On the role of array structure in the simultaneous matching task: a stages of processing analysis

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On the role of array structure in the simultaneous matching task:
A stages of processing analysis

by

John Robert Millsapugh

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ABSTRACT

Five experiments investigated the role of array structure in the simultaneous matching task. Letter pairs were presented in either adjacent arrays (e.g. A A) or offset arrays (e.g. A A) and subjects compared the letters to determine whether they were the "same" or "different". When array type was varied randomly from trial to trial, it greatly affected the relative speeds of "same" and "different" responses. In Experiments 3, 4, and 5 the additive factors method was employed in conjunction with the "stage-analytic" information processing approach in an attempt to pinpoint the "stage" of processing responsible for the observed effect. The results favor a comparison stage locus for the effects of array type on "same" and "different" judgments. It seems that subjects can employ array structure as an indicator of "sameness" or "difference". This "sameness" or "difference" is based upon the degree to which elements are part of the same organized whole. The findings favor a "one process multi-stage" theoretical model of "same-different" judgments in which "same" and "different" responses are conceived to be mutually exclusive outcomes of a single comparison mechanism. An explanation for occasions of "fast-same" responses is advanced which focuses on the role played by irrelevant variables in this comparison process.
INTRODUCTION AND LITERATURE REVIEW

One of the most fundamental human intellectual capacities is the ability to distinguish between "sameness" and "difference". Presented with two elements, people can readily and reliably compare them along one or more dimensions in order to determine whether both are the same or whether they differ in some way. Without this ability, adaptive behavior as we know it would not be possible since organisms could neither discriminate between different stimulus events or circumstances nor generalize across those which are similar or functionally equivalent. It is not surprising, then, that many psychologists have placed a high premium on understanding the psychological processes responsible for judgments of "sameness" and "difference".

In what has come to be known as the "same-different" paradigm, investigators have devised and employed a methodological technique designed to permit a scientific assessment of the psychological processes at issue. By precisely measuring the time it takes a subject to decide that two or more elements are the "same" or "different" (i.e. by recording response latency), an observable and quantifiable measure is provided which may be used to make and test inferences
about the character of the unobservable mental process(es). By systematically manipulating any of several relevant variables such as the type, similarity, or number of elements to be compared, and observing their independent and interactive effects on response latency, hypotheses about the nature of the underlying comparison process(es) may be empirically tested. To this end literally hundreds of "same-different" studies have been conducted during the past decade, each hoping to shed some light on this intriguing issue.

A "Fast-Same" Phenomenon

Of the many functional relationships uncovered by "same-different" investigators, the one that has attracted the greatest attention is the relationship between the type of response (i.e. "same" vs. "different") and the speed of response (response latency). When multidimensional stimuli such as letters, digits, or geometric forms must be compared, response latencies are typically shorter (faster) for "same" responses than for "different" responses. This "fast-same" response is difficult to understand since, presumably, a subject need only discover one differing aspect in order to know that two elements differ whereas determining that elements are identical would require an inspection of all stimulus dimensions in order to be sure that none differ. Logically, then, there seems to be no basis for expecting faster "same" than "different" responses. Indeed, the reverse relationship would seem a more likely outcome.
Why, then, are "same" responses typically faster than "different" responses? What is the nature of the underlying psychological process(es)? Can a testable theoretical model be formulated which satisfactorily accounts for the "fast-same" phenomenon? These questions have prompted a host of investigators to launch a theoretical and empirical foray on the "same-different" problem which is still in progress today. Several different and conceptually distinct explanations for the "fast-same" response have been offered, each based on some form of empirical substantiation. Unfortunately, however, the great wealth of available data does not argue convincingly for any particular theoretical model and the "fast-same" response remains somewhat of an enigma. Let us now turn to a brief consideration of some of the more influential theoretical models.

Major "Same-Different" Theoretical Models

Basically, "same-different" theoretical models may be classified into two conceptually distinct categories; those which postulate separate mechanisms for the mediation of "same" and "different" judgments ("two process" models) and those attributing both types of judgments to a single underlying process ("one process" models). In this section we will consider the major prototypes of each category.

"Two process" models

The two most influential "two process" models of "same-different" judgments are those offered by Bamber (1969) and by Tversky (1969).
While both models ascribe "same" and "different" judgments to separate processes, they differ in the way they attempt to account for the "fast-same" response.

Bamber (1969) postulated the existence of (1) an "analytic" processor which is responsible for detecting differences between elements and (2) an "identity reporter" which checks for element identity. While the analytic processor looks for differences by considering each stimulus dimension independently, the identity reporter checks for "sameness" in a template-matching fashion, wherein stimulus dimensions are not considered individually but, rather, in concert. This conceptualization is analogous to the attempts of a young child to insert a wooden block of a particular shape into an opening with the identical shape. When a "fit" is found, identity is indicated. The child then knows that the two shapes are the "same" perhaps without ever having considered the individual subcomponents of the overall shape. The identity reporter is conceived to operate in a similar fashion by signaling when a "fit" between elements is found. Bamber attributes the typically found "fast-same" response to a natural speed advantage for the identity reporter resulting from its qualitatively different mode of comparison. "Different" responses are usually slower because they must often await the results of several independent tests along different stimulus dimensions.

A "two process" model similar to the one offered by Bamber is proposed by Tversky (1969). Where Bamber's analytic processor and identity reporter operate simultaneously however, the two processes
identified by Tversky operate successively, with the onset of the second process contingent on the outcome of the first. A template-matching mechanism first checks for possible "sameness" and, if successful, will result in a "same" response. If, however, "sameness" is not indicated, a second processor begins a "rechecking" process in order to discern the nature of any possible differences. The speed advantage for "same" responses then, is due to the fixed temporal order of the two processors; "same" responses can often be made immediately during the first stage of the comparison process whereas "different" responses are dependent on a second, later stage.

Supportive evidence for "two process" conceptualizations of "same-different" judgments comes from studies demonstrating differential effects of the same stimulus variable on "same" and "different" judgments. Beller (1970), for example, showed that increasing the number of elements to be compared systematically increased "different" response latencies but had no effect on "same" response latencies. "Different" response latencies have also been shown to be more sensitive than "same" responses to the number of stimulus dimensions relevant for the comparison task (Hawkins, 1969) and to the relative height of irrelevant brackets surrounding the two letters of a simultaneously presented pair (Krueger, 1973). Egeth and Blecker (1971) presented upright and inverted letter pairs to subjects and found that inversion slowed "same" responses but had no effect on the speed of "different" responses. "Two process" proponents argue that results such as these cannot be handled by a "one process" model since if both
"same" and "different" judgments are mediated by the same comparison mechanism, any variable which affects that mechanism should have an impact on both types of judgments.

Many investigators, however, have not been convinced by such arguments. While specific criticisms have been levied at one or both of the "two process" models mentioned here, the critics share a general dissatisfaction with the very logic (or lack thereof) of the "two process" approach. Postulating two mechanisms to look for "sameness" and "difference" is somewhat comparable to flipping two coins, one to look for heads and one to look for tails. It seems more reasonable to think of "sameness" and "difference" as mutually exclusive outcomes of one comparison process.

A "one process" model

Despite widespread dissatisfaction with "two process" accounts of "same-different" judgments, to date, only one viable "one process" account has been offered. From this view the commonly found "fast same" response may be explained by referring to the concept of "priming" (Posner and Boies, 1971). Having encoded one member of a pair of stimulus elements, a subject may be set or "primed" to see that particular element again. Thus, when the second element is the same as the first, processing is facilitated and proceeds fairly rapidly. When the second element is different from the first, however, no such processing advantage exists and therefore "different" judgments will take somewhat longer than "same" judgments.
In support of the priming model, Beller (1971) found that presenting a third, priming letter two seconds before a pair of simultaneously presented letters speeded the comparison process significantly on "same" trials (when both letters matched the prime as well as each other) and to a lesser extent on "different" trials (when one of the pair matched the prime). Additional support for priming comes from a study by Posner and Boies (1971). These investigators found that presenting elements successively, separated by 500 milliseconds, augmented the speed advantage for "same" responses compared to the simultaneous presentation case. This would seem to suggest that the half-second interval between elements allows time for the first element to be more fully encoded thus enhancing the priming effect when the second element is presented.

There is, then, some experimental support for the priming concept and it therefore must be considered as a viable explanation for the "fast-same" phenomenon from a "one process" theoretical perspective. The idea is not without problems however. For one thing the priming concept is rather vague. What exactly does it mean to say that a particular element has been primed? Is the facilitation observed due to a more rapid stimulus registration (encoding) or perhaps simply to a bias to respond to the next input in a similar way? Before we can thoroughly assess the explanatory power of the priming concept its specific characteristics must be more explicitly stated. Another major problem for the priming hypothesis arises when
one considers studies which have found faster "different" responses than "same" responses (e.g. Bindra, Williams, and Wise, 1965; Nickerson, 1972). While it seems reasonable to expect to find conditions where priming fails, resulting in no difference between the speed of "same" and "different" responses, there is simply no way the priming concept can account for occasions of faster "different" responses. Finally, it should be noted that while priming may provide a reasonable account of the "fast-same" response when elements are presented successively, it is much less convincing as an explanation when elements are presented simultaneously. For priming to occur in this case, the rather untenable assumption must be made that elements are encoded serially. In fact, there is much evidence that elements are encoded in a parallel fashion (e.g. Estes, 1972, Gardner, 1973).

