

## Response competition effects in *same-different* judgments

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An account of *same-different* discriminations that is based upon a continuous-flow model of visual information processing (C. W. Eriksen & Schultz, 1979) and response competition and inhibition between the responses by which the subject signifies his judgment is presented. We show that a response signifying *same* will on the average be executed faster due to less priming or incipient activation of the competing response, *different*. In the experiment, the subjects matched letters on the basis of physical identity. The degree of priming of *different* responses on *same* trials and of *same* responses on *different* trials was manipulated by an extraneous noise letter placed in the display. Latency for judgments on *same* trials increased as the feature overlap of noise and target letters decreased. Latencies were shorter on *different* trials when the noise letter was dissimilar to either target letter than when the noise letter was the same as one of the targets. These results were consistent with the response-competition interpretation.

Tasks in which a subject is presented two stimuli and asked to determine whether they are the same or different have been employed to study a variety of human behaviors ranging from psychophysical functions to semantic processing. When employed in psychophysics, the primary dependent variable has been the accuracy of the subject's judgments, whereas, in the investigation of cognitive processes, the task has typically been used to measure the speed with which the subject could arrive at his judgment. Recently, the judgmental act itself has become a subject of increasing interest. Within the past few years, two major attempts have been made to provide a model of the processing steps involved in the subject's *same-different* discrimination (Krueger, 1978; Proctor, 1981).

One of the critical tests of such models has been their ability to account for the counterintuitive finding that *same* judgments often are made more rapidly than *different* judgments. As Nickerson (1975) has pointed out, the subject needs only one aspect or feature of difference between two stimuli for a correct *different* judgment but a correct *same* judgment requires the comparison of the stimuli on every possible feature. The latter operation would appear to require more processing and greater time.

Krueger (1978) has proposed a "noisy operator" theory that assumes that, on a certain proportion of trials, a high difference count between two identical stimuli can be obtained due to random noise in the

perceptual system. Due to erroneous *different* counts that can arise on *same* trials, the subject is required to recheck on true *different* trials. The time required for the recheck operation leads to longer reaction times for *different* judgments, since a large proportion of the *same* trials are not affected by the sensory perceptual noise.

Proctor's (1981) model attributes the longer latencies required for judging *different* stimuli to inhibition in the naming responses. Identical stimuli activate only one naming response, but different stimuli activate two. The two activated name codes mutually inhibit each other, thus slowing processing.

The model we are proposing is similar to Proctor's (1981) in that we attribute many of the observed results of *same-different* judgments to inhibition arising from competing responses. However, our model differs in that we believe the inhibitory effects of competing responses are more pervasive than Proctor's theory envisages. Their locus of action extends not only to naming responses, but also to overt responses by which the subject signifies that the stimuli are the same or different. Specifically, we believe that there need be no difference in the speed with which processing for *same* and *different* is carried out and that, in fact, detection or recording of differences may actually be faster but the execution of the overt response signifying *different* is delayed due to a greater degree of priming in the competing response signifying *same*.

In order to understand the model we propose, it is necessary to briefly review some of our work on response competition that has been performed over the past several years. B. A. Eriksen and C. W. Eriksen (1974) and C. W. Eriksen and Hoffman (1973) discovered that the type of response competition supposedly

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underlying performance on the Stroop task (Stroop, 1935) was a much more pervasive effect than previously had been assumed. It was found, for example, to be a potent variable determining performance in visual search. B. A. Eriksen and C. W. Eriksen (1974) used a rather simple paradigm in which four letters were divided into two sets of two each (H and K and S and C). The subjects were instructed that one of these target letters would appear in the display directly above the fixation point and that they were to move a lever in one direction for an H or a K and in the opposite direction for an S or a C. They were further instructed that if other letters appeared in the display at other positions, such letters were to be ignored.

Appreciable increases in reaction time (RT) to classify the target letter occurred if the letter was flanked by letters of the opposite response set. When the target letter was flanked by repetitions of itself or by the other letter in the same response set, RT was but little affected over a no-noise control condition. Intermediate effects upon RT were obtained when neutral letters (letters not having an experimentally defined response) were used as noise. The amount of the effect was dependent upon the letter's feature overlap with the target or the alternative response set. Thus, when the target letter was H, the neutral noise letter N produced less interference in RT than did the neutral letter O. The converse held when the target letter was S. In subsequent work, this response-competition paradigm was extended to simultaneous *same-different* judgments (Keren, O'Hara, & Skelton, 1977; O'Hara, 1980; O'Hara & C. W. Eriksen, 1979).

There are several clear conclusions that can be drawn from these response-competition experiments. First, it is quite apparent that subjects cannot attend solely to the relevant target elements and ignore the noise. The noise elements are processed unselectively with the targets and to the same level of processing as required for the task (Keren, O'Hara, & Skelton, 1977).

