S_2 came on and the interstimulus interval (ISI) was short enough so that S_1 remained in iconic storage (ISI of about 100 to 150 msec) and RT was found to increase in comparison to the sequential S_1 present condition, the retrieval time from the icon might be measured. While Sperling (1963) showed evidence supporting a serial coding of items from short-term storage into short-term memory and Sternberg (1966) presented evidence of a serial process in retrieval from short-term memory these conclusions are still open to investigation.

The preceding ideas were investigated in terms of two experiments.

EXPERIMENT 1

The purpose of this experiment was to investigate the effects of different methods of presentation of stimuli, of set and no set, and of dimensions on "Same"-"Different" RT.

Method

Subjects

Four Ss were run, two males and two females. They were paid $1.00 per session plus an extra 50¢ which was contingent upon low error scores and RTs faster than 600 msec.

Apparatus

An Iconix three-channel tachistoscope was used in the presentation of stimuli. The subjects, seated in a standard chair, looked into a viewing hood. The hood is contained within an 83 cm by 103 cm finished birch plywood cabinet which is 34 cm high. Four 30 cm legs are used to raise the cabinet above a table top.

Three light boxes, each with two cold cathode fluorescent lamps, allow independent exposure of three fields. A slot at the back of each light box accepted 15 cm by 28 cm cards which had a stimulus figure on a constant gray background (Munsell reflectance: N7/). The actual viewing area was 10 cm by 10 cm.

Below the cabinet were two microswitches which were connected to an Iconix Model 6255 Timebase and Counter and to two lights which faced *E*. These microswitches and lights were labeled "Same" and "Different," respectively. *S* responded either "Same" or "Different" by pressing the appropriate microswitch when the stimuli were presented. The lights indicated to *E* the nature of *S's* response and the counter recorded the reaction times.

A 60 cm high, white matte board was mounted above the viewing box. Another white matte board was erected between the table top and the bottom of the viewing box. The boards served to block any view of *E* and any stray light. Three colored lights (red, green, and white) were mounted on the front of the viewing box. Presentation of the lights was controlled by *E* through a control box located behind the viewing box. Above each light was a label indicating size, form, or brightness.

Stimuli

The stimuli were constructed from three nonsense shapes developed by Dr. Terry Daniel of The University of Arizona. The three shapes were selected in terms of the number of points (8 points for each stimulus), areal density (judged by superimposing one shape over another, and subjective estimates of form differences).

The shapes were constructed from black construction paper (Munsell reflectance: N2/), gray artist's paper (Munsell reflectance: N5/), and white mimeo paper (Munsell reflectance: N9.5/). The three forms were respectively 2, 4, and 6 cm on both the vertical and horizontal plane. They were viewed within four fixation lines, 5 cm long, arranged in a square. The pairs of stimuli were separated by .5 cm.

Varying of the stimuli in terms of three forms, three sizes, and three levels of brightness produced 27 different stimuli and 729 pairs.

Procedure

Subjects were initially tested for uncorrected 20-20 vision by means of a Snellen eye chart. They were then given tape-recorded instructions for the practice trials. The practice trials consisted of 30 presentations of the stimuli AA, BB, and AB. After practice Ss were given the final tape-recorded task instructions.

All of the 27 stimuli were shown to S and 54 practice trials were run. During the 54 trial practice session Ss were requested to initiate the trial by pressing a foot pedal located under the table. The subject was signaled that the trial was ready to begin by the presentation of one or all of the colored lights.

The order of events in the second practice session was: (1) the presentation of the lights, (2) S pressing the foot pedal, (3) a 500 msec delay, (4) presentation of the stimuli, and (5) S's response. The intertrial interval (ITI) was from 10 to 15 seconds. Immediately after S responded, E replied either "Correct" or "That's an error."

After the second practice session the experimental trials were begun. The order of events in the experimental trials were exactly the same as in the second practice session. The stimuli were presented in blocks of twenty trials, 10 "Same" and 10 "Different." Each block within the Set condition varied only one dimension. For example, only brightness might be varied within one block of twenty trials. However, in the No Set condition the dimensions were randomly distributed in order of presentation. Therefore, in the No Set condition, brightness, form, and size varied, one at a time, within one block of 20 trials.

The Set condition was defined by the presentation of only one colored light and the No Set condition by the presentation of all of the colored lights simultaneously.

There were three different methods of presentation: (MOP): simultaneous (Sim), sequential present (Seq p), and sequential absent (Seq a). The Sim method consisted of both stimuli appearing at the same time for 100 msec. The Seq p method had stimulus one (S_1) appear for 200 msec, while S_2 appeared for only the first half of the 200 msec interval. With Seq a S_1 was exposed for 100 msec, then for the next 100 msec there was only the fixation field, and finally S_2 was exposed for 100 msec. Each MOP was introduced to S by means of running S through the MOP. Each MOP consisted of 120 trials run through twice for a total of 240 trials within each MOP. Each dimension had 20 trials run through twice, for 40 trials at each dimension. The Set and No Set conditions had 60 trials run through twice. The presentations of all of the conditions including MOP were counterbalanced both within and across Ss. Total trials for each S was 720. The stimulus presentation was randomized within a dimension for Set and within all of the dimensions for No Set. All of the MOP conditions had the fixation field on continuously, in order to minimize after-images.

Results

Each experiment will be presented with an individual results and discussion section. The final section of the paper will consist of a combined discussion of the two experiments.

