Storage mode of geometrical dimensions in a two-stimulus matching paradigm

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In a two-stimulus matching paradigm requiring "same" and "different" responses to simple geometric dimensions, the successive stimulus presentation mode with several retention intervals was compared to a simultaneous stimulus presentation mode. For the simultaneous condition, the data suggested a wholistic template matching process, but in none of the successive conditions was template matching indicated. The retention interval of the successive condition allows the subject to analyze out the target dimension from the first two-dimensional stimulus. The ability to anticipate the value of the target dimension in the second stimulus could also influence the representation of the first stimulus. The findings shed some light upon the perceptual interactions between dimensions that constitute the stimulus. In particular, an outside-to-inside order of iconic scanning appeared to be supported by the data.

There is currently sufficient evidence available (e.g., Millsaugh, 1978; the Nickerson, 1972, review; Silverman & Goldberg, 1975) to support the contention that in classifying a pair of relatively simple geometrical stimuli into distinct categories—such as "same" and "different"—two essentially different comparison processing mechanisms contribute to the decision: (1) a unitary comparator, and (2) a difference detector. The real problem now becomes the relative importance of the two related strategies.

Conclusive evidence for such a dual process model is the considerable superiority in reaction time (RT) of "same" over "different" responses. The usually obtained $RT_{\text{same}} < RT_{\text{diff}}$ result cannot be accounted for by a pure analytic model. The adoption of an analytic model forces the subject to check exhaustively all constituent dimensions in order to correctly classify a stimulus pair that is "same." But, when the stimulus pair is "different," checking of *all* constituent dimensions is not always required, since interrogation can be terminated as soon as a difference in only one of the dimensions is detected, and this might lead to the longest times for the "same" responses. Since this is at variance with the data, a faster identity matching by a unitary comparator is suggested, working on a Gestalt or template of the stimulus.

When, under simultaneous and successive stimulus presentation techniques, identical RT patterns are obtained in the two-stimulus matching paradigm, one is more inclined to believe that identity matching

is independent of whether a template of the physical stimulus or an isomorphic memorial representation of that stimulus is utilized in the judgment process (cf. Cleaves, 1977). It is known that successive presentation leads to a reduction in RT (Grill, 1971; Nickerson, 1976). But the question of interest is whether the successive RTs also will show a superior "same" response. Several reasons can be formulated as to why it is unrealistic to expect similar data in both stimulus presentation modes. First, the time between the first (memory) and the second (test) stimulus in the sequential stimulus presentation mode can exceed a critical limit beyond which the trace of the isomorphic memorial form has faded away. This process is favored when stimulus complexity is low, so that nontemplate recoding is viable (Baddeley, 1976). Then, the analytic approach will be used throughout, irrespective of response type, and the $RT_{\text{same}} < RT_{\text{diff}}$ result will disappear at long (> 3-sec) retention intervals. Second, the side-by-side placement of simultaneously presented stimuli may create perceptual problems, *not* apparent when stimulus presentation is successive. The simultaneous stimuli may influence each other's perceptual characteristics and, due to "instant" interfigural properties, a new stimulus/stimuli may emerge. This "extra" stimulus could influence the analytic processing of the dimensions that had to be attended to, or even obscure the templates of the stimuli.

An important factor that could further enhance divergent processing strategies under the influence of both stimulus presentation modes may be task complexity. When it is the subject's task to attend to all dimensions of the stimulus, a template-matching approach for the "same" response production is obviously appropriate. Moreover, it is conceivable

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that under such task demands, the subject tends to store the memory stimulus as a whole during the retention interval. In such cases, the subject's processing strategy will be expected to be identical for both stimulus presentation modes. When, in contrast, the subject has to consider fewer dimensions than the stimulus contains, template matching is too comprehensive, since a template encompasses all stimulus aspects, including irrelevant ones. The latter procedure was used by Keuss (1977). His subjects had to judge bidimensional stimuli, simultaneously presented, but had to base their "same" and "different" reactions on only one dimension. Keuss obtained a significant $RT_{\text{same}} < RT_{\text{diff}}$ result. The "same" superiority even held when the secondary (non-relevant) dimension indicated a difference within the figure pair. Further, there were dimensional interactions which indicated the processing of individual dimensions to be hampered by the irrelevant dimension.