Second, the processing of the noise letter is carried to the level of incipient response activation. The effect of noise cannot be attributed to interference on the input side of processing. This conclusion follows from the finding that the effect on RT is determined by the compatibility of the responses. Maximum impairment in RT is obtained when the noise element calls for an incompatible response, and only minimal effects are obtained if the noise is physically different from the target but is response-compatible. Further, O'Hara, Morris, Coles, C. W. Eriksen, and Morris (1981) found evidence of incipient response activation by the noise letter in the form of electromyographic activity in muscles associated with the response appropriate to the noise. They used a response-competition paradigm in which subjects were instructed to respond to one letter with a buttonpress with the right hand and to another letter with the

left hand. When the target letter was accompanied by noise letters of the opposite response class, electromyographic activity was detected in the forearm of the "incorrect" arm even during the occurrence of a correct response by the other hand.

Third, spatial location is processed at least partially independently of identification (B. A. Eriksen & C. W. Eriksen, 1974; C. W. Eriksen & B. A. Eriksen, 1979; C. W. Eriksen & Schultz, 1979). Some of the aspects of the data in these studies were consistent with the interpretation that the subjects knew the identity of the targets and noise before information was available as to which positions were occupied by which stimuli. Similar findings have been reported by Estes, Allmeyer, and Reder (1976) and by Treisman and Gelade (1980).

These conclusions have been used by C. W. Eriksen and Schultz (1979) as the departure for a continuous-flow model of visual information processing. Since the visual system integrates energy over time, C. W. Eriksen and Schultz posit that visual information in the form of the percept develops over time, with the time interval involved being as long as several milliseconds. This developing percept is somewhat analogous to what would be experienced if a complex visual form were presented in a tachistoscope, first at a very brief duration and then at successively longer exposures.

C. W. Eriksen and Schultz (1979) reject discrete stage models in which information processing awaits full development of the percept. Instead, they propose that, as the percept is developing, relevant responses begin to receive a priming flow. Early in the growth of the percept, a wide range of responses are given an initial priming, but as the percept develops, the priming flow is restricted more and more to those responses that still remain viable alternatives commensurate with the degree of clarity of the developing information.<sup>1</sup> Recognition and other responses occur when the information in the developing percept has primed the relevant response to a criterion level at which the response occurs. The speed of execution of the response, however, depends upon the level of priming in competing responses. The response competition that exists in a given situation depends upon the number of competing responses that have been activated and upon the level of priming that they have received. The continuous-flow model further assumes that the effect of set, expectancy or instructions is to preprime the relevant responses so that less priming flow from the developing percept is required for these responses to reach criterion and evocation.

With this brief review of response-competition effects and the continuous-flow model, we are now in a position to provide an account of *same-different* judgments for simultaneously presented stimuli. As the percept begins to develop, a comparator starts to detect both similarities and differences between the stimuli.<sup>2</sup> If the stimulus pair are different, but not

grossly so, the two stimuli will have many features in common, particularly at the early levels of percept development. On the average, the percept will need to develop rather fully before a difference is detected. But before this difference is detected, a number of similarities will have been noted. Each similarity, as it is detected, primes a *same* judgment and the response (buttonpress, vocalization, etc.) by which this judgment is conveyed. Thus, on the average, with stimuli that are similar, although different, the response signifying *different* reaches evocation threshold with a high level of prime in the competing response that signifies *same*. This priming of the competing *same* response inhibits and slows the execution of the *different* response.

If the stimulus pair are identical, the developing percept again leads to an increasing flow of prime to the *same* judgment and the response signifying *same*. But, since the stimuli are identical, no priming of a *different* response occurs, except on those relatively infrequent trials on which random noise in the sensory-perceptual system leads to an apparent difference (Krueger, 1978). Thus, when the evocation threshold for *same* is reached, the execution of the response is not impeded by inhibition arising from a primed *different* response. As a consequence, the response signifying *same* will be executed with a shorter latency, on the average, than that of the response signifying *different*.

We will assume that the two overt responses by which the subject signifies *same* and *different* can have a different criterion for evocation. The *different* response requires detection of only one featural difference between the stimuli. The criterion for evocation of an overt *different* judgment is the confidence that a difference in features or characteristics of the stimuli has been detected. A *same* response, on the other hand, requires detecting sameness on all features of the stimulus pair, which may require a rather high level of development of the percept so that features requiring high resolution are available. The criterion for the *same* response is the confidence level the subject sets that all relevant features in the stimuli have developed enough in the percept to be detected. If the differences in the set of stimuli to be matched are gross and require little resolution, the subject can set his or her criterion for a *same* response lower than if the differences are small and require a high degree of visual acuity and, therefore, a percept that affords more resolution.