In general, then, it seems that the issue of "same-different" judgments or, more specifically, the "fast-same" response, remains unresolved. Several different theoretical explanations have been formulated but all have been shown to be subject to serious logical or empirical criticism. What appears to be called for is a more systematic investigation of the particular stimulus variables and task conditions which affect "same-different" judgments. The experiments to be proposed here focus on one factor which may have an important bearing on "same-different" outcomes when elements are presented simultaneously; specifically, the factor of element spatial organization.
Spatial Organization and Visual Information Processing

When two or more visual elements are presented at the same time their combination results in the formation of an element array. What is particularly interesting about element arrays is that they have properties above and beyond those which may characterize their constituent elements. These properties owe their character not to the features of individual elements but rather to the elements' spatial interrelationships. The same set of elements may be used to form any number of different types of element arrays depending only on how those elements are spatially arranged. The Gestalt psychologists were the first to officially recognize the importance of such factors in visual perception. They formulated a set of organizational principles designed to describe how the spatial arrangement or organization of elements influences the perception of the larger array or "whole" (see Kohler, 1947). The Gestalt principle of "proximity", for example, recognizes a direct relationship between the tendency to perceive elements as members of the same "group" and their relative proximity. Through its demonstrations of the importance of the relations between elements, Gestalt psychology has made a valuable contribution to the study of visual information processing.
On the Role of Pattern "Goodness"

One of the more interesting and important Gestalt principles was the "Law of Pragnanz" (see Koffka, 1935). According to this principle certain figures, forms, or patterns are particularly "good" in that they possess a highly organized structure which allows them to be perceived more readily. A square, for example, is a very "good" figure whereas a trapezoid is not so "good". Unfortunately, the Gestalt psychologists' definition of figural "goodness" was less than rigorous. Whether or not a particular form or pattern was considered to be more or less "good" was dependent upon the subjective assessment of the observer. Not until Garner and Clement (1963) provided an operational criterion for determining pattern "goodness" did the concept become both respectable and amenable to experimental investigation. These authors found that the rated "goodness" of patterns formed by placing dots in five of the nine cells of an imaginary 3 X 3 matrix was inversely related to the size of a subset of patterns which could be produced by rotating a pattern in 90° steps and/or reflecting it along its vertical, horizontal, or diagonal axis. Patterns which produced small subsets in this way were the ones that were rated high in "goodness"; those with the largest subsets were rated lowest in "goodness". Using subset size as an operational criterion, it becomes possible to determine the relative "goodness" of any particular dot pattern.
Several studies have used the Garner and Clement type dot patterns to assess the potential role of pattern "goodness" in visual information processing. Clement and Varnadoe (1967) had subjects sort through decks of cards containing one of two alternative patterns as rapidly as possible. They found that sorting time was fastest when the two patterns to be discriminated were both "good" (subset size = 1). Somewhat slower was a condition requiring the discrimination between patterns of subset sizes 1 and 4. Still slower was the case in which the two patterns had subset sizes of 1 and 8 respectively. The authors concluded that the speed of sorting was affected by the time needed to encode specific patterns and that encoding time was faster for patterns with greater pattern "goodness". A similar conclusion was reached by Garner and Sutliff (1974) who used a two-choice visual discrimination task. In this task one of two patterns was presented on each trial and the subject had to indicate which of the pair was shown by pressing the appropriate response key. Response latencies were faster to "good" patterns than to "poor" patterns.

Another experimental task which has revealed processing consequences of pattern "goodness" is that of pattern reproduction. Attneave (1955) found that reproduction accuracy immediately following dot pattern presentation decreased with the size of the pattern (number of dots) and was poorer for random patterns (low in pattern "goodness") than for symmetrical patterns (relatively "good"). A
more recent study by Bell and Handel (1976) used a backward masking paradigm wherein dot patterns were followed at variable intervals by a visual masking stimulus designed to disallow further processing of the pattern stimulus. These investigators found that "good" patterns were reproduced more accurately than "poor" patterns when the mask came soon after the pattern. The difference between "good" and "poor" pattern reproduction accuracy disappeared at pattern-mask interstimulus intervals long enough to preclude masking, leading the authors to suggest that the advantage for "good" patterns was an encoding one rather than a memorial one. The results of several studies, then, combine to suggest that pattern "goodness" can facilitate performance in certain experimental tasks.

It seems apparent that the arrangement of parts can influence the perception of the whole. A somewhat different question is whether the arrangement of parts can influence the perception of the parts. More specifically, what are the consequences of pattern "goodness" for the elements that comprise the patterns? What little evidence is available on this question suggests that pattern "goodness", in this case, is somewhat less than beneficial. Pomerantz and Garner (1973) had subjects sort through decks of cards bearing five-element patterns to separate those containing a predesignated "target" element from those without a target. They found that sorting time depended on the number of elements present but not on the pattern "goodness" of the element arrays. Sorting time was equal for both
"good" and "poor" element arrays. Banks and Prinzmetal (1976) used the closely related forced-choice detection task and found that detection performance was impaired when the target was grouped together with distractors to form a "good" element array. It seems, then, that the presence of pattern "goodness" may actually be detrimental to performance when the task required of the subject demands consideration of individual elements within the pattern.

Effects of Pattern "Goodness" on "Same-Different" Judgments

A recent study by Millspaugh (1978) has demonstrated interesting effects of array pattern "goodness" on simultaneous "same-different" judgments. In that study, multielement arrays of nine letters each were arranged to form either "good" or "poor" patterns. Subjects were asked to determine whether all of the letters were the "same" or if at least one was "different" from the rest. The "same-different" task, of course, is one that requires a consideration and comparison of individual elements. How those elements are arranged is an irrelevant source of information. Nevertheless, the results of that study showed very clear effects of pattern "goodness" on matching performance. Specifically, whether the elements were presented in "good" or "poor" element arrays had a dramatic impact on the relationship between the speed of "same" and "different" responses. When the letters were presented in "good" arrays, "same" responses were significantly faster than "different" responses. For letters
presented in "poor" arrays, however, "different" responses were slightly (but not significantly) faster.

This interaction between array "goodness" and response type suggests that "same-different" performance can be greatly affected by a stimulus variable which would seem to be totally irrelevant to the task at hand. Such a finding has important implications for the general issue of simultaneous "same-different" judgments. Why should array structure have such an effect on matching performance? Which theoretical model, if any, would predict this outcome? Answers to these questions could provide a better understanding of the nature of the process(es) underlying judgments of "sameness" and "difference".

Focus of the Present Research

The research to be reported herein consists of five independent but related experiments designed to provide a better understanding of the role played by array structure (or pattern "goodness") in the simultaneous matching task. The first experiment is essentially an extension of the Millspaugh (1978) findings with multielement arrays to the more typical "same-different" task in which only two letters are present in an array. The remaining experiments attempt to provide specific answers about how array structure affects simultaneous matching performance.
EXPERIMENT 1

As has been noted, the primary effect of pattern "goodness" found in the Millspaugh (1978) study was on the relationship between the speed of "same" and "different" responses. When letters were presented in "good" arrays, "same" responses were faster than "different" responses. This relationship was reversed when letters were presented in "poor" arrays. This pattern of results implicates array pattern "goodness" as a potentially important factor in the production of "fast-same" responses in simultaneous matching. Most studies investigating simultaneous matching have presented for comparison only two elements at a time. The two elements have typically been arranged to be horizontally (or sometimes vertically) adjacent. Since the elements to be compared are usually approximately equal in size (e.g. the set of capital letters), presenting them side by side results in the formation of a roughly rectangular, or even square, element array. Adjacent elements, then, form somewhat "good" arrays. Might this unwitting employment of adjacent element arrays (i.e. good patterns) be responsible for the "fast-same" phenomenon found with simultaneously presented letter pairs? The first experiment was designed to explore this possibility. Letter pairs were presented in either the commonly used adjacent array (e.g. H H) or in a less organized offset array (e.g. H ^). Relatively speaking, adjacent arrays are "good" patterns whereas offset arrays
are "poor" patterns, since the operations of rotation and reflection produce respective subsets of sizes 2 and 4. If the commonly found advantage for "same" responses is indeed attributable to the "goodness" inherent in an adjacent array, then arranging letters to form a less "good" array should nullify that advantage. If adjacent and offset arrays act like the larger multielement "good" and "poor" patterns, we should expect an interaction between array type and response type similar to the one found with the larger element arrays.

Method

Subjects
Sixteen volunteer undergraduates from introductory psychology classes at Iowa State University served as subjects for Experiment 1. Each subject received course credit for participating in the experiment.

Stimuli
The stimuli were pairs of letters typewritten on Mylar and mounted for presentation as slides. Individual letters used were T, H, M, R, C, L, V, and J and these were formed using IBM Prestige Pica font. All the possible pairwise combinations of letters were used and each subject received a total of 224 stimulus pairs. Half of these trials presented two letters which were the same
(fourteen exemplars of each of the eight possible "same" pairs) and half presented two different letters. "Different" pairs consisted of all the possible combinations of the eight letters, presented once in each order (e.g. RJ and JR). One half of the total 224 trials presented adjacent arrays and the other half offset arrays. Array type was varied randomly from trial to trial. All of the combinations of different letters and "same" pairs occurred equally often in each type of array. The total 224 trials were presented in 4 blocks of 56 trials each and block order was counterbalanced in a Latin-square.

Apparatus and procedure

Stimuli were presented on a black glass rear projection screen using a Carousel slide projector equipped with a tachistoscopic shutter. Letter pairs subtended approximately 2° of horizontal visual angle from a viewing distance of two meters. On each trial an auditory warning signal alerted the subject to fixate the center of the screen. The shutter then opened, illuminating the screen with a stimulus pair. Subjects compared the letters and responded "same" or "different" by depressing one of two appropriately marked response keys. Half of the subjects used their dominant hand to respond "same" and their opposite hand to respond "different". Hand assignments were reversed for the other half of the subjects. Instructions to subjects emphasized "speed but not at the expense of accuracy."
Each stimulus slide was presented for a total of two seconds. At stimulus onset a Lafayette digital clock-counter (Model 54417-A) was triggered and the subject stopped the clock by depressing either response key. The experimenter then recorded the response latency and, after a few seconds, initiated the next trial.