An ANOVA 45 computer program was used to analyze the data. The main effects were dimensions (brightness, size, and form), "Same"-"Different" RT, Set and No Set, MOP (Sim, Seq p, and Seq a), and practice. All of the main effects were significant at the .01 level with the exception of MOP which was significant at the .025 level. Dimensions ($F[2,40] = 36.95$, $p < .01$), "Same"-"Different" RT ($F[1,20] = 27.83$, $p < .01$), Set, No Set ($F[1,20] = 8.99$, $p < .01$), MOP ($F[2,40] = 4.13$, $p < .025$), and practice ($F[1,20] = 249.08$, $p < .01$).

The interactions further qualify the main effects. That is, the main effect test collapsed variables across all of the other variables. Dimensions were tested for across "Same"-"Different" RT, Set-No Set, and MOP. "Same"-"Different" RTs were tested for across dimensions, Set-No Set, and MOP and so on. The tests for interactions separated out the finer detail comparisons.

Two-way interactions showed that "Same"-"Different" RT changed significantly as a function of Set-No Set ($F[1,20] = 9.14$, $p < .01$) and as a function of MOP ($F[2,40] = 5.75$, $p < .01$). However, the "Same"-"Different" RT relationship was not significantly changed by the dimensions. A graphing of the "Same"-"Different" RT and Set-No Set interaction in Figure 1 showed that "Same" RT was always slower than "Different" RT regardless of the Set-No Set condition. However, both "Same" and "Different" RT were faster in the Set condition as opposed to the No Set condition. The graphing of the "Same"-"Different" RT and MOP interaction (Figure 2) again showed the basic relationship of the "Same" RT being slower than the "Different" RT. The order of speed for the different

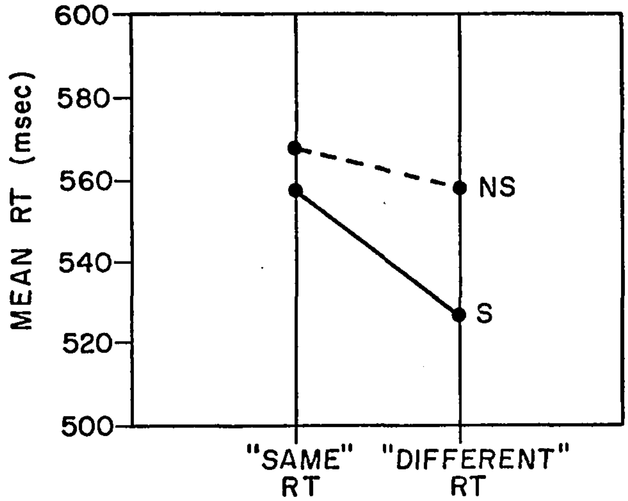

Figure 1. "Same" and "Different" RTs as a function of Set-No Set.

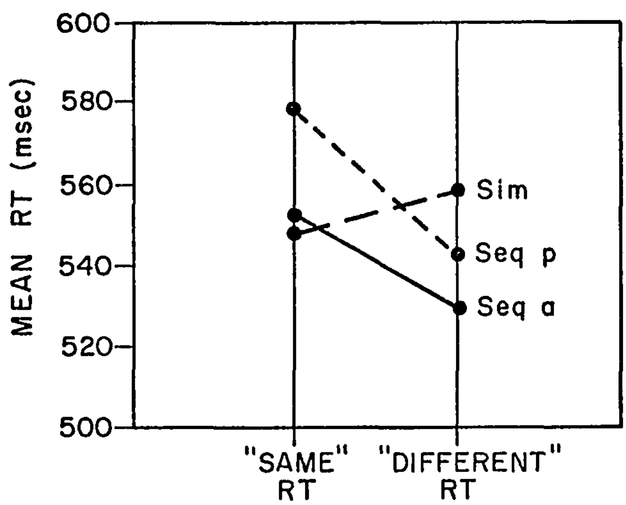

Figure 2. The interaction of "Same"-"Different" RTs and method of presentation.

methods of presentation were for "Same" RT from slowest to fastest: Seq p, Sim, and Seq a. For "Different" RT: Sim, Seq p, and Seq a. The three-way interaction of "Same"-"Different," Set-No Set, and MOP was not significant.

The main effect of Dimensions showed brightness and size to be approximately equal in speed ($\bar{x}B$ = 541 msec and $\bar{x}S$ = 540 msec) with the form the slowest ($\bar{x}F$ = 579 msec). This basic relationship did not change over any of the several conditions. This may be illustrated in terms of four graphs in Figure 3 which also show the four-way interaction of "Same"-"Different" RT, Set-No Set, Dimensions, and MOP. The interaction was not significant. The graphs best demonstrate the dimension effect. They also show that the effects of Set on "Same"-"Different" RT are not as clear as the two-way interactions indicated. When one separates out all of the relevant variables it is difficult to see any consistent relationship. The MOP effect is also confusing, for one must look at the dimension, Set condition, and type of RT involved before one can make any kind of conclusive statement about MOP. However this interaction was not statistically significant, having an F of less than one. It therefore appears valid to make statements about MOP in terms of two-way interactions with the other variables averaged in. The MOP effect becomes clearer with the averaging of the other variables.

