Further confirmation of *same* vs. *different* processing differences

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Two four-digit numbers were matched in a "same-different" reaction time paradigm. In the "all-same" condition, the subject responded *same* if all digits matched and *different* otherwise. In the "all-different" condition, the subject responded *same* if at least one digit matched and *different* if all digits differed. In either condition, the number of matching digits ranged from zero to four. The all-same results supported previous work: the fewer the number of mismatches, the slower the response, except that zero mismatches resulted in a response faster than one mismatch. These findings have been taken as supporting a two-process model: an identity detector mechanism and a self-terminating feature-matching process. An alternative one-process model could explain the results by assuming that the "same" response is primed during the match process. However, the all-different results showed reaction time to be a monotonic function of the number of matching digits. Such a finding contradicted the priming model and supported a two-process model.

Several studies have shown that when an individual has to judge whether two visually presented stimuli are the same or different, response time (RT) is shorter when the stimuli are in fact the same than when they differ in a single dimension or character (e.g., Bamber, 1969; Hawkins, 1969; Silverman, 1973). This finding suggested that the stimuli are processed in a holistic fashion, perhaps corresponding to a *template matching* process (Neisser, 1967). However, data from "different" judgments suggest that a *self-terminating feature testing* process operates to detect loci where the two stimulus members do not correspond. Bamber (1969) resolved these two conflicting results by proposing a dual process model to account for the data. An "identity reporter" stage signaled only "same," and functioned in a *template matching* mode, and a feature testing stage signaled "different" (or "same" when the "identity reporter" failed to detect the homogeneity). Silverman (1973) modified Broadbent's (1958) model in order to avoid Bamber's assumption of a separate and independent "identity reporter," and proposed that the "identity reporter function" could have resulted as a by-product of the normal information flow within a more traditional processing model.

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Briefly, part of Broadbent's original model described information flow into the nervous system as follows: (a) information comes from the environment to the senses; (b) it passes from the senses to some short-term storage (STS) area, where (c) a filter selects what information to pass on for further processing through considerations of perceptual set and expectancies to (d) a limited-capacity channel (LCC) that handles detailed processing of the stimulus input in some appropriate form.

Once the notion of a selective filter is accepted, how is the filtering accomplished? A process whereby relevant information or dimensions are selected implies a decision mechanism within the filter, and this decision must be based on expectancy, set, and information already input into the LCC. In order for all factors to be considered, it seems that the filter should have some capacity to store information for brief periods. Conceptually, this store could take the form of a rapidly decaying memory trace that serves to guide the filter in picking out relevant dimensions, and prevent features already read into the LCC from being immediately and endlessly repeated.

It is possible that in the matching task, the selective filter reads in the first item of the stimulus pair and then scans the second item for some new relevant information (signifying pair incongruence). In order to perform this comparison, the filter must have available the set of features from the first item; the most efficient method of maintaining these features for reference would be to store them in a buffer within the filter. As

this storage buffer operates by storing a set of rapidly decaying traces, only simple stimuli can be completely scanned by the filter before some of the original first-item information is lost.

If the stimulus pair can be compared without information loss, the filter can report that (a) there is no new information in the second pair member, i.e., a "same" response is appropriate, or (b) the second item contains new relevant information, i.e., a "different" response is appropriate. However, because some information loss is always possible, and anything in the second stimulus item that is not in the set of first-item features now stored in the filter must be judged as new information requiring a "different" response, the different decision can never be made at the filter read-in level, even for simple stimuli. The filter can only read the feature in question into the LCC, where a decision is made through a feature testing mechanism as to whether an actual stimulus difference exists or whether the observed "new" information was the product of buffer decay.

Within this processing scheme, a correct "same" response is the result of either a signal from the selective filter that the second stimulus member contains no new relevant information or the end result of *self-terminating* feature testing. A correct "different" response is always the result of the feature testing process.

However, several explanations of these results are possible within single-process models. Krueger (1973) suggested that the difference between "same" and "different" RTs might be an artifact of stimulus sampling, as the total number of possible "same" pairs is less than the number of possible "different" pairs. For instance, if the stimuli consist of letter pairs, there are only 26 possible "same" stimuli while there are 650 (26×25) possible "different" stimuli. Therefore, the possibility that any single stimulus is repeated is greater for the "same" than for "different" stimuli, and RTs for the repetitions could be faster than RTs to novel stimuli. Krueger's results did not support the stimulus sampling artifact as the explanation of the $RT_{\text{same}} < RT_{\text{diff}}$ finding. Silverman (1973) also found that "same-different" RTs to pairs of five-digit numbers showed that RT_{same} was less than RT_{diff} (with one item different) although no specific stimulus was repeated, and Nickerson (1973), using single-letter pairs as stimuli, manipulated the probability of specific items and found that repetition effects could not account for the "identity reporter" effect.