Design

The design was a 2 X 2 X 4 balanced factorial with repeated measures on the factors of response type, array type, and practice block. Response latencies for correct responses for the various combinations of factor levels were evaluated with an analysis of variance.

Results and Discussion

Mean response latencies obtained under the various conditions of Experiment 1 are presented in Table 1. The analysis of latencies revealed significant main effects of array type $F(1,15) = 11.0, p < .01$, response type $F(1,15) = 5.60, p < .05$, and practice block $F(3,45) = 13.6, p < .001$. Responses were faster for adjacent arrays than for offset arrays, faster for "same" responses than for "different" responses, and faster in later blocks of trials than in earlier blocks. More importantly, there was a highly significant interaction between array type and response type, $F(1,15) = 39.6, p < .0001$. This inter-
Table 1. Mean response latencies and error rates obtained under the various conditions of Experiment 1

<table>
<thead>
<tr>
<th>Array type</th>
<th>Adjacent</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response type</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>Mean response latency$^a$</td>
<td>482</td>
<td>521</td>
</tr>
<tr>
<td>Error rates</td>
<td>.023</td>
<td>.058</td>
</tr>
</tbody>
</table>

$^a$Response latencies in milliseconds.

action is shown in Figure 1. As can be seen from Figure 1, "same" responses were faster than "different" responses only when letters were presented in adjacent arrays ($p < .05$ via Newman-Keuls comparison). When letters were presented in offset arrays, "different" responses were actually about 15 milliseconds faster than "same" responses (not a significant difference). This interaction between array type and response type is very similar to the one obtained using the larger, multielement arrays (Millspaugh, 1978). Again we see that the relationship between the speed of "same" and "different" responses is dramatically affected by the spatial arrangement of the elements being compared. When elements are arranged to form an organized whole (a "good" or adjacent array), "same" responses are much faster than "different" responses. When elements form less organized patterns ("poor" or offset arrays), this "fast same" phenomenon disappears.
Figure 1. Mean response latencies as functions of array type and response type from Experiment 1.
The overall error rate for Experiment 1 was .036 and the error rates obtained under the various combinations of array type and response type are presented in Table 1. These error rates were compared using Sign tests. False-"different" responses to offset arrays (.049) and false-"same" responses to adjacent arrays (.058) were significantly more common than either false-"different" responses to adjacent arrays (.023) or false-"same" responses to offset arrays (.013) at the .05 level of confidence.

The results of Experiment 1 present impressive evidence for the importance of the variable of element spatial arrangement (or array structure) in the two-element simultaneous matching task. It appears that the so called "fast same" phenomenon occurs only when letters are presented in adjacent (organized) arrays. This advantage for "same" responses quickly disappears when offset (less organized) arrays are used. The implications of this finding for theoretical interpretations of "same-different" judgments are notable. Previous theoretical explanations of matching performance have been predicated on the results of studies which have employed only adjacent, or organized arrays. Without exception these explanations have ignored element spatial arrangement as a factor of any importance. The present finding suggests that this factor can no longer be ignored. Indeed it may even hold the key to a better understanding of simultaneous matching performance.
EXPERIMENT 2

Before concluding that the "fast-same" phenomenon found with simultaneously presented elements is tied to the use of adjacent element arrays, it should be noted that Experiment 1 is not really directly comparable with previous studies of simultaneous matching. The random, trial to trial variation of array type introduces a factor not present in studies which have used only adjacent arrays, namely, the uncertainty on the part of the subject about which type of array to expect on any particular trial. Before accepting the argument that "fast-same" responses result from the use of adjacent element arrays, it will be necessary to demonstrate the same interaction between array type and response type with the uncertainty factor removed. To this end a second experiment was conducted in which adjacent and offset arrays were presented in separate blocks of trials. With this procedure a subject will always know which type of array to expect on a given trial. Demonstration of the array type by response type interaction using blocked presentation of array type would represent a convincing argument for the importance of array structure in the production of "fast-same" responses.

Method

Subjects

Eight additional volunteer undergraduates from psychology classes at Iowa State University served as subjects for Experiment 2.
Stimuli

The stimuli for Experiment 2 were exactly the same as those used in Experiment 1.

Apparatus and procedure

The equipment and procedure were essentially identical to those employed in Experiment 1. The only difference between the two experiments was that, in Experiment 2, the total 224 trials were divided into two blocks of 112 trials each which corresponded to the two types of arrays used. One half of the subjects received adjacent pair trials first and offset pair trials second. This order was reversed for the other half of the subjects.

Design

The design was a simple 2 X 2 balanced factorial with repeated measures on the factors of array type and response type.

Results and Discussion

Mean response latencies obtained under the various conditions of Experiment 2 are presented in Table 2. The analysis of variance performed on response latencies yielded only one marginally significant effect. Responses to adjacent arrays were slightly faster than responses to offset arrays, F(1,7) = 4.74, p < .05. Most notably there was no hint of the former interaction between array type and response type, F(1,7) = 0.14, ns. The relationship between type of array and type of response is depicted graphically in Figure 2. The four means
Table 2. Mean response latencies and error rates obtained under the various conditions of Experiment 2.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Array type</th>
<th>Adjacent</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same</td>
<td>Different</td>
<td>Same</td>
</tr>
<tr>
<td>Mean response latency&lt;sup&gt;a&lt;/sup&gt;</td>
<td>471</td>
<td>485</td>
<td>491</td>
</tr>
<tr>
<td>Error rate</td>
<td>.042</td>
<td>.054</td>
<td>.045</td>
</tr>
</tbody>
</table>

<sup>a</sup>Response latencies in milliseconds.

shown in the graph were compared via Newman-Keuls comparisons. "Same" responses were found to be faster than "different" responses for both adjacent and offset arrays (p < .05). The overall error rate for Experiment 2 was .049 and the error rates for individual array type by response type conditions were compared with Sign tests. No significant differences were found between the error rates shown in Table 2.

It is clear from the results of Experiment 2 that array type, when varied in a blocked presentation design, has absolutely no effect on the relative speeds of "same" and "different" responses. When the subject knows which type of array to expect on each trial, "same" responses were slightly faster than "different" responses regardless of the type of array used. The idea that the "fast-same" phenomenon found in previous studies may be attributed to the use of adjacent
Figure 2. Mean response latencies as functions of array type and response type from Experiment 2.
element arrays is not supported by the data. When array type is held constant within a block of trials it makes no difference whether arrays are adjacent or offset; a "fast-same" phenomenon results in both cases.
DISCUSSION OF EXPERIMENTS 1 AND 2

Although the first two experiments do not provide a simple explanation of "fast-same" responses, they do raise some intriguing questions about the role of array structure in simultaneous matching. Exactly why does array type have such a dramatic impact on the relative speeds of "same" and "different" responses when varied in a mixed design? Why does this effect disappear when a blocked design is used? Furthermore, what is the nature of the underlying psychological process(es) which permit such a pattern of results? Can a "one process" theoretical model account for the findings or must a "two process" interpretation be invoked? Definitive answers to questions such as these would constitute a significant advance in our understanding of both simultaneous matching performance and the dynamics of perceptual organization.

How one goes about answering the above questions depends largely on one's conceptual approach to the problem. The approach taken by the author is the "stage-analytic" information processing approach. The central assumption of this approach is that there exist separate and functionally independent "stages" of processing which operate on stimulus input in a fixed serial order. The basic idea is that total response latency is an additive function of the durations of the successive and independent stages of processing which intervene between stimulus input and response output. The duration of any
particular processing stage is dependent only on its input and the levels of the variables which affect it, not on the duration of any preceding or following stage.

Determining the number, function, and temporal order of the stages involved in the performance of any particular task is primarily a matter of making some logical assumptions about what the subject must do in order to perform the task successfully. The simultaneous matching task, for example, would seem to require at least three distinct stages of processing. At stimulus onset the subject must, first of all, transduce the information available in the optical array into some suitable form of internal psychological representation. In other words, the subject must **encode** the visual stimulus pair. Following the encoding process, the subject must then **compare** the encoded representations of the visual elements. This, of course, is a distinctly different operation than stimulus encoding and hence can be regarded as a separate stage of processing, namely a **comparison** stage. Finally, the subject must decide upon a response; in this case either "same" or "different". This **response selection** process is the third and final stage of processing necessary for the subject to successfully complete the matching task.

We have, at this point, a three-stage theoretical model of the cognitive processes involved in simultaneous matching. We arrived at this model through a logical analysis of what would seem to be required in order to perform the task. This analysis, however, rests
on several assumptions, the most important being the very existence of separate processing stages. What is clearly needed is some way of assessing the validity of the stages-of-processing conceptualization. With the "additive factors" method (Sternberg, 1969) we have the tool for this purpose.

Application of the additive factors method is restricted to well defined experimental tasks where response latency is the dependent measure and where several independent variables are employed. Its use is predicated on the fact that if there really are separate stages of processing which perform different operations on stimulus input, then it should be possible to isolate variables which affect total response latency by speeding or slowing down particular processing stages. For example, one variable may speed or slow responding by enhancing or disturbing the encoding process. Another variable may have its effect by speeding or slowing the comparison process. Since total response latency is merely the sum of the durations of the individual processing stages, variables which affect performance at different stages of processing should have additive effects on response latency. Conversely, variables which interact, that is combine to influence response latency in a nonadditive fashion, may be assumed to affect at least one processing stage in common. By varying several factors in the same experiment and analyzing the results in order to find which pairs of factors do, or do not, have additive effects on response latency, it is possible to deduce the
number of separate stages involved in the performance of the task. Further, from the patterns of the interactions, it becomes possible to define the function of the processing which occurs at a particular stage. By using additive factors logic in conjunction with multifactor experiments, the adequacy of the processing stage conceptualization may be put to test.