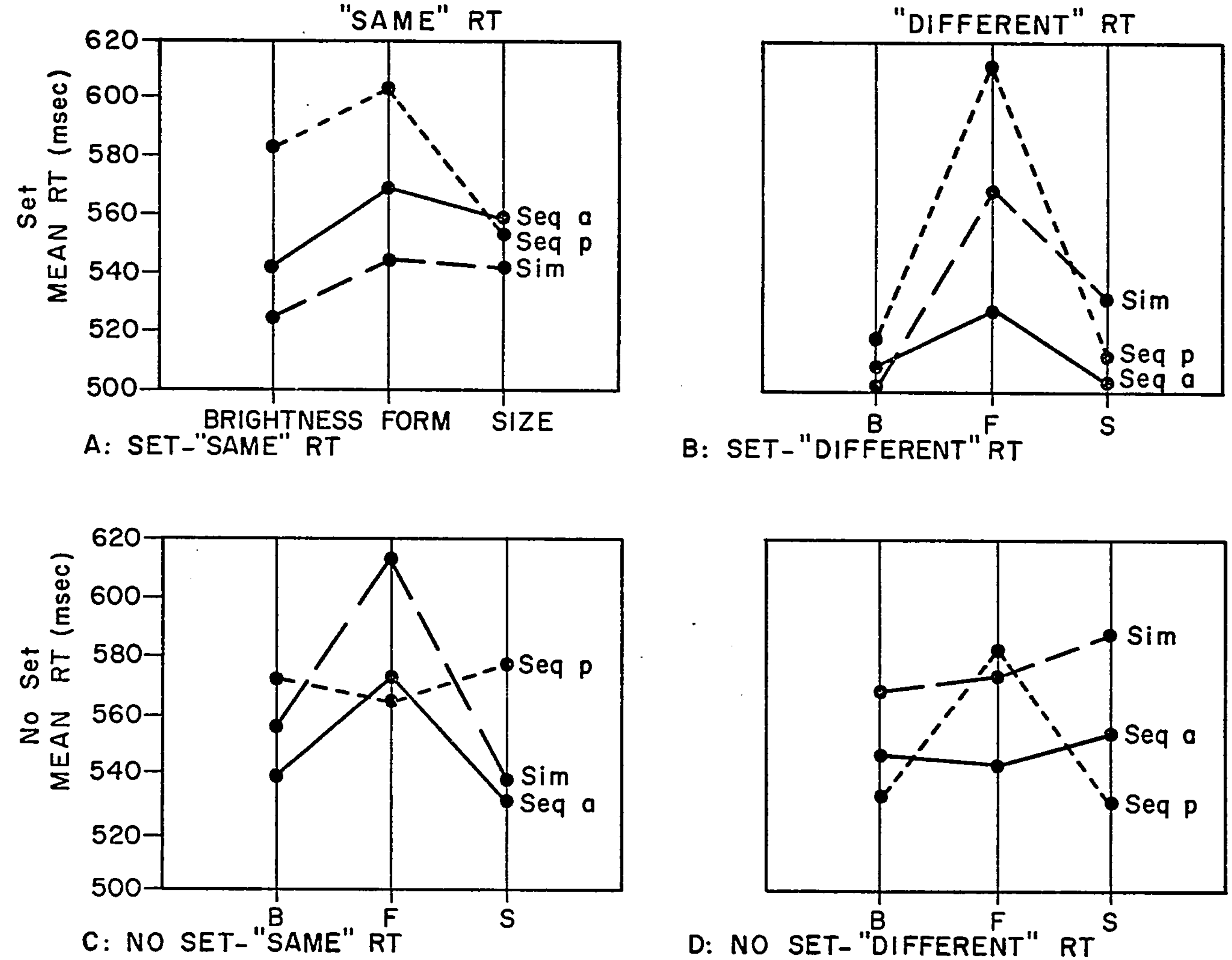

Figure 3. The four-way interaction of "Same"-"Different" RT, Set-No Set, Dimensions, and method of presentation.

Discussion

The dimension effect was the most consistent across the various conditions. However, the fact that form was slower than either brightness or size does not really say much about integrality or parallel and serial processing. It does point to the fact that comparison times are probably constant. That is, the time to compare one dimension between stimuli does not change from one trial to another. At first glance, this may be construed as evidence against integrality for if stimuli are processed as a whole the breaking down of the stimuli in terms of dimensions should not make any difference and should not change the basic processing time. One dimension should not be faster or slower than another dimension for they are all processed as one. However, one may argue that the experimental situation was such that it forced S to process the stimuli in terms of dimensions. That is, S had to adopt some other form of processing other than what he used outside of the narrow experimental situation. The fact that S was able to adopt this different information-processing method merely shows the flexibility of human behavior and says nothing about integrality. More will be said about this in the discussion of Set-No Set.

The dimension effect indicated that the various levels of differences were equal. That is, the size difference was equal to the form difference which was equal to the brightness difference. Furthermore, within each dimension the levels of difference were equal. This was demonstrated by the no change in RT from "Same" to "Different" in terms of dimensional relationship. If the same relationship between dimensions holds whether S has to decide "Same" or "Different" then one may say that changes within dimensional levels did not affect the basic judgment of "Same" or "Different." That is, size differences were approximately psychophysically equivalent to the form and brightness differences and that the differences in speed of discrimination may be related to a difference in dimensional processing time. Dimensional processing time was not confounded by the possibility of processing one dimention change faster than another dimension change.

"Same" judgments were slower than "Different" judgments across all of the conditions with dimensions averaged in. This infers an exhaustive search for "Same" and a self-terminating search for "Different." That is, S apparently checked all of the dimensions when he responded "Same" but checked only to the dimension which was different when he responded "Different." A look at the Set-No Set condition further validates this explanation. "Same" RT in the Set was about 7 msec faster than "Same" RT in the No Set. However, "Different" RT in the Set was 30 msec faster than "Different" RT in No Set. This indicates that S, regardless of the Set-No Set condition, employed an exhaustive search when stimuli were the same but employed a self-terminating search when they were different. The self-terminating search was enhanced when S was able to search only one dimension (Set).