The goal of the present report is to examine the possibility that these results were conditional upon the stimulus presentation mode. Any repetition of Keuss' (1977) study, it is suggested, should include both sequential and simultaneous stimulus presentation modes. (All other procedural details of the present investigation are identical to Keuss, 1977. For a rationale, a reference is made to that study.) The main assumption of the present study is that the use of a retention interval following the first, or memory, stimulus may facilitate subject's analytical approach. The reason is that in the retention interval, the subject has the opportunity to filter out the irrelevant stimulus aspects and analyze out the relevant aspects from the first stimulus. This hypothesis is in line with Lockhead's (1972) statement that each stimulus can ultimately be analyzed, given sufficient time. On first sighting, however, the stimulus dimensions may be inseparable and, as a consequence of such dimensional interaction, analysis is retarded.

The problem of what precise stimulus conditions have to be satisfied in order that there be dimensional interaction is not solved. According to Garner and Felfoldy (1970), dimensions are inseparable when neither dimension is removable without destroying the stimulus. Millspaugh (1978) mentions "figural goodness" as an enhancing condition for inseparability.

For the present, it may be of relevance, therefore, to point to the outcomes of Keuss' (1977) experiment as far as dimensional interactions took place. The dimensions were size and form of a geometrical figure and the orientation of an interior line within the figure which, in two-by-two combinations, formed the bidimensional stimulus. In addition to the aforementioned $RT_{\text{same}} < RT_{\text{diff}}$ result, the processing of form and size interfered with one

another, as they were apparently seen inseparably. Each of these dimensions, size and form, also retarded the individual processing of the interior line. This retardation was supposedly due to the perceptual predominance of the outlines of the figures formed by either size or form, so it can be safely assumed that these dimensions—outline and interior line—do interact.

If retention intervals allow the subject to follow an analytic judgment approach, the $RT_{\text{same}} < RT_{\text{diff}}$ result would no longer be expected, since all judgments must be produced by the difference detector. The "same" responses could even be the longest responses, because the difference detector is only able to identify an intrapair similarity by default. Further, hampering and interfering dimensions in the first, or memory, stimulus may be predicted to be filtered out. (To state the same thing differently, the relevant aspect is analyzed out from the first, or memory, stimulus.) This occurs during the retention interval and before the onset of the test stimulus, so that analyzing out the first stimulus will not be reflected in the reaction time. This may result in a shortening RT. It has to be borne in mind, however, that the test stimulus also contains two dimensions, one relevant and one irrelevant, which, on first sighting, are seen as inseparable. The process of analyzing out the relevant dimension from the test stimulus also takes extra time, which is reflected in the reaction time. The conclusion is that, for the simultaneous presentations, the reaction time contains the analyzing-out times for both stimuli of a pair, while for the successive presentations, the reaction time only contains the time to analyze out the second, or test, stimulus. It is logical to expect that the delay due to "analyzing-out activity" will be smaller for successive presentations. The difference between the control series in which the stimuli contain only the relevant dimension and the experimental series in which the stimuli contain both the relevant and the nonrelevant dimension will be used to estimate the delay due to analyzing-out activity.

Subject's analyzing-out activity in the retention interval could be examined in another way. Each combination of dimension values within a figure might well directly exert an effect on the discriminability of the relevant dimension and, hence, the "analyzing-out process" of that dimension. For example, it would probably make a difference in the processing of the orientation of the interior line if it were presented in squares of differing sizes, since the interior lines would then also be of differing size (see Figure 1). The hypothesis put forward is that, when the retention interval is long enough for the subject to pick up the relevant dimension and to store it in a uniform code, the actual form of the memory stimulus no longer affects the processing

times of the relevant dimension. Thus, in the example given, any variation of "orientation" discriminability, as produced by the value of irrelevant size in the memory stimulus, will not be reflected in the RT. It should be clear that this test is applicable only if there *are* substantial dimensional interactions of this type. This has to be revealed in the processing of the test stimulus.