Since visual stimuli, or forms, vary with respect to complexity or the number of underlying dimensions, there would appear to be a problem with postulating a similarity detector, or counter. The number of possible points of similarity would vary between pairs of stimuli, and thus the subject could not set a criterion of how large the similarity count must be to execute a *same* judgment. We believe this problem is avoided by the recognition that the per-

cept develops gradually over time and the assumption that the criterion for the *same* response is not the *number* of detected or noted similarities but, rather, the confidence that the percept has developed far enough that any differences *would* have been detected.

From this conception we would expect the subject to adjust his criterion for execution of a *same* response to the sample of the stimuli he is judging. If the differences between stimuli are gross, *same* responses will be fast because the subject does not need to await a level of percept development that reveals fine detail. On the other hand, if the differences are minute and require a high level of visual acuity, the subject must await a percept that is developed enough to reveal this level of detail. In a typical *same-different* experiment, the subject makes hundreds of judgments. In the early phases of the experiment, the subject receives enough experience with the stimulus sample to adjust his or her criterion for *same* on the basis of the appropriate level of percept development.

Errors on *different* trials occur when the subject's criterion is set so low that a *same* judgment is made before the percept has developed enough to permit discrimination or detection of all the relevant characteristics of the stimuli. In this latter instance, the subject most likely will know almost immediately that he has made an erroneous response, since the difference will become apparent as the percept continues to develop. For errors on *same* trials, we will assume as Krueger (1978) has done that there is random noise in the visual perceptual system that leads occasionally to apparent differences in the developing percept, which, in turn, trigger an incorrect *different* judgment.

A test of this response-competition model can be made by (1) varying experimentally the amount of priming of the *different* response on *same* trials and (2) by varying the amount of priming of the *same* response when different targets are presented (*different* trials). The model would predict that the RT advantage for *same* judgments would decrease and actually become longer than for *different* trials if sufficient priming of the *different* response was provided on trials on which a *same* judgment is called for. Similarly, on trials on which the stimuli are different, the latency of the *different* response would be increased by increased priming of a competing *same* response. Although the logic of the test is simple, the methodology is a bit more complex. Obviously, one cannot introduce differences in identical stimuli in order to prime a *different* response when a *same* judgment is called for.

A solution to this methodological problem is available in the procedure used by Keren, O'Hara, and Skelton (1977). These investigators modified the simultaneous matching paradigm for letter stimuli by introducing an extraneous noise letter into the dis-

play simultaneously with the target stimuli. Although their experiments were addressed to different issues, their results were highly consistent with our continuous-flow/response-competition model. When the noise letter was different from the target letters on a *same* trial, the RT for the *same* judgment was markedly increased. On the other hand, when the noise letter was identical to the targets, RT was but little affected. On *different* trials, a noise letter that was identical to one of the targets resulted in significantly longer latencies than when the noise letter and the targets were all different letters.

The interpretation of these findings in terms of our model is as follows. The noise and target letters are processed essentially simultaneously. The comparator process detects similarities and differences not only between the targets, but also between the target letters and the noise letters. Each similarity or difference that is noted contributes to the priming of the associated response. Location in the visual field of the letters being compared is at least partially independently processed. Thus, the detection of a similarity or difference between letters must be collated with location information as to whether the letters are in the target or noise positions in the display. If, for example, a difference between a target and the noise letter is noted, location correction occurs. But the prime that the noted difference contributes toward the evocation of the response signifying *different* does not decay immediately. Each difference detected contributes to the priming of the *different* response whether or not the difference is between the targets or between a target and the noise letter. The same is true for the detection of similarities.

The need to collate *similarity* and *difference* detections with location requires the subject to set a higher criterion for the release of the inhibition that holds in check the overt responses signifying his judgment. As a consequence, latencies are longer when the experimental task involves trials on which a noise letter can be present than when the subject knows that only the targets will be presented in the display (C. W. Eriksen & B. A. Eriksen, 1979; C. W. Eriksen & Schultz, 1979).

In the Keren et al. (1977) experiments, the subject had essentially a conjoint discrimination. He had to not only detect similarities and differences but also assign or correlate them with spatial location in the display. The presence of a noise letter in the display that did not match the identical targets resulted in detection of differences that primed the response signifying *different*. This priming remained when collation with spatial information occurred, and the response signifying *same* was slowed by the inhibition arising from the priming or incipient activation of the competing *different* response.

On *different* trials on which the noise letter was identical to one of the targets, the detection of the similarities between these two letters resulted in the

priming of the response signifying *same*, with the result that the *different* judgment was slowed by the inhibition of the primed *same* response. A greater degree of priming of the *same* response would be anticipated when the noise matched one of the target letters than when all letters in the display were unique, a result consistent with the results obtained by Keren et al. (1977).