"Same" and "Different" RTs also changed due to the MOP. "Same" RTs were slower than "Different" RTs in the sequential presentations but were somewhat faster (8 msec) in the simultaneous condition. The difference was so small that the RTs in the Sim may be taken as equal. However, the differences in the sequential modes were large (38 msec in Seq p and 25 msec in Seq a). Within MOP "Same" RTs in Sim and Seq a were approximately equal while Seq p was about 30 msec slower. The fact that Sim did not change speed from "Same" to "Different" whereas Seq p and Seq a did change is further evidence for the exhaustive nature of the "Same" judgment and the self-terminating characteristic of the "Different" judgment. That is, if one assumes a parallel encoding process and an exhaustive search for "Same," the difference between Sim and Seq modes would be very small for the "Same" judgment. The S searched all of the dimensions regardless of MOP but in the Sim both stimuli were present and could be encoded and searched simultaneously. However, when a "Different" judgment was required a serial encoding was used and a self-terminating search thus increased the time for the Sim condition and decreased the two Seq conditions time. The idea of having two separate mechanisms, one for "Same" and one for "Different," was hypothesized by Bamber (1969). Bamber proposed an identity reporter for the "Same" RT and a serial process for the "Different" RT. The identity reporter in Bamber's study enabled the "Same" RT to be faster than the "Different" RT or the serial processor. Bamber explained the speed of the identity reporter as indicating that the reporter processed stimuli as "wholes" while the serial processor broke down the stimuli into its various dimensions. This leads into the question of integrality and the Set-No Set comparison.

The Set condition was always fastest regardless of the MOP. The small amount of significance found in its interaction with MOP was probably a result of the speed of MOP changing with the change from Set to No Set ($F[2,40] = 3.55$, $p < .05$). In the Set condition the order from fastest to slowest was Seq a, Sim, and Seq p. The Set condition probably heightened discriminability and correspondingly decreased the coding time. Set may also have enabled the Sim mode to parallel encode. The No Set condition showed a crossover with all MOPs increasing RT but Sim showing the greatest increase. This may be evidence for a serial encoding in Sim in the No Set condition. The order in No Set was (fastest to slowest): Seq a, Seq p, and Sim. The fact that, overall, the condition Set was always fastest as compared to No Set seems to argue against an integrality form of processing. Referring back to the argument presented at the beginning of the Discussion section about the artificiality of the experimental situation: in a phenomenological approach to perception one does not separate out the various dimensions of stimuli but seems to view them as combined entities resulting in some complex pattern. The ideas of brightness, size, and form combinations are certainly not necessary for one to perceive their end results. However, being dependent on grosser kinds of data such as verbal descriptions, phenomenology is probably not the most scientific way of proceeding. Reaction time measures would appear to do away with much of the subjectivity that is inherent within phenomenology.

In the present situation it appears that S was able to separate out the various dimensions, respond on the basis of those dimensions and, indeed, have his response influenced by the apparent separation. S responded in a manner that could only lead one to conclude that an individual will find a dimension faster if he is told in advance the dimension to search than he will if he is given several dimensions and told to search for all until he finds a target. The fact that Ss were able to separate the dimensions and see differences in one dimension but no difference in another casts doubt on the integrality notion. Perhaps integrality has not been well enough defined. Perhaps what is meant by integrality is the inability to separate dimensions within a single stimulus. The use of two stimuli may provide a totally different situation with the two stimuli not being integral to each other. That is, the dimensions may be integral within one stimulus but not within two separate stimuli. However, the integrality within and the separability between should not have influenced RT. The slowness of "Same" RT and the difference from Set to No Set indicates a parallel exhaustive constant search for "Same" and a serial self-terminating constant search for "Different."

With all of the other conditions averaged in the order of MOP from slowest to fastest was Seq p, Sim, and Seq a. Several different interpretations of this result may be made. First of all, a reexamination of the conditions that made up MOP may help to clarify the results. Seq a produced the fastest RTs and required a comparison of a physically present stimulus with another stimulus physically absent but present in the form of iconic storage. S_1 in Seq a could be viewed as being present for 300 msec. That is, S_1 came on for 100 msec, off for 100 msec, and S_2 on for 100 msec. If one assumes S_1 present in the form of iconic storage for at least 200 msec then total on time for S_1 is 300 msec. The Sim condition consists of S_1 and S_2 coming on simultaneously for 100 msec. They may be present afterwards in the form of iconic storage also but the task is one of comparison of two physically present stimuli. Seq p was the slowest and also the condition which used different physical on times. That is, S_1 came on for 200 msec, whereas S_2 came on only after the first half of that interval had elapsed and remained on for the balance of the interval. Seq p involved a comparison of two physically present stimuli but with the stimuli presented sequentially.

Posner, Boies, Eichelman, and Taylor (1969) have reported evidence that shows a much different relationship than that found in the present experiment. Posner et al. reported that RT was slower when S_1 was removed as compared to RT when S_1 was present. They interpreted their findings as showing that the Seq p situation enabled S to free his attention from the preservation of the visual information of the S_1. However, Posner et al. used different stimuli (letters), different tasks (name and physical matches), and different on and ISI times (Seq p on: 150 and 500 msec; Seq a ISI: 0, 500, and 1000 msec). It is fairly clear why Posner et al.'s findings differ from the present study. They were not dealing with iconic storage in their Seq a condition. Their ISIs of 500 and 1000 msec are well beyond most estimates of iconic duration (250-300 msec). One would expect RTs to be heightened as the icon faces and comparison becomes more difficult. Thus, their comparison showing Seq p to be faster than Seq a does not really conflict with the present experiment.