The subject performs a go/no-go task, implying that he presses the button only for stimulus pairs that are "same" with respect to the relevant dimension (hence, "same" = go; "diff" = no go), while in another run of trials, he presses the button only for stimulus pairs that are "different" with respect to the relevant dimension (hence, "diff" = go; "same" = no go). Furthermore, the value of the second and irrelevant dimension was kept constant in one of the two possible states during a stimulus series. The question that may arise is whether, under this task demand, the speeded-up subject produces an anticipatory mental scheme of the bidimensional *test* stimulus that is connected to his "go" response. An example will clarify this. Suppose that the subject is instructed to make a "go" response only for "different" stimulus pairs. Further, he knows that the size of the test stimulus is always large. The first figure presented is a (relevant) horizontal line, embedded in a small square. When the retention interval starts, he knows that a "go" response will be required if and only if the test stimulus is a vertical line embedded in a large (nonrelevant) square. The "expectation" attitude may be more easily elicited as the retention interval increases. As a consequence, it may be expected that variations in discriminability or "analyzing-out times" with respect to the test stimulus become attenuated as the retention interval increases. Discriminability differences due to the state of the irrelevant dimension will then interact with retention interval.

METHOD

Subjects

Twenty-four students (11 males) at the Free University served as subjects. They were paid a fixed sum for participation. All had normal or corrected-to-normal vision and used their preferred hands for responding. Eight of them were assigned to each group of the experiment.

Apparatus

A PDP-8/I controlled the presentation and duration of the stimuli, time intervals, counting, and recording of elapsed judgment times. A KW-8-IW real-time clock with a basic frequency of 1,000 Hz counted the reaction times and halted upon key-pressing. There was a single response key connected to a micro-switch that required a pressure of 5 oz to be closed. The subject sat in a comfortable position with his eyes about 50 cm from the screen. The stimuli appeared on a 16 × 21 cm Tectronix display unit (611), of which only the center 4 × 5 cm part was visible. The Tectronix 611 was used in store mode. To remove a stimulus

from vision, the screen was erased by a 40-msec yellowish-green flash. At a 50-cm distance, flash intensity was .54 $\mu\text{lm}/\text{cm}^2$ with a background illumination of .18 $\mu\text{lm}/\text{cm}^2$.

Stimuli

The stimuli were pairs of simple geometric figures. Each figure was positioned on either side of the screen, the center of which was indicated by a black spot. There was a distance of 36 mm between the midpoints of the figures, which were situated on fixed-coordinate matrices. Construction time for a stimulus was less than 7 msec. For simultaneous presentation, the figure pairs remained on the screen for .5 sec. For successive presentation, in which the order of appearance of the stimuli was always from left to right, only the left (memory) stimulus, had a duration of .5 sec. Its offset marked the beginning of the retention interval. Thereafter, the right (test) stimulus was displayed and remained until the beginning of the next trial.

The stimuli varied in three dimensions: size (S), form (F), and orientation of an interior line (O). Each dimension had two values. These values were selected in such a way that, by and large, discrimination time in the control series was equal for each dimension.

For one group of subjects, size was the target dimension, for a second group of subjects, form was the target dimension, and for a third group of subjects, orientation was the target dimension. So there is a "judge size" group (the S group), a "judge form" group (the F group), and a "judge orientation" group (the O group). For each individual group, one control series and eight experimental series were constructed. Within any series, there were 30 stimuli.

For the control series, the construction and measurement of the stimuli were as follows (see Table 1). To the S group, pairs of squares were shown measuring either 11 × 11 mm (small) or 16 × 16 mm (large). To the F group, pairs of rectangles, both measuring 11 × 16 mm, were shown. For each figure, the longer side was either the height or the base ($h < b$ vs. $b < h$). To the O group, pairs of lines were shown. Each was 13.5 mm long, and its orientation was either horizontal or vertical.

In the eight experimental series of each part, a second, irrelevant dimension selected from the remaining two was added to the relevant dimension. Its value was kept fixed within any series of 30 stimuli for both the left and the right figure. With one irrelevant, but two-valued, dimension, four sets of stimulus pairings, and, hence, four different stimulus series with respect to that *irrelevant* dimension, can be constructed. For instance, stimulus pairs formed by a combination of relevant and varying O (as shown to the O group) and irrelevant and constant S were presented in: two small identical squares (first series), two large identical squares (second series); left square small, right one large (third series); and left square large, right one small (fourth series). In an analogous way, with two irrelevant dimensions, eight different series per group were formed (see Table 1 for a complete description).

The two-dimensional stimuli of the experimental series were constructed by means of superimposing the appropriate dimensions under these conditions: (1) For stimuli involving O, interior lines were given, bisecting the stimulus but never extending beyond the rectangle; and (2) for stimuli involving both S and F, the rectangles used measured either 9 × 13 or 13 × 19 mm. These areas approximate those of the squares and rectangles shown in the control series of Groups S and F. An illustration of two stimulus pairs is shown in Figure 1.