While a response competition model provides a good account of the Keren et al. (1977) data, it does not necessarily require that response competition occurs in the traditional matching experiment, on which noise stimuli are not present. If the comparison process were at the holistic level, one would expect competition when noise was in the display but not when only the targets were presented. If the two targets A and E were presented along with a noise letter A, a comparison of the letters as wholes would prime the response signifying *same* whenever the target A was compared with the noise A. But if only the targets were present in the display, a holistic comparison ordinarily would not lead to priming of this competing response.

The continuous-flow model, with its conception of the developing percept, requires that stimuli are processed to response priming and identification on the basis of features or characteristics that become available gradually over time in the developing percept. It is the similarity and differences in these developing features that prime the responses signifying *same* and *different*. Thus, a noise letter does not need to be present when a nonmatching pair of targets are presented in order for the response signifying *same* to receive priming. If the two nonmatching letters have features in common, their detection will lead to the priming of the response for *same*.

A test of the continuous-flow/response-competition model of the typical matching task can be made using the technique of noise stimuli. If the noise stimuli or letters are varied in their similarity to or feature overlap with the targets, we can determine whether similarity and differences are being detected at the feature level and not holistically.

In terms of our model, the noise-letter similarity to or feature overlap with the target letters should directly affect the latency of *same* responses when subjects are judging the targets on the basis of physical identity. The latency for *same* judgments will be greater when noise and target letters have minimal feature overlap than when they share a larger degree of featural identity.

### Experimental Design and Rationale

The subjects were instructed to respond *same* when the target stimuli were physically identical. The capital letters S and H were used as the targets to be matched. They occurred in known locations, to the right and left of the fixation point for one group of subjects and above and below the fixation point for a

different subject group. These particular letters were chosen because they have low feature overlap in the Gibson system of feature matching (Gibson, 1969) and low confusability (Gilmore & Hersh, 1979). The capital letters C and K were chosen as noise stimuli because C and S have similar features and K and H have similar features.

The response-competition model makes the following predictions. On *same* trials on which the noise letter is identical to the targets, latency for *same* judgments will be shortest in the control (no-noise) and identical-noise conditions, increase when the noise letter is different from but similar to the targets, and will be longest when the noise letter has the greatest dissimilarity to the targets. For *different* trials, latencies will be shortest under the no-noise condition and when all three letters, targets and noise, are different. Latency will be increased when the noise letter is identical to one of the targets. Furthermore, the latency advantage of *same* over *different* responses will decrease (perhaps the relation will reverse) as the noise letter present on *same* trials increases in dissimilarity.

## METHOD

### Subjects

Six women and two men, undergraduates from the University of Illinois at Urbana-Champaign, served as paid volunteers. All were right-handed and had normal or corrected-to-normal vision.

### Apparatus and Stimuli

The stimuli were presented in a Scientific Prototype Model GA three-field tachistoscope equipped with Sylvania F4T5/CWX fluorescent lamps. Luminance in all three fields was maintained at 9 fL, as measured by a Spectra brightness spot meter. The subject initiated the onset of the stimulus by pressing a button held freely in the left hand. This triggered the tachistoscope and also a Hunter Model 1522 digital Klockounter. A hand rest located to the right of the subject contained a small lever that could be moved either right or left, depending upon the category judgment made by the subject. When the subject moved the lever in either direction, the Klockounter was stopped and light located below the Klockounter indicated which response the subject had made. RT was recorded in milliseconds.

The target and noise letters were all black uppercase letters selected from Zip-a-Tone Futura demibold 24 didot point transfer lettering. Each letter subtended .3 deg of visual angle in height. The letters were presented against white vinyl card backgrounds.

There were four different target displays consisting of all four possible permutations of the letters H and S. These targets provided two *same* displays and two *different* displays. For half of the subjects, the target letters were always positioned one above and one below the fixation point, their positions corresponding to the clock positions 12 and 6 o'clock. The two target letters were separated by 2 deg of visual angle. For the other four subjects, the target letters were always positioned one to the left and the other to the right of the fixation point, their positions corresponding to the 3 and 9 o'clock positions. They were also separated by 2 deg of visual angle.

The fixation point was an off-white dot .15 deg of visual angle in diameter. Although the background card was also white, there was enough contrast between the fixation and the background so that the fixation point was readily visible. A white fixation point was selected because it would not interfere significantly with the

processing of noise letters that would appear in this location during some of the stimulus presentations.

There were four kinds of *same* displays corresponding to the different noise conditions. In the no-noise condition, the display consisted of only the two target letters to be matched. Under the target-noise-identical condition, either the noise letter H appeared with the target pair of Hs or the noise letter S appeared with the target pair of Ss. For the target-noise-similar condition, either the noise letter K was presented with the target letter pair of Hs or the noise letter C was presented with the target pair of Ss. For the target-noise-dissimilar condition, the noise letter K appeared with the target pair of Ss, the noise letter C appeared with the target pair of Hs, and an H occurred as noise with target Ss or an S occurred with target Hs.