However, following Posner et al.'s attention-interpretation of Seq p, a modification may be made to fit the present data. The stimuli used were random forms which are difficult if not impossible to label and thus probably involve some degree of encoding time. Posner and Boies (1970), using Gibson forms, has shown encoding functions to continue for as long as 500 msec. With the physical presence of S_1 for only 100 msec before S_2 it appears safe to assume that encoding was still progressing on S_1. That encoding may have captured Ss attention to the degree that it slowed his attentional shift to S_2.

The Sim condition exhibited some degree of parallel encoding by its faster RTs in comparison with Seq p. However, an alternative explanation is that the physical presence of two stimuli presented simultaneously may speed encoding time. The possibility that encoding parameters were influenced by the nature of the task should not be overlooked. That is, in Seq p the situation was such that S was able to slow encoding due to the smaller demand placed on that mechanism. However, in Sim the situation demands immediate encoding of two stimuli which may have caused S to increase the coding functions to the point that it was proceeding faster than in Seq p.

Seq a was confounded by the longer on times for S_1 than in the other two conditions. S_2 came on when S_1 was in about the middle of iconic duration. Most of the encoding functions would probably have taken place and a point may be made here for faster encoding when the stimulus is in the icon. This faster encoding would have facilitated the shift in attention to S_2 and freed the encoding mechanism to transform S_2. The comparison mechanism evidently scans the icon after the encoding of S_2 and this scanning was faster than the scanning of physically present stimuli. Of course, S_1 in Seq a had 200 msec to be encoded while S_1 in Sim and Seq p had only 100 msec to be encoded. However, the difference in RTs do not reflect this large a difference (Seq p $\bar{x}$ = 562 msec, Sim = 556, and Seq a = 543), a difference at the most of 19 msec, certainly not proportional to the extra 100 msec given in Seq a.

Another explanation of the Seq a effect deals with the increased amount of radiant energy input. As luminance increases, RT decreases. In Seq a, when S_1 went off, the fixation field remained on which added more luminance to the display and may have been partially responsible for the decreased RT. The temporal luminance summation explanation and the attention-encoding explanation along with Set-No Set, "Same"-"Different" RT, and dimensions were tested for in the second experiment.

EXPERIMENT 2

The purpose of this experiment was to further test for encoding functions by varying ISIs, to test for more evidence concerning integrality by using the Set-No Set conditions, and to test for the validity of the dimension effect. All of the testing was again based on the changes in "Same"-"Different" RTs.

Method

Subjects

Four Ss (1 female and 3 males) were run. None had any previous experience with RT experiments. The same payoff matrix was used in the second experiment as was used in the first experiment.

Apparatus and Stimuli

The same apparatus and stimuli used in the first experiment were used in the second experiment.

Procedure

The instructions and initial practice session were identical to the first experiment. The second practice session was somewhat longer in the second experiment. The results of the first experiment had shown that practice was a strong effect in terms of decreasing RT. In an attempt at controlling for that practice effect, 54 practice trials with the test stimuli were run in experiment two. All of the other conditions, except for MOP, were identical with experiment one.

There were six different ISIs or temporal intervals (TI). The intervals were measured from the presentation of S_1 which had a constant on time of 100 msec across all intervals. Therefore Sim had an interval of zero msec (0 msec). The rest of the intervals were: 50, 100, 150, 200, and 300 msec. To further explain what TI refers to in the 100 TI S_1 comes on for 100 msec, goes off, and S_2 comes on immediately for another 100 msec. In the 150 TI S_1 came on for 100 msec, went off, and 50 msec later S_2 came on. The rest of the TIs should be self-explanatory. The TIs were presented in an ascending and descending order counterbalanced over Ss.

Results

The dimension effect was repeated with Form again being the slowest and Brightness and Size being approximately equal. The effect was significant ($F[2,18] = 5.61$, $p < .025$).

The "Same"-"Different" RT effect was significant ($F[1,12] = 17.27$, $p < .01$). However, "Same" RTs were faster than the "Different" RTs.

Surprisingly there was no Set-No Set effect while the TI effect was one of the largest ($F[5,36] = 36.89$, $p < .01$). The order in TI from fastest to slowest was: 150, 200, 100, 300, 50, and 0.

There was no dimension interaction with either "Same"-"Different" RT or with Set-No Set but a significant interaction was found with "Same"-"Different" RT and TI ($F[5,36] = 82.10$, $p < .01$). The Set-No Set interaction with TI was not significant.

None of the three- and four-way interactions tested for were significant.

Discussion

The dimension effect remained constant across all conditions. The significant interaction with TI was graphed in Figure 4 and showed only one interval (150) that did not show the Brightness, Size, Form order. This repeats the first experiment's finding and lends further evidence to the assumption of constant attribute checking time.

The "Same"-"Different" effect was reversed from the first study. The present results are consistent with the majority of previous research but are also somewhat more difficult to interpret. The slower "Different" RTs were consistent across all conditions. The significant interaction with TI was graphed in Figure 5 and the basic

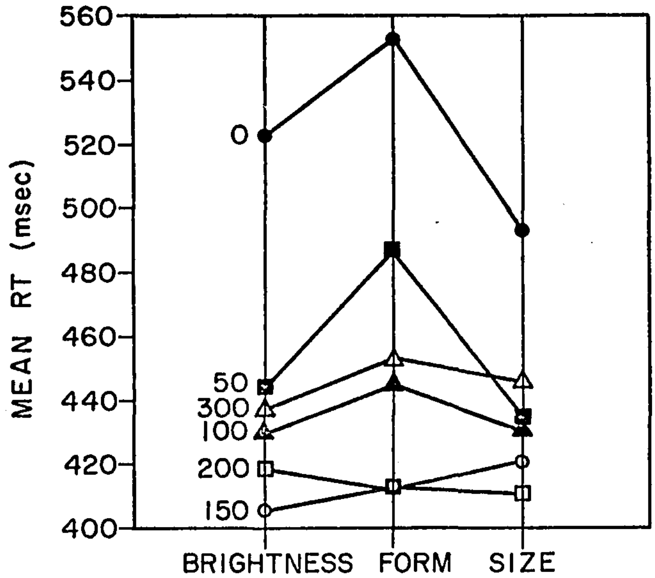

Figure 4. The interaction of temporal intervals with dimensions.