Design and Procedure

Each group had the same four intervals between offset of the first stimulus and onset of the second stimulus. Length of the retention interval (RI) between memory and test stimulus was either 0 (simultaneous presentation), 1½, 3, or 6 sec (successive presentation). Each RI was tested in a separate session, so there

Table 1
Construction and Measurements of the Stimuli

Stimulus Series	Varying Dimension in Both Figures	Left Figure	Fixed Dimension Right Figure
S Group Size Relevant			
1 Irrelevant Orientation (s)	11 × 11/16 × 16 mm	Hor Int Line	Hor Int Line
2 Irrelevant Orientation (s)	11 × 11/16 × 16 mm	Vert Int Line	Vert Int Line
3 Irrelevant Orientation (d)	11 × 11/16 × 16 mm	Hor Int Line	Vert Int Line
4 Irrelevant Orientation (d)	11 × 11/16 × 16 mm	Vert Int Line	Hor Int Line
5 Irrelevant Form (s)	9 × 13/13 × 19 mm	b > h	b > h
6 Irrelevant Form (s)	9 × 13/13 × 19 mm	h > b	h > b
7 Irrelevant Form (d)	9 × 13/13 × 19 mm	b > h	h > b
8 Irrelevant Form (d)	9 × 13/13 × 19 mm	h > b	b > h
Control	11 × 11/16 × 16 mm		
F Group Form Relevant			
1 Irrelevant Orientation (s)	11 × 16/16 × 11 mm	Hor Int Line	Hor Int Line
2 Irrelevant Orientation (s)	11 × 16/16 × 11 mm	Vert Int Line	Vert Int Line
3 Irrelevant Orientation (d)	11 × 16/16 × 11 mm	Hor Int Line	Vert Int Line
4 Irrelevant Orientation (d)	11 × 16/16 × 11 mm	Vert Int Line	Hor Int Line
5 Irrelevant Size (s)	b > h/h > b	*13 × 9 mm	*13 × 9 mm
6 Irrelevant Size (s)	b > h/h > b	13 × 19 mm	13 × 19 mm
7 Irrelevant Size (d)	b > h/h > b	13 × 9 mm	13 × 19 mm
8 Irrelevant Size (d)	b > h/h > b	19 × 13 mm	9 × 13 mm
Control	11 × 16/16 × 11 mm		
O Group Orientation Relevant			
1 Irrelevant Size (s)	Hor/Vert Int Line	11 × 11 mm	11 × 11 mm
2 Irrelevant Size (s)	Hor/Vert Int Line	16 × 16 mm	16 × 16 mm
3 Irrelevant Size (d)	Hor/Vert Int Line	11 × 11 mm	16 × 16 mm
4 Irrelevant Size (d)	Hor/Vert Int Line	16 × 16 mm	11 × 11 mm
5 Irrelevant Form (s)	Hor/Vert Int Line	*11 × 16 mm	*11 × 16 mm
6 Irrelevant Form (s)	Hor/Vert Int Line	16 × 11 mm	16 × 11 mm
7 Irrelevant Form (d)	Hor/Vert Int Line	11 × 16 mm	16 × 11 mm
8 Irrelevant Form (d)	Hor/Vert Int Line	16 × 11 mm	11 × 16 mm
Control	Hor/Vert Line of 13.5 mm		

Note—b = base, h = height, Hor = horizontal, Vert = vertical, Int = interior, s = same, d = different. *The first digit refers to the length of the base.

were four sessions. Session time ranged between 1½ and 2 h, depending on RI length.

Once assigned to one of the groups, S, F, or O, the subject was instructed which dimension was relevant throughout all his sessions. A session contained two cycles. In the first cycle, the subject was instructed to press the key as soon as possible, when the relevant dimension was different in the figures. In the second cycle, he was to respond when the relevant dimension was *not* different. Half of the subjects started with the "same" response requirement, and half of the subjects started with the "different" response requirement. Within a cycle, 10 series of 30 trials each were presented. The control series was presented first and last (10th). Administration of the 8 experimental series was counter-balanced across subjects.

Only two different stimuli (thus, four different stimulus pairings) were constructed for the relevant or target dimension in a particular series. Each series had 15 "same" and 15 "different" pairings, which were presented in random order. Equal emphasis was laid upon speed and accuracy.