For the *different* displays, there was a no-noise control condition in which the target pair S and H appeared as the sole letters in the display. On the remainder of the *different* trials, S and H appeared with each of the four letters S, H, C, and K, which were used equally often as the accompanying noise letter. For both groups of subjects, the distance between the noise and target letters was 1.4 deg of angle on half of the trials and 1 deg on the other trials. For the subjects with vertically arranged targets, the noise letter was placed to the right or left of fixation at a distance of 1 deg and thus at a diagonal distance from either target of 1.4 deg of visual angle. The noise letter appeared, to the right and left equally often. For the subjects with the horizontally arranged targets, the noise letter was similarly located above or below the fixation dot. On trials on which the target and noise letter were separated by only 1 deg of angle, the noise letter occurred at fixation for both subject groups.

### Procedure

The subjects were instructed to initiate each trial by pressing a pushbutton (held in the left hand) when the fixation point was in clear focus. The fixation field was replaced for 100 msec by a blank white field, which in turn was replaced by the stimulus field for 75 msec. The stimulus field was then followed by the blank field for 100 msec, and, upon termination, the fixation field reappeared. The subjects were instructed to compare the two target letters on the basis of physical identity and to move the response lever with the right hand to the left (right) if the stimuli were physically identical and to the right (left) if they were different. Response directions were counterbalanced across subjects. Subjects were also instructed to attend only to the target letters. They were told that the target letters always appeared in exactly the same locations with reference to the fixation point and that any extra letters that appeared in the display were to be ignored. Their task was merely to respond *same* or *different* in response to the target letters only. The subjects were further instructed to respond as quickly as possible but to avoid guessing. Error trials were rerun later in the session. The subjects were also given accuracy and speed information after each trial.

Each subject participated in five experimental sessions. The first session was considered to be practice, and data collected during this session were excluded from analyses. Before data were collected during the other four sessions, 10 warm-up trials were given.

During each session, five blocks of trials were presented. One block was for the control condition and contained displays with only target letters. The other blocks were for the noise conditions. Two of these blocks contained displays with a noise letter directly in the center of the target letters. The other two blocks of trials had displays with the noise letter separated from the target letters in a diagonal direction by 1.4 deg of visual angle (at the 6 or 12 o'clock position for the horizontal target group and 3 or 9 o'clock for the vertical target subjects). All blocks contained an equal number of *same* and *different* target displays. In the blocks with noise letters, there were three *same* trials under each of four noise-letter conditions (identical, similar, dissimilar, and dissimilar-other target). The trials within each block were randomly presented, and the order of block presentation was counterbalanced over sessions to balance practice effects.

## RESULTS AND DISCUSSION

## Same Judgments

Mean RTs for *same* judgments were analyzed in a modified analysis of variance in which position of the target letters was a between-groups factor and the remaining variables (target letters H and S, noise distance, and noise type) were within-groups factors. The control, or no-noise, condition was not included in the analysis. The main effect for noise type was significant ( $p < .001$ ), as was the effect of noise distance ( $p < .001$ ). The only significant interaction was that of noise type  $\times$  noise distance ( $p < .01$ ).

Our major interest lies with the noise-type effect. In Figure 1, mean latencies for *same* judgments averaged across target letters and subject groups are shown as a function of the relation between the targets and the noise letter. Separate functions are plotted for the 1 and the 1.4 deg of angle distance between noise-letter and target-letter positions. The results show that when the subject is presented identical targets, the time he requires to move a lever to record a *same* judgment is a function of the amount of dissimilarity present in the total display. If the noise letter is identical to the target pair, response latency is not appreciably or significantly different from the latency for the no-noise control. If the noise letter is similar to but different from the target pair (a C with target Ss or a K with target Hs), response latency increases 33 msec over the identical-noise condition for the 1 deg noise spacing ( $p < .01$ ) and 16 msec for the 1.4 deg spacing ( $p < .01$ ). If the noise-letter dissimilarity is increased further (H or K with S targets or S or C with H targets), there is a further increase in response latency ( $p < .01$ ). These

results are in agreement with the continuous-flow/response-competition interpretation of the *same-different* task.

In accordance with this model, the developing percept of the displays is scanned for similarities and differences. The detection of similarity or difference primes a corresponding response. This priming is irrespective of the location of the detected similarity or difference. In the no-noise control and the identical-noise condition, no differences are detected except on those occasional trials on which there is noise in the sensory perceptual system. Consequently, there is little priming of the competing *different* response, and thus the execution of the *same* response is not impeded by inhibition from a response conflict. When the noise letter differs from the targets, detection of featural differences leads to priming for the *different* response. In the noise-similar condition, fewer differences will be detected than in the noise-dissimilar condition. The greater the priming of the different response, the greater is the response conflict in executing the *same* judgment.