A recent paper by Shwartz, Pomerantz, and Egeth (1977) nicely illustrates the utility and power of the additive factors method. These authors employed a simple two-choice discrimination task, asking subjects to determine as rapidly as possible which of two possible stimuli was present on a given trial by hitting one of two response keys. Stimulus intensity, stimulus similarity, and stimulus-response compatibility were used as independent variables and their effects on response latency were assessed. Stimulus-response compatibility was varied in one experiment by asking the subject to press either the response key toward which a stimulus arrow pointed or the opposite key. The results showed the effects of the three independent variables to be additive in their effects on response latency. The authors concluded that stimulus intensity, stimulus similarity, and stimulus-response compatibility operate at three distinct stages of processing. Stimulus intensity affects the rate or efficiency of stimulus encoding. A dim or degraded stimulus pattern takes longer to encode than a brighter, more clear pattern. Stimulus similarity, on the other hand, would logically affect the comparison
process. Stimulus elements which are highly similar necessitate a more careful, or slower comparison of the elements presented with their stored, memorial representations than do nonconfusable, or distinct elements. Finally, stimulus-response compatibility would seem to affect the ease of the response selection process. Stimulus-response pairs which are highly compatible would facilitate the selection of a response.

As was noted earlier, the simultaneous matching task would seem to require the same three stages of processing. If so, the task should be amenable to an additive factors analysis. By varying several factors in the same experiment we should be able to learn more about the role of certain variables in the matching task. For present purposes, we are particularly concerned about the role of array structure. We know from the first two experiments that under the right circumstances, array structure can have a dramatic impact on the relative speeds of "same" and "different" responses. Under other circumstances, this effect disappears. How does array structure affect processing? Understanding how array structure affects matching performance would be greatly facilitated if we knew where in processing it operates. At which stage does array structure have its differential effects on "same" and "different" responding? What is clearly needed is experimentation designed to isolate the locus of the array type effect on simultaneous matching. Experiments 3 and 4 were designed with this purpose in mind.
EXPERIMENT 3

One possible site for the effect of array type on "same" and "different" responding is the response selection stage of processing. Perhaps, for example, the presence of an adjacent array facilitates the selection of a "same" response while offset arrays benefit the selection of "different" responses. An explanation of this sort might conceivably account for the interaction between array type and response type found in Experiment 1. Evidence for such a claim would be established if the effect were found to be modified by another variable known to affect the response selection process. One variable which would seem to affect this process is the relative probability of occurrence of "same" and "different" trials. Downing (1971) has shown that "same" response latencies are inversely related to the probability of occurrence of "same" pairs in a given block of trials. When "same" response probability was equal to "different" response probability \( p_{\text{same}} = .50 \), "same" responses were faster than "different" responses. When "same" response probability was low \( p_{\text{same}} = .25 \), "same" responses were much slower. Very reasonably, Downing attributed his findings to the subject's relative readiness to select the "same" response as the correct answer. When the probability of occurrence of "same" pairs is low, subjects are less ready to select that response and indeed are probably better prepared to select the "different" response.
In Experiment 3 the probability of occurrence of "same" pairs is varied across different groups of subjects. For some subjects, "same" pairs are presented three times more frequently than "different" pairs \(p_{\text{same}} = .75\). For other subjects "same" pairs occur on half of their trials \(p_{\text{same}} = .50\) and for still others "same" pairs are presented only on one fourth of the total trials \(p_{\text{same}} = .25\). As in the Downing study, we should expect "same" response latencies to be inversely related to the relative probability of occurrence of "same" pairs. In other words, we should expect to find a strong two-way interaction between response probability and response type.

A question of greater interest is whether varying response probability can alter the effects of array type on response type found in Experiment 1. Experiment 3 incorporates the response probability variable with a mixed presentation of array type as was employed in Experiment 1. A significant three-way interaction between array type, response type, and response probability would indicate that the response selection stage is the site at which array type has its differential effects on "same" and "different" responses. If, however, the array type by response type interaction is unaffected by the level of response probability (i.e. no three-way interaction occurs), then there will be evidence that the effect is localized at some stage in the processing sequence other than the response selection stage.

Also incorporated in Experiment 3 are two levels of letter confusability. The relative confusability of letters being compared is a factor which should affect the difficulty or speed of the comparison
process. When the set of letters the subject must work with are highly similar, a more prolonged or careful comparison process must be undertaken before the subject may select either the "same" or "different" response with a reasonable degree of certainty. We should expect to find then, a sizable main effect of letter confusability. More importantly, the addition of the letter confusability factor will permit an assessment of the comparison stage as the possible site for the interaction between array type and response type. A comparison stage locus would be indicated by a three-way interaction between array type, response type, and letter confusability. The absence of this interaction would permit the elimination of the comparison stage as a likely candidate.

With the employment of the response probability and letter confusability factors, it will be possible to examine both the comparison and response selection stages for their potential involvement in the interaction between array type and response type. If neither variable is found to influence this interaction, an encoding stage locus would be suggested. The use of these two variables will also permit a test of the assumptions we have made in adopting the stages-of-processing conceptual approach. Of critical importance if this approach is to remain a viable one, is that the response probability and letter confusability factors be additive in their effects on response latency. If letter comparison and response selection are truly temporally discrete operations, and if response probability affects response selection while letter confusability affects letter comparison, then the
effects of these two variables on response latency should not be expected to interact.

Method

Subjects

Twenty-four undergraduate students from psychology classes at Iowa State University served as subjects for Experiment 3.

Stimuli

As in Experiments 1 and 2, letter pairs arranged to form either adjacent or offset arrays were used as stimuli. These letter pairs, however, were formed from a different set of letters in order to include the variable of letter confusability. Stimulus pairs for the nonconfusable letter condition were formed from the letters R, V, I, and C. Pairs for the confusable letter condition were comprised using the letters R, P, B, and F.

Apparatus and procedure

The equipment and basic experimental procedure were the same as those employed in Experiments 1 and 2. Confusable and nonconfusable letter pairs were presented in separate sessions on consecutive days. Half of the subjects received confusable letter pairs on the first day while the other half received nonconfusable pairs on the first day. Within a session, each subject received a total of 192 trials presented in two blocks of 96 trials each. Block presentation order was reversed for half of the subjects. Eight subjects were randomly assigned to
each of three response probability conditions. In the $p_{\text{same}} = .25$ condition, only one out of every four trials presented contained two letters which were the same. Subjects in the $p_{\text{same}} = .50$ condition received equal numbers of "same" and "different" pairs and those in the $p_{\text{same}} = .75$ condition were presented "same" pairs on three fourths of their trials. The total number of trials per subject was held constant across the three response probability conditions, with each subject receiving 192 trials in each session. The ratios of "same" to "different" pairs in the $p_{\text{same}} = .25$, $p_{\text{same}} = .50$, and $p_{\text{same}} = .75$ conditions were, respectively, 48:144, 96:96, and 144:48. Half of the trials in each condition presented adjacent pairs and the other half offset pairs.

**Design**

The design was a $2 \times 2 \times 2 \times 2 \times 3$ factorial with repeated measures on the factors of array type, response type, letter confusability, and practice block. Response probability was a between-subjects variable.

**Results and Discussion**

Mean response latencies and error rates for Experiment 3 are presented in Table 3. The analysis of response latencies revealed several significant main effects. "Same" responses were made faster than "different" responses, $F(2,21)= 13.9, p< .001$, and responses to adjacent arrays were faster than responses to offset arrays, $F(1,21)= 27.4, p< .001$. Responses were also faster when nonconfusable letters
Table 3. Response latencies and error rates obtained under the various experimental conditions of Experiment 3.\(^a\)

<table>
<thead>
<tr>
<th>Array type</th>
<th>Adjacent</th>
<th>Offset</th>
<th>Adjacent</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response type</td>
<td>Same</td>
<td>Different</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>Nonconfusable</td>
<td>471 (.042)</td>
<td>463 (.024)</td>
<td>503 (.109)</td>
<td>453 (.021)</td>
</tr>
<tr>
<td>Confusable</td>
<td>514 (.068)</td>
<td>508 (.035)</td>
<td>534 (.130)</td>
<td>500 (.014)</td>
</tr>
<tr>
<td>Combined</td>
<td>492 (.055)</td>
<td>486 (.030)</td>
<td>519 (.120)</td>
<td>477 (.018)</td>
</tr>
</tbody>
</table>

"Same" response probability = .25

| Nonconfusable | 440 (.021) | 467 (.045) | 469 (.094) | 460 (.038) |
| Confusable | 480 (.049) | 514 (.083) | 513 (.132) | 514 (.024) |
| Combined | 460 (.035) | 491 (.064) | 491 (.103) | 487 (.031) |

"Same" response probability = .50

| Nonconfusable | 420 (.009) | 509 (.115) | 455 (.026) | 493 (.068) |
| Confusable | 468 (.009) | 551 (.089) | 503 (.031) | 551 (.052) |
| Combined | 444 (.009) | 530 (.120) | 479 (.029) | 522 (.060) |

\(^a\)Error rates are in parentheses.
were used than when confusable letters were used, $F(1,21) = 28.7$, $p < .001$, and faster in the second block of trials (of each session) than in the first block, $F(1,21) = 24.0$, $p < .001$.

As in Experiment 1, there was a highly significant interaction between array type and response type, $F(1,21) = 40.3$, $p < .001$. This interaction, which is illustrated in Figure 3, is very similar to the one obtained in Experiment 1 and demonstrates the reliability and generalizability of the effect, since it was obtained with a new subject pool and a different set of letters. Newman-Keuls comparisons of the four means involved in the interaction showed that the mean for "same" responses to adjacent arrays was faster than any of the other three means at the .05 level of confidence.