The trials were marked by the yellowish-green erase flash, serving as a "ready" signal. Half a second after the ready signal, either both stimuli (simultaneous presentation) or the first stimulus of a pair (successive presentation) were displayed. The onset of the second stimulus started the clock. If the subject did not press the key within 1 sec, he was considered to have opted for a "no-go" response. Knowledge of results, i.e., RT in milliseconds and correctness, was presented just below the stimulus as soon as the subject's reaction was known. One and a half seconds after onset of the second stimulus, the next trial started. For

simultaneous presentations, there were 2.75 sec between stimulus onset and the beginning of the next trial. Errors resulted in a fixed intertrial time prolongation of 2 sec. Following an error, two extra trials, chosen at random from the running series, were added, but they were not used for the analysis.

The subject began with a practice session, to become familiar with the dimension on which he had to base his response during the whole task. Prior to each session, he received practice with the particular RI of that session. Prior to each stimulus series, he was informed about which irrelevant dimension was added to the relevant or target dimension, and at least six extra trials served for exercise. After the first cycle of 10 series, a 30-min break

Figure 1. Illustrations of the stimulus material. Left stimulus pair is employed for both the size and the orientation groups. For the orientation group, the correct response is "same," as the orientation of the interior lines is in the same state (both horizontal). For the size group, the appropriate reaction is "different," since the two figures differ in size. The right stimulus pair is used in both the size and the form groups. Since the figures differ on both size and form, the correct response is "different," irrespective of groups. Note that the left stimulus of a pair always appears first when a retention interval is used.

was inserted. The session then continued with a second cycle which was identical to the first cycle except for the responding requirement. If the subject in the first cycle was instructed to press the key only at "same" stimuli, he now was required to press only for "different" stimuli, and vice versa. Changing the responding requirement was introduced by some practice. Each subject completed the practice session and the four experimental sessions within a fortnight.

Data Analysis

A set of ANOVAs was employed for each group, using a within-subjects design. The mean RT per (sub)condition and per subject was used as an individual value. Each effect and each interaction was tested against its appropriate error mean square.

Two tests were applied on the four RI levels. The one test with $df = 1$, compared the simultaneous condition ($RI = 0$) to all successive conditions ($RI = 1\frac{1}{2}$, 3, and 6 sec). The second test with $df = 2$, compared the three RIs within the successive condition. These two comparisons were pooled into one factor with $df = 3$ whenever the first and second test were both significant or both insignificant.

Errors were of two types. The relatively infrequent "no-go" reaction occurred when the subject failed to press the key (.1%). The other type of error, the relatively frequent false "go" response, occurred when the key was pressed when *not* pressing was required (5%). Statistical analysis made sense only for this more frequent error type. These error frequencies were analyzed (ANOVA) in parallel with the RT data.

RESULTS

First, the effects of retention interval on the reaction time—averaged over "same" and "different" responses—will be considered. For both experimental and control series of each part, a significant ($p < .01$) proportion of the variance appeared to be attributed to RI [for the S group, $F(3,21) = 9.5$ (control) and 6.9; for the F group, $F(3,21) = 5.4$ (control) and 7.1]. For the O group, only the test between simultaneous and successive presentation reached significance [$F(1,7) = 14.7$ (control) and 40.1]. The curves of Figure 2 consistently show, for all parts, RT to decline from $RI = 0$ sec to $RI = 1\frac{1}{2}$ sec and to

Figure 2. Mean reaction time (correct "go," averaged over "same" and "different" responses) for control and experimental series, and percentage of false "go" responses as a function of retention interval. The three panels illustrate the results for the three groups of the experiment.

Figure 3. Superiority of the "same" response ($RT_{diff} - RT_{same}$) as a function of the retention interval. The curves depict the trend across groups. In the lower panel (a), the state of the irrelevant dimension is always "same," and in the upper panel (b), the state of the irrelevant dimension is always "different."

increase from $RI = 1\frac{1}{2}$ sec to $RI = 6$ sec. Post hoc Scheffé testing at the 5% level confirmed the increases from $1\frac{1}{2}$ to 6 sec, except for the O group, while the decline from 0 to $1\frac{1}{2}$ sec held for all three groups.

The number of incorrect "go" responses, also presented in Figure 2, was positively related to RT. But as there were no significant relationships within these error data, erroneous reactions will not be further discussed.