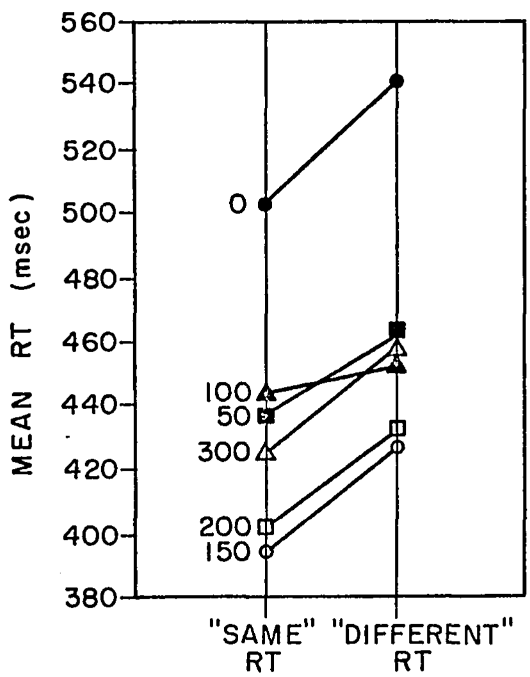

Figure 5. The interaction of temporal intervals with "Same"-"Different" RTs.

relationship of slower "Different" RTs was unchanged at all of the intervals. However, there was a crossover from the "Same" 100 TI to the "Different" 100 TI. That is, "Same" RTs for 100 TI were slower than the 50 and 300 TIs but the "Different" RTs for 100 TI (although slower than "Same" RT for 100 TI) were faster than the 50 and 300 TI "Different" RT. It was assumed that was where the significant interaction came from.

Bamber's (1969) model can again be applied to the data in experiment two. The speed of the "Same" RT in comparison with the "Different" RT along with the no Set-No Set effect provides evidence for an integrality-type of processing. That is, Ss processed stimuli as complete stimuli thus enabling a fast comparison and a much quicker "Same" judgment when the stimuli were the same. But, when the stimuli were different, the serial/self-terminating process took longer than the identity process. The lack of the Set-No Set effect combined with the faster "Same" RT appears to be strong evidence for an integrality interpretation.

A graphing of the TI, Set-No Set, and "Same"-"Different" interaction in Figures 6 and 7, although not significant, is the best illustration of the second experiment's findings. "Same" RTs (Set) show a consistent drop from the 0 interval to the 50 interval where they made a slight rise at 100 and then dropped again to the lowest

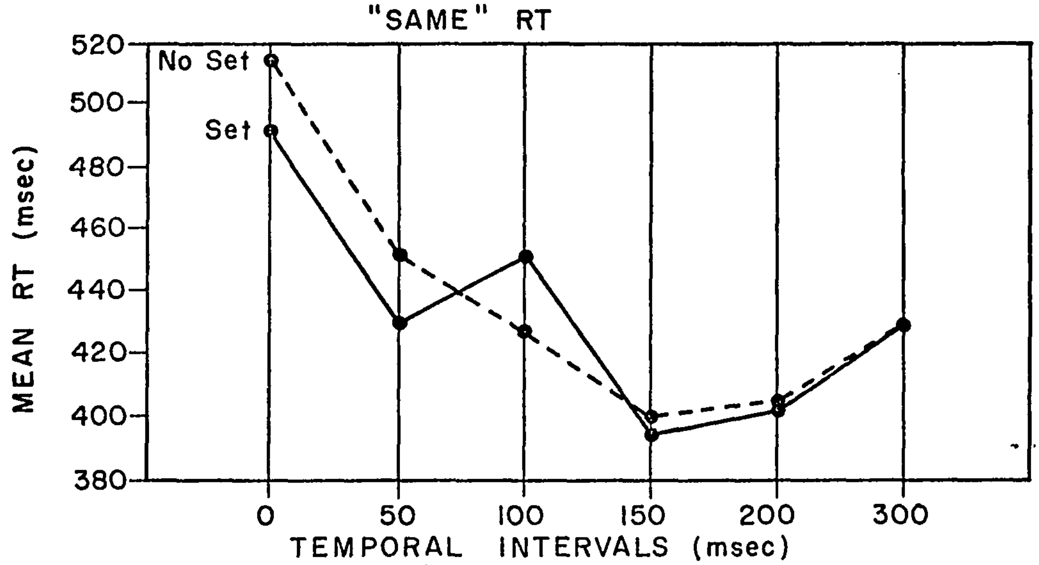

Figure 6. The interaction of temporal intervals, Set-No Set, and "Same" RT.