As expected, the relative probability of occurrence of "same" pairs dramatically influenced the relative speed of correct "same" and "different" responses, $F(2,21) = 29.0$, $p < .001$. Mean "same" and "different" responses as functions of "same" response probability are shown in Figure 4. As is apparent from the figure, the relative speed of "same" responding was directly related to the probability of occurrence of "same" pairs. Conversely, the speed of "different" responding was inversely related to this factor. This finding accords nicely with the idea of a separate response selection stage of processing. The selection of a particular response type is facilitated when the response is required frequently.

Also in line with the predictions made by a discrete stage model of processing was the absence of an interaction between response
Figure 3. Mean response latencies as functions of array type and response type from Experiment 3.
Figure 4. Mean response latencies for "same" and "different" responses as functions of the probability of occurrence of "same" pairs.
probability and letter confusability, $F(2,21)= 0.07$, ns. The additive relationship of these two variables is exactly what would be expected if letter confusability affects the comparison process while response probability affects the response selection stage. The results of the third experiment, then, support the three-stage conceptual model of simultaneous matching advanced earlier.

By far the most important finding of Experiment 3 was the total absence of a three-way interaction between response probability, array type, and response type, $F(2,21)= 0.22$, ns. Figure 5 shows the two-way interactions between array type and response type for each level of "same" response probability. As is clearly evident in Figure 5, the effect of array type on "same" and "different" responses was essentially identical for all three levels of response probability. This outcome strongly suggests that the response selection stage is not the site at which array type differentially influences "same" and "different" responses.

Another interesting result of Experiment 3 was a marginally significant three-way interaction between array type, response type, and letter confusability, $F(1,21)= 5.11$, $p < .05$. This interaction is presented graphically in Figure 6. As can be seen from the graph, when letters were presented in adjacent arrays "same" responses averaged about 35 milliseconds faster than "different" responses. This was true for both levels of letter confusability. For offset arrays, however, the speed advantage for "same" responses
Figure 5. Mean response latencies for "same" and "different" responses as functions of array type (A = Adjacent, O = Offset) and the probability of occurrence of "same" pairs from Experiment 3.
Figure 6. Mean response latencies for "same" and "different" responses as functions of array type and letter confusability from Experiment 3.
is eliminated, with this effect being greater for the nonconfusable letter condition than for the confusable letter condition. In fact, this was the case for 18 of the 24 subjects, enough to reach the .01 level of confidence by a Sign test.

The overall error rate for Experiment 3 was .040. With the addition of the response probability and letter confusability factors, there were too many error rates of interest to use Sign tests on all the possible pairs. Instead, error rates were evaluated with an analysis of variance. An interaction between array type and response type, $F(1,21)= 43.8$, $p< .001$, paralleled that found for response latencies. There was also an interaction between response probability and response type, $F(2,21)= 13.5$, $p< .001$, with the frequency of false-"same" responses being directly related to the probability of occurrence of "same" pairs. There was, however, no interaction between array type, response type, and letter confusability as was found with response latencies.

In summary, the most important finding of Experiment 3 was the absence of a three-way interaction between response probability, array type, and response type. The clear implication of this is that the response selection stage may be ruled out as the site for the effect of array type on response type. That the level of letter confusability was found to slightly alter the relationship between array type and response type seems to suggest a possible comparison stage locus for the effect. There are at least two good reasons,
however, for not accepting this conclusion at this point. First, the effect was quite small and, second, the pattern of errors did not parallel the response latency data. Additional evidence will be necessary before we may pinpoint the comparison stage as the stage responsible for the interaction between array type and response type.
EXPERIMENT 4

Experiment 3 explored the possible roles of the response selection and comparison stages in the production of the array type by response type interaction. What is still needed is an assessment of the stimulus encoding stage. Several studies concerned with the processing consequences of array structure have argued for an encoding stage locus for their findings (e.g. Banks & Prinzmetal, 1976; Bell & Handel, 1976; Garner & Sutliff, 1974). The general view shared by these authors is that pattern goodness facilitates stimulus registration or encoding. Perhaps this facilitation is greater for "same" responses than for "different" responses. This might explain why "same" responses are particularly fast to adjacent (good) arrays. Experiment 4 was designed to test this possibility. Two levels of stimulus intensity (dim vs. bright) are employed with the intent of examining the consequences of this factor for the two-way interaction between array type and response type. Since the logical site for the impact of stimulus intensity is the encoding stage, a three-way interaction between stimulus intensity, array type, and response type would implicate the encoding stage as the site at which array type has its differential effects on "same" and "different" responses.

As in Experiment 3, two levels of letter confusability are employed to further test the adequacy of the discrete stage model
of matching. Since stimulus intensity should affect encoding while confusability should affect comparisons, these two variables should have additive effects on response latency (i.e. they should not interact). Varying the level of letter confusability will also permit a further assessment of the comparison stage as a possible site for the array type by response type interaction.

Method

Subjects

Sixteen volunteer undergraduates from psychology classes at Iowa State University served as subjects for Experiment 4.

Stimuli

The stimulus pairs were those used in Experiment 3. Confusable and nonconfusable letter pairs were again presented in separate sessions on consecutive days.

Apparatus and procedure

The equipment and experimental procedure were the same as those employed in the first three experiments. Presentation order of confusable and nonconfusable letters was reversed for half of the subjects. Within a session each subject received 192 trials in two blocks of 96 trials each. Eight of the subjects were presented stimuli at the same level of stimulus intensity used in the first
three experiments ("bright" stimulus intensity). The other eight subjects performed the task under impoverished viewing conditions ("dim" stimulus intensity). To achieve this reduction in stimulus intensity a Kodak neutral density (2.1) filter was placed immediately in front of the projector lens. The filter value was chosen on the basis of pilot data which showed that this value slowed responding significantly.

**Design**

The design was a 2X2X2X2X2 factorial with repeated measures on the factors of array type, response type, letter confusability, and practice block. Stimulus intensity ("bright" versus "dim") was varied between subjects.

**Results and Discussion**

Mean correct response latencies and error rates from Experiment 4 are presented in Table 4. The analysis of variance performed on response latencies revealed the effectiveness of the stimulus intensity factor. Responses were significantly slower in the "dim" condition than in the "bright" condition, $F(1,14)= 39.9, p< .001$. There were also significant main effects of response type, $F(1,14)= 5.97, p< .05$, array type, $F(1,14)= 26.3, p< .001$, letter confusability, $F(1,14)= 46.2, p< .001$, and practice block, $F(1,14)= 9.13, p< .01$. These effects were all in the same direction as their counterparts from Experiment 3.
Table 4. Response latencies and error rates obtained under the various experimental conditions of Experiment 4.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Array type</th>
<th>Adjacent</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response type</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>&quot;Bright&quot; stimulus intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonconfusable</td>
<td>435 (.016)</td>
<td>479 (.068)</td>
</tr>
<tr>
<td>Confusable</td>
<td>477 (.031)</td>
<td>526 (.055)</td>
</tr>
<tr>
<td>Combined</td>
<td>456 (.024)</td>
<td>503 (.062)</td>
</tr>
<tr>
<td>&quot;Dim&quot; stimulus intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonconfusable</td>
<td>508 (.029)</td>
<td>534 (.055)</td>
</tr>
<tr>
<td>Confusable</td>
<td>580 (.049)</td>
<td>603 (.049)</td>
</tr>
<tr>
<td>Combined</td>
<td>544 (.039)</td>
<td>571 (.052)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Error rates are in parentheses.
As predicted there was no interaction between the effects of stimulus intensity and letter confusability, $F(1,14)=2.33$, ns. This finding adds further credence to the claim for separate encoding and comparison stages.

As in Experiments 1 and 3 there was again a significant interaction between array type and response type, $F(1,14)=13.1$, $p<.01$. Beyond this two-way interaction, however, there were also significant three-way interactions between array type, response type, and confusability, $F(1,14)=5.35$, $p<.05$, between array type, response type, and stimulus intensity, $F(1,14)=4.52$, $p<.05$, and between response type, stimulus intensity, and letter confusability, $F(1,14)=7.71$, $p<.05$. More importantly, there was a very strong four-way interaction between array type, response type, letter confusability, and stimulus intensity, $F(1,14)=35.2$, $p<.0001$. This interaction is illustrated in Figure 7. The only other significant effect was the two-way interaction between response type and practice block, $F(1,14)=6.57$, $p<.05$. "Different" response latencies improved with practice to a greater extent than did "same" responses.

In an attempt to better understand the meaning of the four-way interaction shown in Figure 7, data from the "bright" and "dim" stimulus intensity conditions were evaluated in two separate analyses of variance. The analysis for the "bright" condition showed a significant interaction between array type and response type, $F(1,7)=20.3$, $p<.01$. Also significant was the three-way interaction between
Figure 7. Mean response latencies as functions of array type (A = Adjacent, 0 = Offset), response type, stimulus intensity, and letter confusability from Experiment 4.
array type, response type, and letter confusability, $F(1,7)=11.9$, $p<.01$, (see two left-most panels of Figure 7). As is apparent from Figure 7, for offset arrays the speed of "different" responses relative to "same" responses was faster when letters were confusable. Indeed this was the case for seven out of the eight subjects ($p<.01$ by a Sign test). Surprisingly, this three-way interaction differs from its counterpart from Experiment 3 (see Figure 6). There, the array type by response type interaction was stronger when non-confusable letters were used. The reason for this inconsistency is not immediately clear. The matter will be considered in more detail in the final section of the paper.