For testing the decreasing RT_{same} over RT_{diff} superiority over RI, the RTs of each subject group were split into two parts defined by the state of the irrelevant dimension. Figure 3a shows the plottings of the data for which the irrelevant dimension was in a "same" state as a function of RI. This figure (lower panel) depicts the difference between RT_{diff} and RT_{same} as a function of retention interval length. A set of t tests applied at each retention interval reveals that there is a "same" superiority for simultaneous presentations only [$t(23) = 4.48$; $p < .001$], not for any of the successive presentations (t values below 1.56).

The data for which the irrelevant dimension was in a "different" state are shown in Figure 3b (upper panel). Again, superiority of the "same" response was present for simultaneous presentations only [$t(23) = 2.15$; $p < .025$]. Irrelevant difference apparently did not interfere with the "same" reaction, nor did it favor the "different" response (cf. Keuss, 1977).

Dimensional interactions were tested by comparing RTs to the relevant dimension when presented alone

Figure 4. Delay due to the addition of an irrelevant dimension in "same" vs. "different" state as a function of the retention interval. Delay is relative to control conditions that omitted the irrelevant dimension.

to yield baseline data, against RTs to that dimension presented in combination with an irrelevant dimension. Figure 4 shows the delays due to the addition of the irrelevant dimension as a function of RI, with the state of the irrelevant dimension (same vs. different) as the parameter. Since response type did not interact with the remaining factors of the ANOVA employed, the delays shown in Figure 4 are averaged over the "same" and "different" responses. The data of the size and form group obtained with irrelevant orientation as the added dimension are omitted in the figure, since the addition of this irrelevant dimension did not affect the RTs to both relevant S and F, either for simultaneous or successive presentation.

The upper panels of Figure 4 indicate, for the S and the F group, a delay that was produced by the addition of irrelevant form (left panel) and irrelevant size (right panel), respectively. The curves clearly show that the delays in both the S and the F groups were present only in the simultaneous condition, and only when the irrelevant dimension was in a "different" state. These findings are statistically confirmed by the interactions of presentation mode with state (same-different) of the irrelevant dimension [$F(1,7) = 11.2$; $p < .025$ for the S group; and $F(1,7) = 19.5$; $p < .005$ for the F group].

Concerning the O group, the lower panels of Figure 4 depict delays due to the addition of irrelevant form that were highly significant when form was in the "same" state [$F(1,7) = 50.0$; $p < .001$] as well as when it was in the "different" state [$F(1,7) = 123.1$; $p < .001$]. Both delays hold for all RIs (see left panel), but presentation mode (simultaneous-successive) interacted with state of irrelevant form [$F(1,7) = 52.3$; $p < .001$]. Significant delays in part O were also produced by the addition of irrelevant size—be it in the "same" state [$F(1,7) = 30.6$; $p < .001$] or in the "different" state [$F(1,7) = 33.4$; $p < .001$]. Both curves are depicted in the lower right panel of Figure 4.

Table 2 presents, for each dimensional combination, the outcomes of a set of ANOVAs which tested the hypothesis that RT is not differentially affected by the two values of the irrelevant dimension. (In the ANOVAs, the state of the irrelevant dimension was nested under the state of the relevant dimension.) The null hypothesis was rejected for the test stimulus in the two combinations in which orientation was relevant. This means that the discriminability of orientation was affected by the state of the irrelevant outline. More significantly, the effect was limited to the test stimulus and was absent in the memory stimulus. These findings were not qualified by any interaction with RI. (Note that $RI = 0$ sec—the simultaneous condition—is excluded.) Apparently, analyzing out the critical dimension from the memory stimulus could be done within all RIs (1½, 3, and 6 sec).

DISCUSSION

The clearest outcome of the present study appears to be the considerable time gain (RT decrement) produced by the transition from the simultaneous to the successive presentation mode in the two-stimulus matching paradigm. This result is in accordance with the findings of other classification studies (Grill, 1971; Nickerson, 1976). However, a somewhat confusing aspect of the data is the increase in judgment time as the retention interval between the first and the second (test) stimulus increases—the simultaneous and the 6-sec RI conditions give approximately equal performance for two groups (for a comparable retention interval length/RT function, see the study of Smith & Nielsen, 1970). An ad hoc interpretation is that the RT increase reflects an increasing time uncertainty as to when to expect the test stimulus. In particular, after a 6-sec retention interval, the subject meets problems in timing the onset of the test stimulus, but not in retaining or retrieving the memorial representation of the first stimulus. This hypothesis was confirmed by the outcome of a small follow-up