Grill (1971) implied another possible explanation of the $RT_{\text{same}} < RT_{\text{diff}}$ result. She noted that as feature testing proceeds without the detection of a difference between the two stimuli the conditional probability that a difference is present drops. The "same" response might then be "primed" and if a "difference" is detected late in processing the "primed" response

would have to be inhibited before the correct "different" response could be made. This possibility cannot be eliminated when the two response probabilities are kept equal if multidimensional stimuli are used. However, if unidimensional stimuli are matched, determination of processing differences between "same" and "different" judgments is impossible because evidence of a self-terminating mechanism as the determinant of the "different" decision cannot be obtained. All responses must be based on functionally exhaustive processing. Grill manipulated the response probabilities in order to attempt control of this potential "priming," but a bias favoring the "different" response may have resulted, making the data difficult to interpret clearly.

The present study attempted to replicate the earlier results of Silverman (1973), and to examine this "priming" mechanism while using complex stimuli and maintaining equal response probabilities. This was accomplished by changing the basic task form for one of the experimental conditions. Past investigations required the presence of a minimal difference in order to define the "different" response and total homogeneity to define the "same" response. One condition of this experiment, termed "all different," reverses this defining scheme, with unanimous difference defining the "different" response and minimal commonality defining the "same" response. Thus, in this condition, an exhaustive search is required to reach a "different" response decision while a "same" response can be signaled when any common stimulus elements are detected. In this condition, the tendency toward "priming" should then favor the "different" response; as processing continues without the detection of any pair congruity, the conditional probability that common elements are present drops. If response "priming" was responsible for the $RT_{\text{same}} < RT_{\text{diff}}$ (with one pair differing) result in past experiments, an $RT_{\text{diff}} < RT_{\text{same}}$ (with one pair matching) result should be found in the present study in the "all different" condition.

Nickerson and Pew (1973), using a similar task requiring the matching of pairs of two letter sequences, have found that RTs to totally "different" stimulus pairs were slower than RTs to pairings containing common elements if one response was defined by unanimous difference. Also, RTs to totally "same" stimuli were faster than RTs to "different" pairings when "identity" defined one response. These results seem to contradict a response "priming" model, but in the Nickerson and Pew experiment the "all different" judgment was not the inverse of the "identity" judgment. Subjects were required to find any common items in the "total different" condition, ignoring order information. While in the "all same" condition, subjects had to make two comparisons in order to reach a correct "same" judgment (the first and the second

member of each pair had to be matched); for the "all different" condition, subjects had to make four comparisons in order to reach a correct "different" judgment (the first and second member of one stimulus had to be compared to both the first and second member of the second stimulus). The irrelevance of order information therefore makes interpretation of the result unclear. In the present study, "difference" is defined as a pair difference in a specific sequence location, and any "priming" effect must be reflected in the results for both decision tasks.

METHOD

Subjects

Forty-four subjects, enrolled in introductory psychology at SUNY at Buffalo, volunteered for participation in this study in order to help fulfill a course requirement. There was no further compensation.

Stimuli

All stimuli were pairs of four-digit numbers presented simultaneously, one directly above the other. Each four-digit number was generated randomly by computer; the digits "8, 9" were not used. In order to avoid obvious visual patterns, no two consecutive digits were the same, and all stimuli were used only once. The number sequences were typed and photographed, and the negatives were used to make slides. The actual stimuli were viewed as bright numbers on a dark gray background. When projected, the entire stimulus array was approximately 5.72 cm square and subtended a visual angle of $1^{\circ}10'$ when viewed by the subject.

Examples of the various types of sequence pairings are given in Table 1. For the "all same" (AS) condition, there were four types of "different" stimuli, representing various levels of pair difference (1, 2, 3, or 4 positions differing between the two pair numbers). For each level of difference, the specific locus of difference varied randomly over all possible positions. There were a total of 10 stimulus pairs for each level of stimulus difference, yielding a total of 40 "different" slides. These were combined with 40 "same" slides, consisting of two identical number sequences, to yield a total of 80 slides which were grouped into five blocks containing two examples of each difference level and eight "same" slides. Within each block, the slides were ordered randomly, the only constraint being that not more than five successive trials required a similar response, and the blocks were combined to form the final order of stimuli for the AS condition.

The "all different" (AD) condition was similarly constructed, although no specific stimulus from the AS condition was duplicated. Here, however, there were four levels of pair "sameness" (1, 2, 3, or 4 positions being the same for the two pair members). Again, for each level of "sameness" the specific "same" position(s) varied randomly. There were a total of 40 "same" pairs (10 for each level of "sameness") which were matched with 40 "different" pairs differing in all four digits. The order of slides within the AD condition was analogous to that of the AS condition.