The effect of target noise similarity held for both separations between target and noise letters, 1 and 1.4 deg of visual angle, with the 1 deg separation producing more interference with the *same* judgment when the noise letter differed from the targets. There are two possibilities for the greater interference effect of the 1 deg separation. At this separation, the noise letter was located at the fixation point, whereas at the 1.4 deg separation, the noise letter and the two target letters were all 1 deg angle from fixation. The fixation location may have made it more difficult to discriminate spatial location of targets and noise letters, but this possibility would seem to require an overall elevation in RT, during which spatial location of target letters and noise were sorted out. The failure to obtain differences for spatial distance of target and noise in the identical-noise condition argues against this explanation.

The second possibility is that the fixation location of a noise letter facilitated its processing. C. W. Eriksen and Schultz (1977) and Lefton and Haber (1974) have shown that RT to letters is faster at fovea center than at 1 deg of angle removed. Further, C. W. Eriksen & Schultz (1979) found suggestive evidence that the interference effect of the noise letter was greater if it preceded target letters by 100 msec. Thus, the fovea-center location of the noise letter, with its more rapid processing, may have given greater effect to response inhibition.

There was no significant or appreciable effect of target orientation in the present experiment. We had employed two groups of subjects, one for which the target letters were displayed horizontally, one on each side of the fixation point at positions corresponding to 3 and 9 o'clock. The other group had the target letters presented vertically at positions corresponding

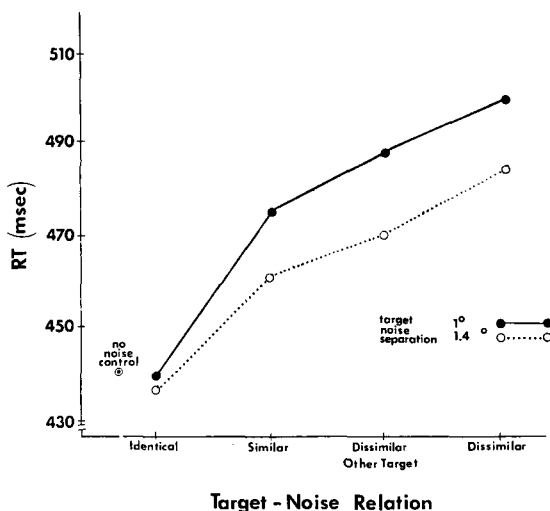


Figure 1. Mean reaction time for correct judgments of *same* as a function of target- and noise-letter similarity. The parameter in the figure is for the visual angle of separation between the noise and target letters.

to 6 and 12 o'clock. The F test from the analysis of variance had a value less than 1 for target orientation.

### Different Judgments

According to our model, some priming of *same* response occurs when the target letters are not identical. This priming of the incorrect response occurs even in the absence of a noise letter, because different letters normally do have some similarities or features in common, especially in the early stage of percept development. Differences between letters that require high acuity or resolving power in the visual system become apparent only at advanced levels of the percept development. The addition of a noise letter to the display permits us to vary the amount of priming that the *same* response will receive. In the present experiment, the *different* trials can be broken down into two kinds, those on which all three letters were different (e.g., targets S and H and noise C or K) and those on which the noise letter matched one of the target letters (e.g., targets S and H and noise S or H). Our model would predict longer response latencies for those trials on which the noise letter matched one of the two target letters. The incorrect *same* response on these trials would receive a higher degree of priming due to the detection of the common features between one of the target letters and the noise letter.

In Figure 2, latency for *different* responses is shown as a function of whether the display had all three letters different or two letters the same. Separate plots are given for the two levels of target noise separation. The data agree with the prediction. At both noise distances, the latency for the response *different* is significantly longer ( $p < .01$ ) when the

noise letter is identical to one of the targets. As with the *same* judgments, there is a significant effect ( $p < .01$ ) for noise-target distance. The explanations advanced for this effect with the *same* judgments would also apply for the different judgments.

There is an appreciable and significant increase in latency of different judgments when the display contains three different letters rather than only the two different letters in the no-noise control. Two factors may account for this. If three letters are present in the display, there would appear to be a greater probability for similarities between them to be detected during the early stage of percept development than if there were only two letters. Thus, the *different* response in the displays with three different letters is made with more competition from the competing response signifying *same*.

A second cause of this latency difference may be attributed to the use of blocked trials for the no-noise control. Data for this condition were obtained in blocks on which all trials were without a noise letter. C. W. Eriksen and B. A. Eriksen (1979) used the response-competition paradigm and compared no-noise trials that were blocked with no-noise trials that were intermixed with trials containing an opposite-response noise letter. They found that the blocked trials resulted in significantly shorter latencies, and attributed the result to the subjects being able to lower their response criterion on the blocked trials. When no-noise trials were intermixed with noise trials, the subjects had to set their criterion high enough to insure that location information was also processed so that they could avoid responding to a noise letter. When the subjects knew that the trials would contain only the target letter, the criterion no longer had to be high enough to insure location information in addition to identification.