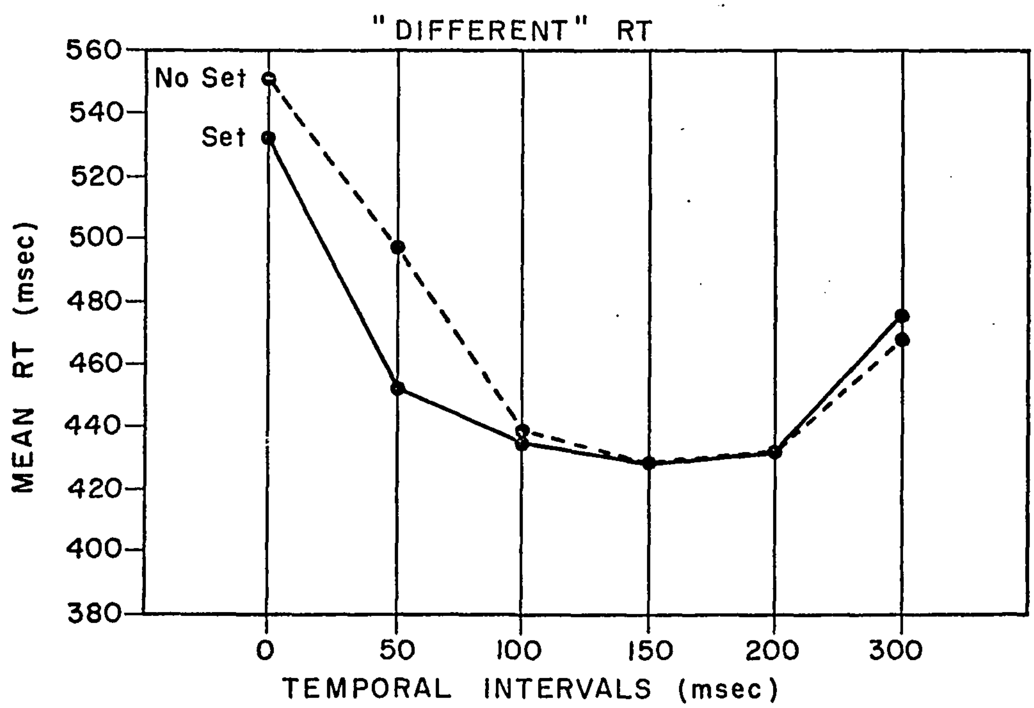

Figure 7. The interaction of temporal intervals, Set-No Set, and "Different" RT.

level at 150. The speed of "Same" RTs rises again at the 200 level and is continuing to rise at the 300 level. The "Same" (No Set) RTs, the "Different" (Set and No Set) RTs all showed the same U-shaped function without the slight rise at the 100 TI.

The slowness of the RTs at the zero interval can only be interpreted as serial encoding. Stimuli must be coded before they can be analyzed by the identity reporter or the serial processor. That does not mean that the coding cannot be serial or parallel. The coding was serial in the sense that both stimuli were encoded, one at a time, rather than simultaneously. However, the coded stimulus was processed as a whole by the identity processor and dimension by dimension by the serial processor.

The optimum interval for both "Same" and "Different" RT and Set-No Set conditions was 150. Evidently the icon was at its clearest after about 50 msec. Coding had apparently been completed and S could shift attention to S_2 while maintaining S_1 in the icon for comparison. Another 50 msec and the icon began to fade causing a slight increase in RT. After 150 msec the icon had degraded to the point where it was difficult to maintain S_1, encode S_2, and begin comparison with S_1. The resulting attempt to maintain a fading image, encode, and compare a second stimulus increased RT. One would expect that if the intervals were carried out further, to 400 and 500 msec, RTs would probably degrade to a point at least equal to the zero interval.

Finally, the initial decrease in RT from the zero interval to the 150 interval appears to have been due to a serial encoding process. The rise in RT after 150 was due to the fading of the icon. The comparison of S_2 with a fading image of S_1 was apparently more difficult than a comparison of S_2 with a clear image of S_1. Although most estimates of iconic duration are of about 250 msec (Sperling, 1963) fading would be expected to begin after about 50 msec. The fact that the image had not faded completely after 100 msec was supported by the small rise at the 200 interval but after 200 msec the icon has begun to lose most of its clarity as demonstrated by the 300 interval RT.

The individual S means were graphed in Figure 8 for the interval effect. As can be seen all of the Ss showed the same basic relationship. The two Ss that received ascending TI have elevated RTs at the zero interval but the two Ss that received descending TI also have their RTs at the zero interval as their slowest. All of the Ss showed the same basic U-shaped function with a rise at the 200 and 300 TIs.