The analysis performed on the data from the "dim" condition found no interaction between array type and response type, $F(1,7)=0.90$, ns. There was, however, a highly significant three-way interaction between array type, response type, and letter confusability, $F(1,7)=23.5$, $p<.005$, (see two right-most panels of Figure 7). As is clear from the figure, with nonconfusable letters, the obtained array type by response type interaction is very similar to that found in the "bright" conditions. For confusable letters, however, the results are markedly different. Here, the results look similar to those obtained in Experiment 2 where adjacent and offset arrays were presented in separate blocks of trials. "Same" responses appear to be faster than "different" responses for both adjacent and offset arrays. Apparently, when "dim" viewing conditions are paired with confusable
letters, the typical two-way interaction between array type and response type drops out.

Four separate tests of simple interactions were performed on the two-way interactions shown in the four panels of Figure 7. For the bright-confusable $F(1,7) = 105.3$, $p < .001$, the bright-nonconfusable $F(1,7) = 29.0$, $p < .001$, and the dim-nonconfusable $F(1,7) = 22.3$, $p < .001$ conditions these simple interactions were highly significant. For the dim-confusable condition, however, the array type by response type interaction did not reach an acceptable level of statistical significance, $F(1,7) = 4.7$, ns. What Figure 7 suggests visually is confirmed. The array type by response type interaction occurs for all combinations of stimulus intensity and letter confusability except the dim-confusable combination.

The overall error rate for Experiment 4 was .046 and errors occurring under the various experimental conditions were evaluated with an analysis of variance. Errors were more common for confusable letters than for nonconfusable letters, $F(1,14) = 17.4$, $p < .001$. Also significant were the array type by response type interaction $F(1,14) = 13.9$, $p < .005$, and the four-way interaction between array type, response type, confusability, and stimulus intensity, $F(1,14) = 7.18$, $p < .05$. 
DISCUSSION OF EXPERIMENTS 3 AND 4

The results of Experiments 3 and 4 combine to offer a much clearer idea about where in visual processing the variable of array type has its differential effects on "same" and "different" responses. It seems clear from the results of Experiment 3 that the response selection stage is not the site at which this happens. In that experiment, the array type by response type interaction was unaffected by the relative probability of occurrence of "same" pairs. This additive relationship with a variable which exhibits such a powerful influence on the response selection process (see Figure 4) argues strongly against a response selection stage locus for the interaction of interest.

In ruling out the response selection stage, the results of Experiment 3 indirectly suggest the involvement of either the comparison or encoding stage in the production of the array type by response type interaction. More direct evidence for the importance of the comparison stage in this regard is provided by the significant three-way interactions between array type, response type, and letter confusability both in Experiment 3 and in the "bright" condition of Experiment 4. Since confusability affects matching performance by requiring a slower or more careful comparison process for confusable elements, these three-way interactions clearly implicate the comparison stage as the site at which array type has its
selective effects on "same" and "different" responses. Several factors, however, weaken the force of any such conclusion. First of all these interactions, although marginally statistically significant, are less than striking. A much stronger case for the involvement of the comparison stage could be made were these interactions of greater magnitude. Also problematic is the reversal in the role played by confusability in the two experiments. In Experiment 3, the array type by response type interaction was slightly stronger for nonconfusable letters. In the "bright" condition of Experiment 4, the interaction was slightly stronger for confusable letters. This reversal is both surprising and difficult to understand. Any explanation for the differential effects of array type on "same" and "different" responses must be able to accommodate this puzzling outcome.

A more serious problem for any comparison stage hypothesis is found in the four-way interaction of Experiment 4. When subjects had to compare confusable letters under "dim" viewing conditions the array type by response type interaction completely disappeared. If the comparison stage is indeed the site of the array type by response type interaction, why should stimulus intensity, a variable believed to affect the encoding process, be involved? Does this mean that the encoding stage is partly responsible for the effect?

Clearly the results of Experiments 3 and 4 do not provide a simple answer to the question the experiments were designed to address. Although the evidence seems to definitely rule out the response selec-
tion stage, the results do not provide a clear basis for isolating the effect at either the comparison or encoding stage of processing. On the other hand, neither do they favor the abandonment of the discrete stage conceptualization of processing. In both experiments the predictions of critical importance for the discrete stage model were borne out. In Experiment 3 the effects of response probability and letter confusability did not interact. This additive relationship supports the original assumption that response probability affects response selection while letter confusability affects the comparison process. In Experiment 4 the effects of confusability were additive with the effects of stimulus intensity. Again, this is exactly what would be expected if stimulus intensity affects only the encoding stage. In light of such supportive evidence it would be most unwise to attribute the somewhat ambiguous findings of Experiments 3 and 4 to the use of a faulty conceptual approach. Instead, more careful consideration should be given to how those findings might be incorporated by a discrete stage model. The hypothesis advanced in the next section is an attempt to do just that.
A Tentative Explanation for the Array Type by Response Type Interaction

In the opinion of the author, the most satisfactory explanation for the array type by response type interaction designates the comparison stage as the site at which the effect occurs. The hypothesis advanced here is based on the premise that varying the spatial arrangement of letter pairs introduces an additional dimension upon which letters may be compared. This is a dimension beyond those of individual letter features such as linearity, curvature, or line segment orientation. Perhaps the best definition of this dimension would be the extent to which letters are members of the "same" larger whole. From an earlier discussion we saw that adjacent letter pairs are "good" patterns. That is, they form highly organized arrays. Letter members of these arrays, therefore, exhibit a type of "sameness" derived from their coexistence in a larger organized whole. This "sameness" is present whether the letters share the same features (e.g. A A) or differ in this respect (e.g. A B). Letters presented in offset arrays, on the other hand, do not display this kind of "sameness". Offset arrays are not "good" patterns and, therefore, their letters do not manifest the kind of "sameness" which results from shared membership in a larger whole. In this respect the letters are more "different" than letters in adjacent arrays. This is as true for a pair like (A A) as it is for a pair like (A B).
From the present point of view, the interaction between array type and response type reflects a subject's tendency to employ the array type dimension as an indicator of "sameness" and "difference". At least on some trials, subjects base their judgments on the "sameness" or "difference" inherent in the letters' spatial interrelation-ship. Adjacent letters, being part of the same larger whole, tend to elicit the "same" response. Offset letters, by virtue of their configural independence, suggest a "different" response. Of course this does not happen on every trial. If it did performance would be at a .50 chance level. When it does happen, however, two outcomes are possible. The subject will either make an error or a particularly fast correct "same" response to an adjacent array or a correct fast "different" response to an offset array. The inclusion of these fast correct responses has the effect of lowering the mean response latencies for "same" responses to adjacent arrays and "different" response latencies to offset arrays. Errors, of course, are excluded from the analysis of response latencies.

If the above theoretical explanation is correct, it should also provide reasonable accounts of those occasions on which array type and response type do not interact. Such was the case in Experiment 2 where adjacent and offset arrays were presented in separate blocks of trials. Why does this mode of presentation wipe out the interaction observed when a mixed presentation design is used? The answer would seem to be that the regular, predictable, trial to trial occurrence
of the same array type enables the subject to ignore this factor in his determinations of "sameness" and "difference". Prior knowledge of the way in which letters will be spatially arranged permits the subject to disregard this information and focus on letter featural characteristics. When array type is varied randomly from trial to trial, ignoring array structure becomes difficult or impossible, thus the interaction between array type and response type with mixed presentation designs.

The other occasion on which the interaction did not appear was in Experiment 4 when subjects were required to compare confusable letters under "dim" viewing conditions. This finding represents a challenge for the adequacy of the comparison stage hypothesis offered above. Why should reducing stimulus intensity, a variable which ostensibly affects only the encoding stage, have consequences for the relationship between array type and response type? Of course, there was no general effect of reducing stimulus intensity on this relationship. Only when the "dim" viewing condition was paired with the presentation of confusable letters did the interaction drop out (see Figure 7). For nonconfusable letters the interaction was essentially unchanged by the stimulus intensity manipulation. What can this pattern of results be telling us? More importantly, how can they be accommodated by the proposed comparison stage hypothesis?

Fortunately, there is a way of explaining the results of Experiment 4 which makes them compatible with the comparison stage hypothesis.
This explanation is based upon the following three assumptions. (1) Although the encoding and comparison stages are separate and independent processes, they may, nevertheless, overlap temporally. All that is necessary for the onset of the comparison stage is that some stimulus features have been encoded and passed on for comparison. The onset of the comparison stage, then, may actually precede the termination of the encoding stage. (2) When confusable letters are paired with "dim" viewing conditions the comparison process is a particularly slow one. This would be so for two reasons. First, the confusable letters would necessitate more careful (and therefore slower) comparisons. Second, the comparison process may be further lengthened due to the delay in receiving input from the slowed encoding stage. (3) With such a long, drawn out comparison stage, the saliency of the array type dimension is diminished. A subject's judgment is therefore less influenced by the type of letter array than by the specific features of the individual letters. Thus, when confusable letters and "dim" viewing conditions are combined, the array type by response type interaction drops out.
A Test of the Proposed Hypothesis

In general the results of the first four experiments are compatible with the proposed experimental hypothesis for the effects of array type on "same" and "different" responses. Perhaps the least convincing argument however, is the one just offered to explain the absence of an array type by response type interaction in the "dim"-confusable condition of Experiment 4. Several important assumptions about processing were made in order to make this finding consistent with the proposed hypothesis. A much stronger case for the hypothesis could be made if the validity of these assumptions could be tested.