Since location information is also necessary on noise trials in the present experiment, subjects also could have used a strategy of a lower response criterion for the blocked no-noise control. This lower response criterion would also have been applicable to the *same* judgments. We found no reliable difference between the no-noise control and the identical-noise condition for *same* judgments. However, if the subjects had been able to adopt a lower criterion on the blocked no-noise trials, this would have suggested that, had the no-noise trials been intermixed with noise trials in the experimental block, the latency for *same* judgments with identical noise would have been shorter than the latency for no-noise trials.

The response-competition model states that, in a typical matching experiment, differences may be processed faster than similarities but the longer observed latency for the *different* response is due to the slowing of the execution of this response by the inhibition resulting from priming in a *same* response. This response-competition effect is asymmetric in

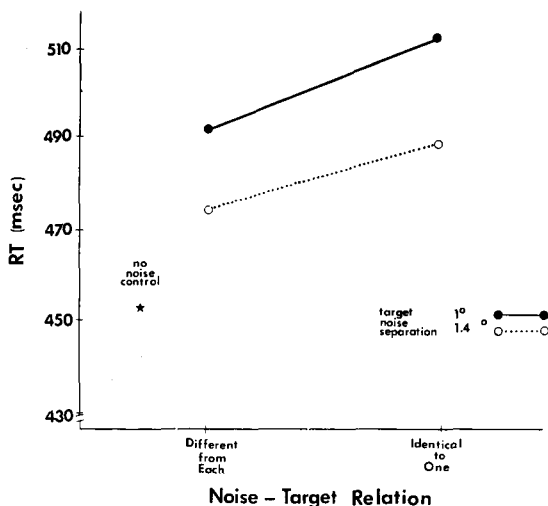


Figure 2. Mean reaction time for correct *different* judgments as a function of target- and noise-letter similarity. The parameter in the figure is for the visual angle of separation between the noise and target letters.

that *same* responses are not executed against as high a level of response competition as *different* responses. *Same* trials do not lead to as much priming of a competing *different* response. Based upon this formulation, we would expect that the latency difference between *same* and *different* responses would decrease and perhaps even reverse if a *different* response could be primed on trials on which the stimuli were identical. In the present experiment, on those trials on which no noise letter was presented, *same* judgments were made significantly faster than *different* judgments (440 msec, as opposed to 453 msec;  $p < .05$ ). However, if a similar but different noise letter was added to the display, *same* judgments were then 10 msec longer than *different* judgments ( $p < .05$ ), averaged over noise distance. The priming of a competing *different* response had reversed the relation between latencies for *same* and *different* judgments.

There may be some question as to whether the above was the appropriate comparison. The presence of a noise letter in the *same* display may have had an effect other than inducing response competition, and the comparison with the *different* judgment latencies for the no-noise control would thus not have been appropriate. The problem can be avoided by comparing the latency of *same* and *different* judgments when both types of displays contain a noise letter. The latency for *different* responses when all three letters in the display were different was 483 msec, averaged over noise distance. The comparable latency for *same* responses when the accompanying noise letter was dissimilar was 492 msec. In this comparison, both *same* and *different* displays had the complexity of a third letter, but the difference in latency between *same* and *different* judgments had been reversed.

### Errors

An analysis of errors complemented the results from the latency data. For *same* trials, the percentage of errors increased as the dissimilarity between the noise letter and the target increased. Errors for identical noise were 2.1%, for similar noise, 8.8%, and for dissimilar noise, 10.6%. A positive correlation between latency and errors was also obtained for *different* judgments. In keeping with previous findings (see Krueger, 1978), more errors were made on *same* trials. Averaged over the experimental conditions, the error rate on *same* trials was 7.8%, as contrasted with 5.6% for *different* trials.

## GENERAL DISCUSSION

The results we have obtained in the present experiment are quite robust in that other investigators who have used extraneous noise stimuli in matching tasks have obtained quite similar results. In addition to the Keren et al. (1977) experiment, Krueger (1973)

used noise consisting of underlines, plus signs, and equal signs. These noise stimuli increased latency for *same* trials more than for *different* trials when the noise accompanying each member of the target pair was different. When the noise for each target member was identical, latency effects for both *same* and *different* judgments were equivalent. In another study, Krueger (1970) found that when the noise was similar for each member of the target pair, latencies for *different* judgments were increased. Although these results were not interpreted in terms of competition between the responses signifying *same* and *different*, they are consistent with our model and with the results of the present experiment.