Table 2
F(2,14) Values for the Two Values of the Irrelevant Dimension

Relevant Dimension	Irrelevant Dimension	Memory Stimulus	Test Stimulus
Size	+ Form	< 1	2.00
	+ Orientation	1.36	2.03
Form	+ Size	1.88	< 1
	+ Orientation	2.67	< 1
Orientation	+ Size	< 1	9.06*
	+ Form	< 1	45.33**

Note—For each particular dimensional combination, two *F* values are given, the first indicating RT variation due to the irrelevant variation in the memory stimulus, and the second indicating the same variation in the test stimulus. Only the successive conditions are considered here. * $p < .01$; ** $p < .001$.

experiment, where the exclusion of time uncertainty eliminated the performance decrement at the longest (6-sec) retention interval.¹ Consequently, it is assumed that *all* successive conditions should have shown the time gain, had time uncertainty been eliminated.

In establishing conclusions about the sort of time-saving activity employed by the subject during the retention interval, it is noticeable that *all* judgments were speeded up. Thus, the time gain is not limited to the judgments of the bidimensional stimuli. It is also present in the judgments of unidimensional stimuli, even the most simple two lines without "context" (see Figure 2, middle curve of the orientation group), which makes it unlikely that the RT differences between the simultaneous and the successive condition might be accounted for by the application of the more efficient "analyzing-out" strategy. This judgment approach assumes the splitting of the stimulus into relevant (or target) and irrelevant dimensions, which makes no sense for the judgments of stimuli consisting of only one dimension. Similarly, Grill (1971) and Nickerson (1976) found that the time shortening for successive presentations, in comparison with simultaneous presentations, holds for the most simple stimuli. Nickerson supposes that successive input is preferable to simultaneous input, because of limitations at the encoding level. For the present study, using geometric stimuli, there may be an alternative explanation of the RT difference between the stimulus presentation modes. When stimuli of this sort are presented simultaneously and side by side, the figure pairs may initially be perceived or processed as single, whole configurations. Before the elements of a pair can be compared, the perceiver must "break apart" the larger whole (Hershenson & Ryder, Note 1, cited by Millspaugh, 1978). The RT will therefore be lengthened by the time to separate the elements in case of the simultaneous stimulus presentation mode. Obviously, this time loss will be absent when the stimuli of the pair are already separated by a retention interval, as under the sequential stimulus presentation mode.

The transition from the simultaneous to the successive presentation mode was further accompanied by the expected change in stimulus-matching strategy. Only the simultaneous condition yielded a statistically reliable $RT_{\text{same}} < RT_{\text{diff}}$ result, as in the Keuss (1977) study. In terms of mode of processing, the activity of a unitary comparator, responsible for the faster "same" response, was only evidenced by the simultaneous condition. Some authors claim, however, that an isomorphic representation of the stimulus, as needed by the unitary comparator, is available for a short retention period of up to 3 sec (cf. Smith & Nielsen, 1970). Yet in the present study, the subject tends to adopt an analytic strategy at all retention intervals, as further revealed by the differential interactions in memory and test stimulus. From Table 2,

it appeared that discriminability differences in the test stimulus affected the RTs, while identical discriminability differences in the memory stimulus did not affect the RTs. More explicitly, the data support the contention that the subject used an "analyzing-out" strategy of the target dimension from the memory stimulus. Apparently, even the shortest retention interval of 1½ sec provided the subject with enough "dead" time to analyze out the target dimension from the memory stimulus, since all judgments could take place within a 1-sec limit. It should be clear that the "analyzing-out" strategy cannot lead to a time gain for the simultaneous condition. Analyzing out demands extra processing time, and a time gain is, therefore, achieved only when the start of the analysis precedes the start of the reaction-time clock. In the simultaneous condition, presentation of both stimuli coincides with the onset of the reaction-time clock, and no time gain due to analyzing out will be observed.

It might be argued that, following an analytic strategy, the "same" decision could only be provided by default and, thus, be expected to take longer than the "different" decision. This is clearly at odds with the data that show no difference in RT between both types of responses. It is more likely that the "analyzing-out" approach of the subject hints at his ability to pick up the relevant aspect of the memory stimulus and to recode it in a more or less uniform code, independent of the irrelevant aspect.