Fortunately, there is a prediction made by these assumptions which is amenable to experimental investigation. Recall that the absence of an interaction under the "dim"-confusable condition was postulated to be due to a decreased saliency of the array dimension resulting from an inordinately long comparison stage. If this is true, then forcing subjects to respond sooner (earlier in the comparison stage) should reinstate the effectiveness of the array dimension influence. Or, by requiring subjects to respond more rapidly, it should be possible to obtain the array type by response type interaction under the "dim"-confusable condition of Experiment 4. Experiment 5 was designed to test this prediction.
EXPERIMENT 5

In Experiment 5 all subjects received only confusable letters under "dim" viewing conditions. To test the prediction made above, two different sets of instructions were used. Subjects in the "standard" instructions condition received the same instructions used in the first four experiments. Speed was emphasized but not at the expense of accuracy. Subjects in the "speeded" instructions condition were instructed to respond on each trial before a certain "deadline". This deadline was predetermined individually for each subject by multiplying the subject's mean correct response latency obtained under "standard" instructions by a constant .85. To meet his deadline, then, a subject was forced to respond sooner than he normally would have responded.

Several outcomes of Experiment 5 will be of major interest. First of all, the effectiveness of the instructional set manipulation would be indicated by faster response latencies (and higher error rates) under the "speeded" instructions condition. Without this effect the other results would be uninterpretable. Of critical interest will be the effect of instructional set on the relationship between array type and response type. For "standard" instructions this relationship should be similar to the one obtained for the "dim"-confusable condition of Experiment 4. Under the "speeded" instructions condition, however, the comparison stage hypothesis predicts an interaction between array type and response type similar
to the ones found in the "bright" conditions of Experiment 4. In other words, the comparison stage hypothesis predicts a significant three-way interaction between array type, response type, and instructional set.

Method

Subjects

Twelve additional volunteer undergraduates from psychology classes at Iowa State University served as subjects for Experiment 5. A randomly selected eight of these subjects received the "speeded" instructions and the other four the "standard" instructions. Data for an additional four subjects in the "standard" condition were provided by using the data from the four subjects in the "dim" condition of Experiment 4 who received confusable letter pairs during the first session.

Stimuli

The stimuli were those used in the confusable letter condition of Experiment 4. Half of the total 192 trials presented adjacent pairs and the other half offset pairs. Within these two categories there were equal numbers of "same" and "different" pairs. Trials were presented in two blocks of 96 each and block presentation order was reversed for half of the subjects. All trials were presented under the "dim" stimulus intensity condition used in Experiment 4.
Subjects in the "standard" instructions condition received the same instructions as subjects in Experiments 1 through 4. Those subjects who received "speeded" instructions were asked to attempt to respond within a particular time constraint. These subjects first received the "standard" instructions. They then received 48 trials containing equal numbers of "same" and "different" pairs and equal numbers of adjacent and offset arrays (all pairs were comprised of confusible letters). Following these trials the subject's mean correct response latency was computed. This "base rate" was then multiplied by .85 in order to determine the "deadline" for that subject. For example, a subject who has a mean correct response latency of 600 milliseconds for the 48 "standard" instruction trials would be assigned a deadline of (.85)(600) = 510 milliseconds. The .85 value was selected on the basis of pilot data. The subject was then instructed that during the rest of the session it was important that he attempt to "...respond fast enough to meet the deadline on each trial." The subject then received the same 192 trials presented to subjects in the "standard" instructions condition. The clock was positioned immediately below the viewing screen so that the subject could tell when he had, or had not, met the deadline. Also, the value of the deadline was printed on a 3 X 5 card which the subject placed on the table in front of him. This was done to help the subject keep in mind the value he was to "shoot for".
Results and Discussion

Mean response latencies and error rates obtained in Experiment 5 are presented in Table 5. As expected, responses were faster under the "speeded" instructions than under "standard" instructions, $F(1,14) = 14.8, p < .005$. "Same" responses were faster than "different" responses, $F(1,14) = 10.9, p < .01$, and responding was faster during the second block of trials than during the first, $F(1,14) = 14.3, p < .01$. There was a very strong three-way interaction between array type, response type, and instructional set, $F(1,14) = 13.9, p < .005$, which is shown in Figure 8. As the figure clearly illustrates, the "speeded" instructions not only greatly increased the overall speed of responding, but also restored the interaction between array type and response type. This interaction (right panel of Figure 8) looks remarkably similar to those obtained in earlier experiments under "bright" viewing conditions. For the "standard" instructions, the array type by response type interaction looks very much like its counterpart from Experiment 4. These two-way interactions for the "standard" and "speeded" conditions were evaluated with tests of simple interactions. For the "speeded" instructions condition, the interaction was significant, $F(1,14) = 5.87, p < .01$. Newman-Keuls comparisons revealed that the mean for "same" responses to adjacent arrays was significantly faster than the other three means at the .05 level of confidence. The array type by response type interaction was also significant for the "standard" instructions condition, $F(1,14) = 8.16, p < .01$. Newman-
Table 5. Response latencies and error rates obtained under the various experimental conditions of Experiment 5.

<table>
<thead>
<tr>
<th>Array type</th>
<th>Adjacent</th>
<th></th>
<th>Offset</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same</td>
<td>Different</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>&quot;Standard&quot; instructions</td>
<td>605 (.060)</td>
<td>631 (.042)</td>
<td>597 (.073)</td>
<td>655 (.052)</td>
</tr>
<tr>
<td>&quot;Speeded&quot; instructions</td>
<td>498 (.135)</td>
<td>523 (.120)</td>
<td>516 (.242)</td>
<td>513 (.096)</td>
</tr>
</tbody>
</table>

*Error rates are in parentheses.
Figure 8. Mean response latencies as functions of array type, response type, and instructional set from Experiment 5.
Keuls comparisons showed both means for "same" responses to be faster than both means for "different" responses. Also, the mean for "different" responses to offset arrays was significantly slower than the other three means at the .01 level of confidence.

The overall error rate for Experiment 5 was .103 and error rates for individual conditions were evaluated with an analysis of variance. As was expected, more errors were made under the "speeded" instructions than under the "standard" instructions, $F(1,14)= 35.4, p< .001$. False-"different" responses were more common than false-"same" responses, $F(1,14)= 7.98, p< .01$, and more errors were made to offset arrays than to adjacent arrays, $F(1,14)= 6.21, p< .05$. There were also significant interactions between array type and response type, $F(1,14)= 5.29, p< .05$, and between array type, response type, and instructional set, $F(1,14)= 4.88, p< .05$.

The results of Experiment 5 confirm the predictions made under the assumptions of a temporally overlapping discrete stage model of matching performance. Asking subjects to respond rapidly apparently forced them to shorten the comparison stage and make their decision between "same" and "different" while the influence of the array dimension was still potent. Thus, we see the typical array type by response type interaction even for the case where letters are confusable and viewing conditions are "dim".
GENERAL DISCUSSION

The results of Experiments 3, 4, and 5 permit an informed evaluation of the role of array structure in simultaneous matching. Operating within the framework of a discrete stage conceptual approach these experiments furnish evidence for the "where", and therefore the "why", of the observed relationship between array structure and response type. Collectively, the results point to the comparison stage of processing as the important process in this regard. Isolating the effect at this stage provided a means for arriving at a satisfactory theoretical explanation. The hypothesis advanced by the author focuses on the role of array structure as an indicator of "sameness" or "difference". This "sameness" or "difference" is based on the degree to which elements may be considered parts of the same organized whole. Elements arranged to create organized arrays exhibit this type of "sameness" to a high degree. Elements which do not form organized arrays are not members of a larger whole and, therefore, are "different" in this respect. It was postulated that although array structure is an irrelevant dimension, it is nevertheless employed by the subject as a compelling harbinger of "sameness" or "difference".

On the Importance of Errors

The characterization of array structure as an irrelevant dimension which is used in the comparison process implies that, when it is used,
errors will sometimes result. For this reason the type and frequency
of errors made in the present experiments constitute important
additional criteria for verifying the correctness of the proposed
theoretical account. Specifically, the tendency to respond "same"
to adjacent pairs would be reflected in a relatively high
frequency of false-"same" responses to adjacent arrays. Conversely,
the tendency to respond "different" to offset pairs should produce
frequent false-"different" responses to offset arrays. These types
of errors, therefore, should be especially prevalent in those
experiments (conditions) which yield the interaction between array
type and response type for response latencies.

Table 6 presents proportions of false-"same" and false-"different"
responses to both adjacent and offset letter pairs for Experiments
1 through 5. The entries in the table are categorized into those
conditions which obtained the typical array type by response type
interaction for response latencies (top) and those which did not
(bottom). The two columns on the left permit a comparison of the
frequency of false-"same" responses to adjacent arrays with false-
"same" responses to offset arrays. The two columns on the right
permit the same comparison for false-"different" responses. To
achieve a degree of uniformity, Sign tests were used to compare
errors made to adjacent arrays with those made to offset arrays.

Let us first look at the relative frequencies of false-"same"
responses. For those experimental conditions which obtained the
Table 6. Comparison of adjacent and offset arrays for proportions of false-"same" and false-"different" responses for Experiments 1 through 5.

<table>
<thead>
<tr>
<th>Type of error</th>
<th>False-&quot;same&quot;</th>
<th>False-&quot;different&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Array type</td>
<td>Adjacent</td>
</tr>
<tr>
<td>Conditions which displayed array type by response type interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 1</td>
<td>.058**</td>
<td>.013</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>.048**</td>
<td>.026</td>
</tr>
<tr>
<td>Experiment 4, except &quot;dim&quot;-confusable</td>
<td>.044*</td>
<td>.025</td>
</tr>
<tr>
<td>Experiment 5, &quot;speeded&quot; instructions</td>
<td>.120</td>
<td>.096</td>
</tr>
<tr>
<td>Conditions which did not display array type by response type interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 2</td>
<td>.054</td>
<td>.054</td>
</tr>
<tr>
<td>Experiment 4, &quot;dim&quot;-confusable</td>
<td>.049</td>
<td>.060</td>
</tr>
<tr>
<td>Experiment 5, &quot;standard&quot; instructions</td>
<td>.042</td>
<td>.052</td>
</tr>
</tbody>
</table>

* p .05 by Sign test.
** p .01 by Sign test.
significant array type by response type interaction for response latencies, false-"same" responses were significantly more common to adjacent arrays than to offset arrays in three out of four cases. In the "speeded" instructions condition of Experiment 5, this difference did not reach an acceptable level of statistical significance. It was, however, in the expected direction. For the three occasions on which the array type by response type interaction failed to occur, the picture is markedly different. Here, without exception, there were no significant differences between the proportions of false-"same" responses to adjacent and offset arrays.