Apparatus and Procedure

Subjects were seated at a desk in a darkened room. On the desk were two response keys, mounted 2.5 cm apart, which subjects operated with the preferred hand. One half of the subjects responded "same" with the index finger, while the remainder responded "same" with the middle finger. Stimuli were presented by a Kodak 900 Carousel slide projector, and projected onto a screen 264 cm in front of the subject. The stimulus duration, controlled by a Gerbrandt (Model G-1166) tachistoscopic shutter mechanism mounted in front of the projector, was 2.5 sec for all

Table 1
Stimulus Types and, in Parentheses, the Frequency of Occurrence of Types Within Each Condition

Stimulus	Number of Positions Diverging from Unanimity	
	All Same	All Different
ABCD ABCD	0 (40)	4 (10)
ABCD ABCE	1 (10)	3 (10)
ABCD ABDF	2 (10)	2 (10)
ABCD ACEF	3 (10)	1 (10)
ABCD EFGH	4 (10)	0 (40)

stimuli. A Standard clock (Model F-1) measured the time between stimulus onset and the depression of one of the response keys to the nearest 10 msec. Between trials, there was an interval of approximately 5 sec when the subject's response and RT was recorded. No feedback was given during the experimental session.

Subjects were randomly assigned to the AD or AS condition, and were instructed as to the exact nature of the task and stimuli; both speed and accuracy were emphasized. Twenty subjects were assigned to the AD condition and 24 subjects to the AS condition.¹ Before the actual experimental trials, the subjects were given 24 practice slides, consisting of pairs of letter sequences similar in construction to the test stimuli. The subjects were then presented with the block of 80 experimental trials, and the first 16 trials were counted as additional practice.

RESULTS

Median RTs were calculated for each subject in each condition from only correct responses, and the means of these medians are illustrated in Figure 1. Statistical analysis of the RT data was done in parts. First, a three-way analysis of variance (Conditions by Number of Incompatible Positions (NIP) by Subjects within Condition) was run on the RTs from only the points which required an "incompatible" response (i.e., excluding the "same" response in the AS condition and the "different" response from the AD condition). The NIP main effect and the Condition main effect were both significant, $F(3,126) = 106.20$, $p < .01$, and $F(1,42) = 5.85$, $p < .05$, respectively. The interaction was also significant, $F(3,126) = 2.78$, $p < .05$, and further analysis showed that this was due to the linear component of the interaction, $F(1,126) = 7.26$, $p < .01$.

The second part of the data analysis compared the RTs from the "unanimous" stimuli (the "same" pairs from the AS condition and the "different" pairs from the AD condition) to the RTs from the stimuli with only one position indicating a pair incompatibility (NIP(1) from both the AS and AD conditions). This analysis showed that the AS was faster than the AD condition, $F(1,42) = 46.44$, $p < .01$; the NIP(1) were faster than

Figure 1. Reaction time and error rate (in percent) as a function of the number of positions incompatible with the "unanimous" response (NIP) for the two experimental conditions. (For the AD condition, NIP(0) represents "different" responses, while for the AS condition, NIP(0) represents "same" responses.)

the NIP(0) stimuli, $F(1,42) = 13.63$, $p < .01$; and NIP interacted with Condition, $F(1,42) = 83.62$, $p < .01$. Follow-up analyses on the individual conditions showed that for the AD slides RTs were faster to NIP(1) than to NIP(0) stimuli, $F(1,19) = 53.59$, $p < .01$, while for the AS condition the relationship was reversed, $F(1,23) = 24.70$, $p < .01$.

The last aspect of the analysis of the RT data compared the obtained results with predictions of a *serial self-terminating* processing model. Such a model implies that the obtained RTs should be a linear function of the average number of comparisons made between the elements of the two stimulus pair items.² To test this, four correlation coefficients (Pearson r) were calculated. For only the "incompatible" data, the correlations between the obtained results and the expected number of digit pairs processed were significant for both the AS and AD conditions, $r = 0.989$ and $r = 1.000$, respectively, $p < .01$. However, the correlations between the obtained results and the expected number of digit pairs processed when all the data from each condition were included in the analysis showed a different picture. For the AD condition, the correlation remained unchanged ($r = 1.000$), while for the AS condition, the correlation dropped to insignificance, $r = 0.516$, $p > .1$.