Although response-competition effects seem to be well demonstrated when noise stimuli are included in matching tasks, one can question whether response competition is involved in the typical matching task when only the target stimuli are present. The expectation of response-competition effects on the latter task is based upon our assumption that, when only targets are present, they are processed as wholes. Instead, each member of the target pair is processed or analyzed in terms of subunits such as features. This is a common assumption made by models of form processing, and Wolford's (1975) *feature perturbation* model and the work of Treisman and Gelade (1980) suggest that, early in processing, the features of a form are not anchored very precisely as to location. Our present results fit in quite well with this interpretation. The placing of noise forms in the display gets their features involved in the comparison process. The present experiment lends strong support to this interpretation by showing that response latency effects for both *same* and *different* responses are directly related to the manipulation of the feature overlap between the noise and the target forms.

W. T. Neill has pointed out to us that our matching displays with a noise letter present are quite comparable to the displays used by Posner and Snyder (1975) and that their results are consistent with the response-competition interpretation. Posner and Snyder presented a "priming" letter for 500 msec and then an array of two letters. Their subjects were asked to press a "yes" button if the letters in the array matched and a "no" button for a mismatch. "Yes" responses were facilitated when the priming letter was identical to the letters in the array and delayed when the prime was different. When the array letters were different, "no" responses were facilitated if the prime was different from each letter and impaired if the prime was the same letter as one of those in the array.

In their experiment, Posner and Snyder (1974) also varied the probability of the prime's matching the array letters and found that facilitation and inhibition of judgments were determined in part by this probability. These results were interpreted in terms



of attentional control, but, as the authors note, "the most serious problem with the experiments reported in this paper is that attention to the prime often appears to be used to match the prime item against the array. This serves to facilitate the "yes" responses to matching pairs when the prime also matches the array and "no" responses to mismatching prime-array pairs. This strategy alone can account for many of our results without invoking any effect of attentional capacity per se. Particularly suggestive is the tendency for a mismatching prime to speed the "no" response to a mismatching letter pair (e.g., <sup>A</sup>BC). According to an attentional account, the tendency to process the prime should interfere and not enhance RT to the letter pair. This result surely indicates that the matching strategy explanation plays a role in the tasks studied here" (Posner & Snyder, 1975, p. 680). We suggest that Posner & Snyder's unexplicated *matching strategy* is the manifestation of the response competition interacting with attentional processes.

There are a number of variations on the *same-different* judgmental task. We have restricted our present work to what is probably the simplest and most basic form of the task: simultaneous presentation, with judgment in terms of physical identity. We felt that the simpler the situation, the fewer the processes involved and the clearer the possible effects of response competition. Variations on the *same-different* judgment, such as string matches (Bamber, 1969) and search lists (Krueger & Shapiro, 1982), bring in new processes and complex interactions of response competition. However, the demonstration of response competition effects in the simpler version of the matching task would strongly suggest that they are present in the other variations of the task and must be considered.

The response-competition model is readily extended to what Proctor (1981) has termed the name-physical disparity. When subjects are required to match target pairs on the basis of name rather than physical identity (e.g., E and e), judgments that the stimuli have the same name are faster when the letters are physically identical as well. Proctor attributes these latency differences to a difference in the level of processing at which the match is made. When the stimuli are physically identical, the match is made at the level of the physical code rather than at the higher level of a name code. Our model would attribute the latency difference to greater priming of a competing *different* response when the stimuli were not physically identical. The differences in features between the upper- and lowercase versions of a letter would prime a response signifying *different*, and the correct response thus would be delayed in execution due to the inhibition of this primed competing response.

The response-competition interpretation of the name-physical disparity does not preclude the pos-

sibility that part of the latency difference in judgments of name-same and physically same targets is attributable to levels of processing. However, it would need to be shown that these latency differences are greater than can be accounted for by response competition.

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#### NOTES

1. The general theory of human reaction time that has been developed by Grice and his colleagues (Grice, Nullmeyer, & Spiker, 1977) also rejects a model of discrete stages. Their theory makes assumptions identical to those of the continuous-flow model in regard to the gradual accumulation of information with the concurrent priming of relevant responses. There is further

agreement in their conception that the specificity of priming to the correct response develops with time and that the degree of specificity varies with the similarity of stimuli associated with competing responses.

2. We believe that the noting of similarities is a primary and basic characteristic of the visual perceptual system. It is not just the absence of the detection of differences, since we can note that two stimuli are highly similar while also being aware of their differences. The older work on stimulus generalization (see Grice, Nullmeyer, & Spiker, 1979, for a modern treatment within a context compatible with a continuous-flow model) is a concrete demonstration of this basic similarity detection. Also, as Lenneberg (1967) has pointed out, categorization is a universal characteristic of languages and categorization requires the detection of similarities.

3. The interference with *same* judgments is significantly greater when the noise letter is dissimilar but not a member of the target set (C or K) than when the noise is the other member of the target set (H or S). The finding is not readily interpretable. Since we have no absolute measure of the similarity or difference between letters, the observed effect may represent no more than the specific choice of letters for target and noise set. The letter C may be more dissimilar to H than is the letter S, and K may be more dissimilar to S than is H.

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