The subject's analytic approach under the successive condition may be prompted by the task demands of this study, which were different from other recognition studies (Cleaves, 1977; Smith & Nielsen, 1970) on two task characteristics: (1) For the subject, only one (bivalued) dimension was critical for all his decisions, and (2) he performed a "go/no-go" task, thus his "same" and "different" responding systems were not placed in direct competition in the same run of trials. Consequently, during the retention interval, the active subject could have produced a simplified uniform code or scheme of the target dimension that was inspired by his overt response. The anticipated value of the target dimension in the test stimulus may then have influenced the processing of the test stimulus itself. A strategy of checking whether the anticipated value of the target dimension is present or absent in the test stimulus may enable the subject to directly pick up the target dimension from the test stimulus, i.e., without loss of time.

Pertinent to the question is the pattern of dimensional interaction in the processing of the two-dimensional test stimuli. The data are equivocal, however. On the one hand, bringing size and form together in one test stimulus did not hamper the individual processing of either dimension when presentation was sequential. The opposite held for the

simultaneous condition, where size and form apparently are inseparable dimensions (Keuss, 1977). Moreover, according to Garner and Felfoldy (1970), both dimensions fulfill the main criterion for integrality or inseparability, since taking away either of them would destroy the stimulus. Thus, this outcome supports evidence of the subject's ability to directly pick up the target dimension from the test stimulus, in spite of integrality.

On the other hand, this ability is contraindicated by the delay in the processing of the interior line in the test stimulus when size or form are given as irrelevant "context" or outline. Although the delay due to the presence of an outline is largest for the simultaneous condition, the retardation is still considerable at each retention-interval condition. This suggests that directly picking up the interior line is not possible given the presence of an outline.

Possibly, the retardation due to the presence of an outline is related to the way the subject inspects a stimulus. As in White's (1976) iconic processing, the scanning of the visual field is apparently from outside to inside, so that the subject is forced to process the outline first, before entering the figure, in order to inspect the interior line. Hence, neglecting the outline dimensions of size and form is ruled out, and the presence of an outline dimension retards the judgment of the interior line, irrespective of the subject's ability to anticipate the value of the interior line. But when only the outline has to be judged, neglecting the inside aspect occurs without loss of time, as is supported by the fact that the data of both stimulus presentation modes evidenced no delaying effect of the presence of the interior line upon the processing of size and form when these outline dimensions were critical. The implication is that in constructing an iconic representation, the subject is able to read off the icon before the interior aspect is taken into account. The asymmetry of the interaction between outline (size or form) and interior aspect (orientation) may be an illustrative specimen of what Garner (1976) termed asymmetric configurality. However, Garner's terminology is mainly based on card-sorting tasks and might be different from the meaning of integrality and asymmetric configurality in the two-stimulus matching paradigm.

In conclusion, the main result of the present study affirms that the subject's processing strategy changes by the transition from simultaneous to successive stimulus presentation mode. The subject no longer employs the wholistic stimulus-matching approach. Instead, he follows a pure analytic strategy in that, during the retention interval, the target dimension is analyzed out from the memory stimulus. For some of the stimuli (formed by size and form), the absence of dimensional interactions reflects some form of anticipating the target dimension of the test stimulus. This anticipation may be prompted by the "go/no-go"

task, as well as by the instruction to attend to only one critical dimension during the whole task.

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1. Hershenson, M., & Ryder, J. *Perceptual organization and visual feature structure in a physical matching task*. Paper presented at the 17th annual meeting of the Psychonomic Society, St. Louis, November 1976.

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NOTE

1. In an additional experiment, time uncertainty about test-stimulus onset was minimized by sounding a 250-msec buzzer 1 sec before onset of the test stimulus. A random four out of eight subjects from the size group were selected. They were presented with the series 5-8 (from Table 1) in a counterbalanced order, preceded and followed by a control series. In his session, the subject worked through these six series twice, the first time reacting to the "same" stimuli, the second time to the "different" stimuli. For two subjects, order of responding was reversed. The RI was kept fixed at 6 sec. Other conditions were similar to the main experiment. Mean RTs were 281 msec. This is equivalent to subjects' previous performance at $RI = 1\frac{1}{2}$ sec and is shorter than the previous $RI = 6$ -sec result of 333 msec [$t(3) = 2.85$; $p < .05$]. Although practice effects were not properly controlled in making those comparisons, the data strongly suggest that temporal uncertainty, more than retrieval difficulty, is the critical factor that slows the RT down at longer retention intervals.

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