The overall percent of erroneous responses was 3.3%. The error data, illustrated in Figure 1, showed the same type of picture as the RT data. Analysis of

variance revealed that the AD condition had a higher error rate than the AS condition, $F(1,42) = 6.40$, $p < .05$, and the error rates for the NIP main effect were significantly different, $F(4,168) = 36.84$, $p < .01$. This significant NIP effect was due to the larger error rate of the NIP(1) groups when compared to the other groups, $F(1,168) = 135.53$, $p < .01$, and a larger error rate for the NIP(2) groups when compared to the NIP(0), NIP(3), and NIP(4) conditions, $F(1,168) = 5.59$, $p < .05$. No other groups differed significantly.

A significant NIP by Condition interaction was also present, $F(4,168) = 9.42$, $p < .01$. A breakdown of the interaction showed that the only difference accounting for the significance of the result was a higher error rate for the NIP(1) group of the AD condition than the NIP(1) group of the AS condition, $F(1,168) = 36.16$, $p < .01$.

DISCUSSION

The results of the present study replicated earlier findings of Silverman (1973), and showed that the RT_{same} data from a typical "same"-"different" task (the AS condition) did not fit a self-terminating model that successfully fitted the $RT_{\text{different}}$ results.³ The result was obtained without any stimulus repetitions, and therefore also supports the findings of Nickerson (1973) and Krueger (1973) which implied that stimulus repetition artifacts cannot account for the deviation of the "same" response data from a self-terminating processing model.

The effect of response priming also seemed eliminated as a possible explanation of the present data. The $RT_{\text{different}}$ data from the AD condition fitted a self-terminating model nicely, while the RT_{same} data from the AS condition did not. Any response priming should have been operating in a similar fashion for both conditions, yet the "identity" decision yielded the only data point diverging from self-terminating processing. The error data further support the notion of a real processing difference between the "identity" judgment and the others. The very high error rate found for the NIP(1) stimuli of the AD condition implied that any speed-accuracy tradeoff accelerating "same" judgment in the AS condition should have had a greater effect on the "different" judgment of the AD condition.

The divergence of RT_{same} in the AS condition from self-terminating processing does fit the dual process model described earlier (Silverman, 1973). If the "same" judgment is the end product of self-terminating feature testing on some trials and the result of a match at the filter read-in level for other trials, the average RT_{same} should be somewhere below the expected value calculated on the basis of a single-process self-terminating model. In contrast, the

"different" response in the AD condition could never be detected at the filter read-in level. "New" second-item features could always have resulted from decay in the filter's storage buffer, necessitating further information processing. The final "different" judgment must therefore be the end result of an exhaustive feature comparison process.

The difference in the RT functions of the AS and AD conditions plotted against NIP for the "incompatible" stimuli indicated that subjects processed information more efficiently for the AS than for the AD instructions. There does not seem to be any obvious theoretical reason why this difference should have occurred. If a digit position-by-position comparison took place for each stimulus pair, as was indicated by the high correlations between the obtained data and the expected number of pairs processed to respond correctly, the time to locate a "match" in the AD condition should have been equal to the time to locate a "nonmatch" in the AS condition if each digit was processed exhaustively (i.e., each digit was an "integral" stimulus, Lockhead, 1972). But if the comparison between the members of a single-digit pair was self-terminating, the slope of the AD condition should have been less than that of the AS condition as NIP decreased from four to one, as any pair "match" should have taken longer than a pair "nonmatch," but this prediction is opposite in direction to the obtained result. (For the AD condition, the number of "nonmatches" increased, while for the AS condition, they decreased as NIP decreased).

Some ambiguity certainly remains regarding the nature of the information processing involved in this type of matching task. However, the results of this study strongly infer processing differences between "same" and "different" judgments when "same" is defined as stimulus pair "identity," and it appears that a dual-process theoretical system is needed to fit the data from this type of matching task. Several two-process models were discussed by Nickerson (1971) and Silverman (1973). Although the model proposed by Silverman has been discussed in detail, the data in the present study is also compatible with other dual-process models, and there are no strongly compelling advantages of any particular model over the others; the present question was whether or not any dual-process system is needed to account for this type of data. There seems to be no way of explaining the

present results within any single-process system, and therefore some dual-process system seems the only workable theoretical framework that accommodates the "same"-"different" data.

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NOTES

1. The last four subjects of the AD condition could not be run due to equipment failure.
2. Assuming there are four pairwise comparisons possible, the expected number of comparisons made for the conditions are: $NIP(0) = 4$, $NIP(1) = 2.5$, $NIP(2) = 1.67$, $NIP(3) = 1.25$, and $NIP(4) = 1$.
3. A serial model was used to test the self-terminating nature of data rather than an analogous parallel model, which could have fit the data equally well. The critical feature of the obtained results was their self-terminating vs. exhaustive aspect, and whether a parallel or serial process is involved is irrelevant for the purpose of this investigation. No exhaustive model can predict the results obtained for the "incompatible" data.

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