False-"different" responses were significantly more common to offset arrays than to adjacent arrays for all four conditions exhibiting the interaction between array type and response type. On the other hand, adjacent and offset arrays produced approximately equal numbers of false-"different" responses when the array type by response type interaction did not occur.

The pattern of errors obtained in the present five experiments, then, strongly favors the comparison stage hypothesis for the effects of array type on "same" and "different" responses. The occurrence of false-"same" responses to adjacent arrays and false-"different" responses to offset arrays was almost perfectly correlated with the occurrence of the interaction between array type and response type with response latencies. The idea that subjects employ array type as an indicator of "sameness" or "difference" is clearly supported by these results.
The Additive Factors Method: Some Limitations

If the comparison stage is truly responsible for the effects of array type on response type, why was this relationship not greatly influenced by letter confusability, a variable which ostensibly affects the comparison process? By the logic of the additive factors method, variables which affect the same processing stage should interact. In Experiments 3 and 4 the three-way interactions between array type, response type, and letter confusability were less than impressive. Furthermore, they were not even consistent. In Experiment 3 the array type by response type interaction was slightly stronger when nonconfusable letters were compared. In the "bright" condition of Experiment 4 this interaction was slightly stronger for confusable letters. How is this reversal to be explained?

Increasing the confusability of the letters to be compared would seem to have two distinctly different consequences for the comparison process. First, since confusable letters share many features, feature comparison would be more difficult. This would have the indirect effect of increasing the likelihood that the irrelevant dimension, array type, would be employed as an indicator of "sameness" or "difference". Thus, we might expect to find a stronger array type by response type interaction when confusable letters are used. A second consequence of increasing letter confusability, however, is a prolonged comparison stage. As was postulated earlier (and supported by the results of Experiment 5) the saliency of the array type dimension decreases with
time. Hence, we might expect, for this reason, a stronger array type by response type interaction for nonconfusable letters. In actual practice these two opposing consequences of increasing letter confusability would tend to cancel each other, resulting in similar array type by response type interactions for confusable and nonconfusable letters.

This account of how letter confusability combines with array type to affect "same" and "different" responses makes the smallness of the three-way interactions between array type, response type, and letter confusability less mysterious. It also provides a basis for being less surprised at the reversal in the role played by confusability in these two interactions. It seems reasonable to expect to find occasions on which the two factors do not perfectly cancel each other out, with either factor playing a more dominant role at some particular point in time. Exactly why they behaved as they did in Experiments 3 and 4 is not known and is a matter for future investigation.

Implicit in the above explanation is a criticism of the additive factors method. If two variables can operate at the same stage of processing in a way which prevents their interaction, then using the absence of interactions to indicate that variables affect different processing stages is not a foolproof method. In other words, in some cases at least, factors which exert additive effects on response latency may nevertheless operate at the same stage of processing. Although this is a serious criticism of the additive factors logic, it is not
without a precedent. A similar argument was advanced by Taylor (1976) who pointed out that it is logically possible for two variables to affect the same two processing stages and yet show additive effects on response latency. If the two variables were to affect the two stages in opposite ways (i.e. to speed up one stage and slow down the other), this could lead to additivity and the spurious conclusion that the factors affected only one processing stage each. The present results seem to suggest a similar limitation in the logic of using additivity as an indication that variables operate at different processing stages.

An additional problem for the additive factors method is found in the four-way interaction between array type, response type, letter confusability, and stimulus intensity obtained in Experiment 4. Why should stimulus intensity, a variable which affects the encoding stage, be involved in the effects of array type on response type? The explanation offered by the author rested partly on the assumption that the encoding and comparison stages may overlap temporally. In other words, the comparison stage may begin before the encoding process is complete. Support for this view was obtained with the results of Experiment 5 and at least one other investigative team has arrived at a similar conclusion (see Stanovich and Pachella, 1977).

With temporally overlapping stages one of the most fundamental assumptions of the additive factors method is violated. This is the assumption of strict seriality of stages. With overlapping stages total response latency is no longer equal to the sum of its stage durations.
It becomes possible for variables which affect different processing stages to interact and herein lies the problem for the additive factors method. No longer can interactions be regarded as reliable indications that variables operate at different stages of processing. There is at least some chance that their interaction reflects the temporally overlapping nature of their separate stages.

The criticisms levied at the additive factors method here are serious. They point out conditions under which it would be impossible to be certain that variables which have additive effects on response latency operate at different stages as well as circumstances which would prohibit the opposite conclusion. It is not the intention of the author, however, to discredit the method as a useful investigative tool. It would seem that the merits of the method far outweigh its limitations. Rather, the present considerations should serve as warnings to the users and interpreters of the method of its potential abuses.

Toward a Satisfactory Theoretical Model of "Same-Different" Judgments

The results of the present experiments offer new and challenging information about how people go about making "same-different" judgments. It was shown that array structure can greatly affect the relative speeds of "same" and "different" responses in the simultaneous matching task. In an attempt to discover why this happens, the stage-analytic information processing approach was taken. The approach was successful in
that it provided a basis for making predictions about the effects of certain experimental variables and these predictions were supported by the results of the experiments. That the approach was successful has important implications for theoretical models of matching performance.

In the introduction of this paper we discussed the major theoretical models of "same-different" judgments. We noted that these models may be categorized into those which attribute "same" and "different" responses to two separate processing mechanisms ("two process" models) and those which postulate only one processing mechanism which is responsible for both types of responses ("one process" models). The discrete stage conceptual approach used here falls into the latter category and might best be described as a "one process multi-stage" model of "same-different" judgments. With this model it is not necessary to make the rather unparsimonious and logically unpalatable claim that two completely separate processing mechanisms underlie "same" and "different" judgments. Instead, the model considers both "same" and "different" judgments to be products of the same three-stage process. The processing which occurs on both "same" and "different" trials includes an initial encoding stage followed by a comparison process and, finally, the selection of one of the two responses. "Same" and "different" judgments are simply mutually exclusive outcomes of a single comparison process.

What about the "fast-same" phenomenon? Probably the most important criterion which has been used to evaluate the adequacy of "same-different"
models is their capacity to explain the "fast-same" response. With the results of Experiment 2, it was necessary to rule out the simple hypothesis that previously found "fast-same" responses have been due to the employment of adjacent element arrays. We saw that when array type was held constant within a block of trials, a "fast-same" response occurred for both adjacent and offset arrays. In light of this finding, how may the discrete stage model be used to explain the "fast-same" phenomenon?

One possible solution to this problem would be to employ the "priming" hypothesis in conjunction with the discrete stage model. As we noted earlier, "priming" occurs on "same" trials when the processing of a particular element "primes" the subject for that element, thus facilitating the processing of a second, identical element. In the context of the three-stage model advanced here, this "priming" could take place at the encoding stage, with the encoding of one element "priming" the encoding of the other. The problem with this conceptualization lies in the shortcomings of the "priming" concept itself. As was noted earlier, the "priming" hypothesis is particularly ill-suited to explain occasions of faster "different" responses than "same" responses. Further, to explain "fast-same" responses found when elements are presented simultaneously, the hypothesis must make the rather untenable assumption that elements are encoded in a serial fashion. The best available evidence on this point suggests that elements (and element features) are not encoded serially but rather in parallel (see Estes, 1972, 1975).
The results of the present experiments suggest an alternative explanation for the "fast-same" response. This explanation focuses on the role played by irrelevant variables in the matching task. The present results showed that subjects can employ the extent to which elements belong to the same organized whole as a dimension for determining whether elements are the "same" or "different". It seems very likely that there are other such irrelevant dimensions upon which a subject might base his response. Dimensions which might be used include element size, element color, element figure-to-ground contrast, and even element taxonomic category (e.g. letters, digits, etc.). Of particular importance is the fact that the elements presented to subjects are generally equated on these factors. That is, all elements are the same size, the same color, display the same figure-to-ground contrast, and belong to the same taxonomic category. To the extent that any (or all) of these dimensions are used in the subject's determination of "sameness" or "difference" there will result a tendency to respond "same". The typical "fast-same" response, then, would be the product of processing influenced by these irrelevant dimensions which all indicate "sameness".

The array type dimension used here was found to influence responding only when varied randomly from trial to trial. When it was held constant, it had no impact on the relative speeds of "same" and "different" responses. It does not necessarily follow, however, that this would be the case for dimensions like element size and element color. These fac-
tors may well be powerful enough to force responding toward "same" even when they do not vary from trial to trial. Of course, only future investigation will permit an evaluation of the merit of this argument. For now, the irrelevant dimension hypothesis must be considered a possible explanation for the "fast-same" response within the context of a three-stage theoretical model of "same-different" judgments.

Summary

The results of the five experiments reported here provide a reasonable answer to the question of how array structure influences "same-different" responding. Apparently, subjects employ the array structure dimension as an indicator of "sameness" and "difference". The findings are consistent with a "one process multi-stage" theoretical model of "same-different" judgments and implicate the possible role of certain irrelevant variables in the production of the "fast-same" response.
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This dissertation is dedicated to my beloved wife, Wendy. Your constant encouragement, unconditional devotion, and personal sacrifice have played the major role in the completion of my graduate program. Certainly, the PhD degree shall be not mine, but ours.