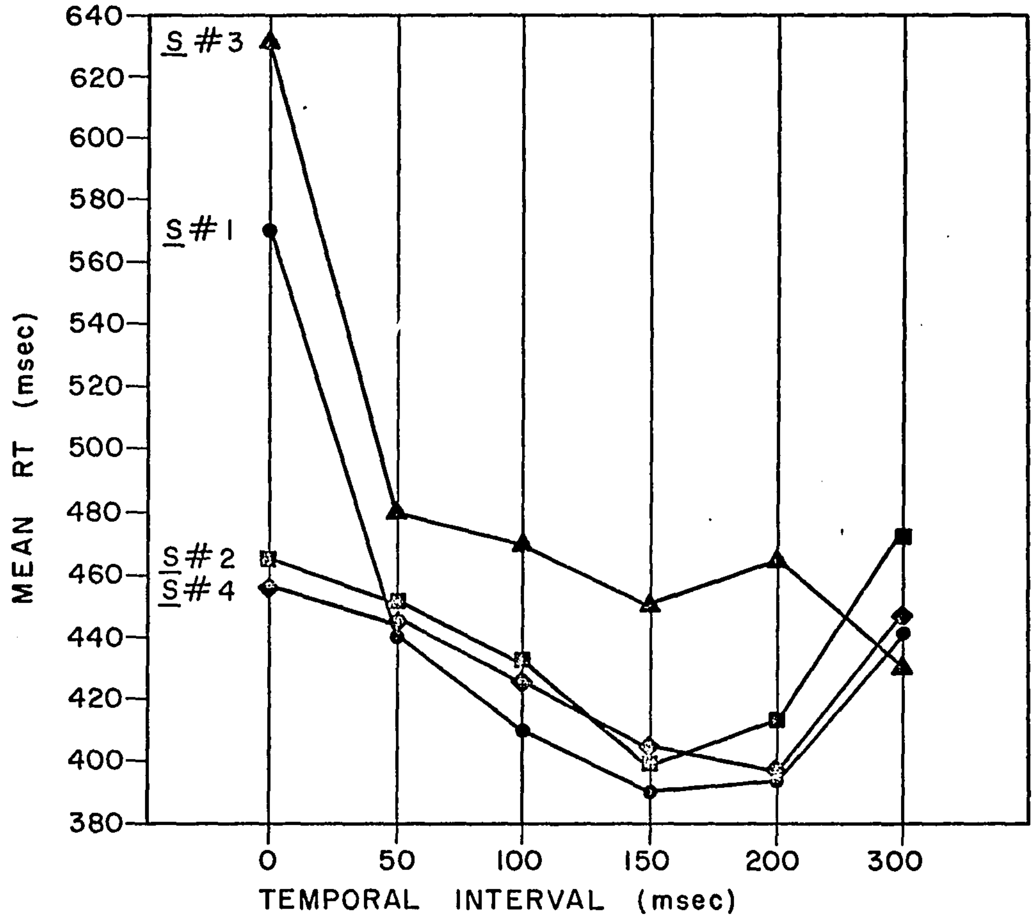

Figure 8. The interaction of subjects with temporal intervals.

COMBINED DISCUSSION

The main difference in RT from E1 to E2 was the change from what appeared to be a dimensional analysis in E1 to an integrality type of processing in E2. The three variables that might have caused the shift in processing strategy were: practice, stimulus on times, and the number of temporal intervals.

Practice was shown to be a major effect on the speed of RT in E1. However, the basic relationships of RT from one condition to another did not change with practice. Practice was controlled for in E2 by giving preexperimental practice (the same as in E1) and counterbalancing the intervals. A graphing of the individual S means showed that the control was apparently successful. All Ss showed the same basic RT-interval relationship regardless of the order in which they received the intervals. The number of trials at each interval varied from 240 in E1 to 120 in E2. However, again RT decreased in E1 but the form of processing did not change. Therefore, practice did not appear to be responsible for the change in processing strategy in E2.

The number of temporal intervals presented in E1 was three while in E2 it was six. This coincided with a varied stimulus one on time in E1 from 100 msec to 200 msec and a constant stimulus on time of 100 msec in E2. The

ISIs in E1 ranged from 0 to 200 msec and from 0 to 300 msec in E2. E2 tested a wider range of intervals and presented the intervals in a more continuous fashion. That is, in E1 the transition from Sim (0) to Seq a (200) was in a 100 msec step and from Seq a to Seq p (50) the S_1 on times changed from 100 msec to 200 msec. The last change was further complicated by the presence of the fixation field in Seq a between S_1 and S_2. E2 showed an orderly progression of temporal intervals in 50 msec steps with one 100 msec step and a constant S_1 and S_2 on time of 100 msec. That continuous flow of information apparently enabled Ss to process stimuli in an integral manner through their identity processor and to decrease processing times in the serial processor. E1 set up a task that required a dimensional analysis, thus slowing down the identity processor to a point where it was slower than the serial processor.

The combined data from the two experiments generated a model of the flow of information that appeared to occur within the experimental situation. The proposed model is in no way intended to represent the entire scope of human-information-processing. Indeed, the abrupt and dramatic shift in processing strategies from E1 to E2 represented the extreme flexibility of the human information-processing system.

AN INFORMATION-PROCESSING MODEL OF DISCRIMINATION

1. The transduction of physical energy into neuronal firing is termed coding. Coding is serial from stimulus to stimulus and may also proceed dimension by dimension within a stimulus or in an integral manner depending on the task demands. If there is heightened discriminability of the stimulus the coding proceeds in a faster manner than if the stimulus is an uncertain stimulus. The coding transforms the visual input into the form of the icon.
2. The characteristics of the icon that concern this model have only to do with discrimination. However, the icon has many properties (for a review see Decker, 1972). The iconic duration remains clear for comparison purposes up to 50 msec after the offset of the stimulus. After the 50 msec the icon begins to gradually decay. After 200 msec it has decayed to the point where it begins to interfere with the comparison process.
3. The comparison mechanism has two sub-mechanisms: the identity reporter and a serial processor which proceed in parallel with each other. The identity reporter may process in a serial or

parallel/exhaustive/constant fashion or in an integrality fashion. The identity reporter is responsible for any judgments of "Same." When processing as an integrality mechanism the identity reporter is faster than the serial processor but when the identity reporter is processing as a serial-parallel/exhaustive/constant mechanism it is slower than the serial processor. The task demands determine the processing strategy adopted by the identity reporter.

The serial processor proceeds in a serial/self-terminating/constant manner and is responsible for any judgments of "Different." The speed of this mechanism is determined by the task demands and practice. However, the basic processing strategy of the serial processor does not change.

Both mechanisms may process faster depending on practice and task demands but the identity reporter may also change processing strategies depending on the task demands.

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