Evidence that the *same-different* disparity in letter matching is not attributable to response bias

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When pairs of letters or letter strings are judged as *same* or *different*, correct *same* responses are usually faster than correct *different* responses. Recently, Ratcliff and Hacker (1981, 1982) have argued that this *same-different* disparity is likely attributable solely to a bias to respond *same*. The present article reports an experiment in which the relative bias to respond *same* or *different* was varied for matches of single-letter pairs. Bias was manipulated by having 80, 60, 40, or 20 pairs in a block of 100 be *same*, with the remainder being *different*. For both sequential and simultaneous presentation of the letters, *same* reaction times had an overall advantage over *different* reaction times that could not be attributed to response bias. Moreover, consistent with Proctor's (1981) facilitation principle, this reaction time disparity was greater with sequential presentation than with simultaneous presentation. The larger reaction time advantage for *same* pairs with sequential presentation was obtained without an increase in the relative number of false-*same* responses, supporting the view that the facilitation is attributable to changes in sensitivity and not to changes in encoding criteria.

When people classify pairs of letters as *same* or *different*, correct *same* responses are faster than correct *different* responses (Krueger, 1978; Nickerson, 1978). Similarly, when classifying multiletter strings, *same* responses are facilitated relative to *different* responses (Bamber, 1969; Proctor & Hurst, 1982). This *same-different* disparity has been the subject of intensive investigation, and several theories have been developed that attribute the phenomenon to fundamental aspects of the human perceptual-cognitive system (Eriksen, O'Hara, & Eriksen, 1982; Krueger, 1978; Proctor, 1981; Taylor, 1976).

Recently, Ratcliff and Hacker (1981, 1982) have concluded that, rather than reflecting fundamental perceptual and cognitive processes, the *same-different* reaction time disparity is likely attributable solely to a bias to respond *same*.¹ Previously (Proctor & Rao, 1982; see also Proctor & Rao, 1983a, 1983b), we have argued on the basis of existing evidence that such is not the case. However, because of the critical nature of the issue raised by Ratcliff and Hacker, and the fact that the evidence against a response bias interpretation is not air-tight, a study clearly demon-

strating that the *same-different* disparity is not attributable solely to response bias seemed necessary. The present study was designed to provide this demonstration.

The primary basis for Ratcliff and Hacker's (1981) claim that the *same-different* disparity may be entirely attributable to response bias was an experiment in which they manipulated the relative criteria for responding *same* or *different*. Subjects were presented pairs of four-letter strings that were to be classified as *same* if the strings matched at all positions and *different* if they differed at one or more positions. Bias was manipulated by asking subjects to respond *same* only when sure in certain sessions (cautious *same* condition) and *different* only when sure in others (cautious *different* condition). Although *same* judgments were faster than *different* judgments in the cautious *different* condition, the pattern was reversed in the cautious *same* condition. This ability to manipulate the relationship between *same* and *different* response latencies by introducing response bias led Ratcliff and Hacker to conclude that the commonly obtained *same-different* disparity is likely attributable to a subjective bias to respond *same*.

Proctor and Rao (1982) indicated that one aspect of Ratcliff and Hacker's (1981) data ran counter to their conclusion that the *same-different* reaction time disparity was a bias phenomenon. Specifically, the advantage for *same* responses in the cautious *different* condition was 52 msec greater than the advantage for *different* responses in the cautious *same* condition, suggesting a true benefit in processing for *same* pairs. Moreover, a similar difference of 16 msec was

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apparent in a study by Krueger and Shapiro (1981b), in which single-letter pairs were employed and bias was manipulated by varying the proportion of *same* and *different* pairs. However, as Ratcliff and Hacker (1982) noted, these data do not rule out a bias interpretation. In Ratcliff and Hacker's (1981) experiment, there was a corresponding tendency toward more false-*same* responses that was consistent with a bias interpretation, whereas in Krueger and Shapiro's experiment the reaction-time disparity was not significant. Thus, the existing studies in which response bias was directly manipulated are equivocal regarding the bias hypothesis of the *same-different* disparity.

Although the literature on the *same-different* disparity runs counter to the response bias hypothesis, showing a tendency toward greater false-*different* errors (Krueger, 1978), the strongest evidence against this hypothesis would be to show unequivocally that, when bias is manipulated, there is a latency advantage for *same* pairs that prevails over and above the effect of bias. The intent of the present investigation was to obtain this evidence. Bias was manipulated in a manner similar to that of Krueger and Shapiro (1981b), by varying the proportion of *same* and *different* pairs within a block of trials. Four bias conditions were employed, rather than the two examined by Krueger and Shapiro (1981b) and Ratcliff and Hacker (1981), to provide a more sensitive manipulation. The proportion of *same* and *different* pairs in four distinct blocks of 100 trials was varied such that 80, 60, 40, or 20 of the pairs were *same*, with the remainder being *different*.

Rather than examining multiletter matches, as did Ratcliff and Hacker (1981), we decided to focus initially on single-letter matches. Single-letter matches were examined (1) because the task is considerably less complex than multiletter matching, and (2) more importantly, because the *same-different* disparity obtained with single-letter pairs is likely the more basic phenomenon (cf. Proctor, 1981). The experiment was conducted in two steps. First, a group of subjects was tested using sequential presentation because the *same-different* disparity is obtained most clearly and consistently with this method of presentation. Having obtained evidence that the reaction time disparity obtained with sequential presentation is not attributable to response bias, another group of subjects was tested using simultaneous presentation to see if a reliable disparity could be obtained for that situation, as well. For ease of presentation, the data for these two groups of subjects are considered together.

METHOD

Apparatus

Stimuli were presented on the display screen of a Radio Shack TRS-80 Model III microcomputer. Stimulus durations, inter-

stimulus intervals, and intertrial intervals were controlled by the computer.

Responses were made by pressing one of two response keys on the computer's keyboard (a standard typewriter keyboard). For half of the subjects, *same* responses were indicated by pressing the Z key with the left index finger, whereas *different* responses were indicated by pressing the ? key with the right index finger. For the other half of the subjects, this pairing was reversed. Reaction times were recorded by the computer to the nearest millisecond.

Stimuli

Stimuli were pairs of uppercase letters selected at random from the entire alphabet. Each letter subtended a visual angle of approximately .34 deg wide and .57 deg high as viewed by the subject. The two letters in a pair were placed side by side horizontally, with approximately 1.0 deg separation between their inner borders. They were centered approximately .68 deg above an asterisk that served as a fixation spot.

Within each session, a block of 20 practice trials was presented (10 *same* pairs and 10 *different* pairs), followed by four blocks of 100 trials. The proportion of *same* and *different* pairs was varied between blocks such that there were 80 *same* and 20 *different* pairs, 60 *same* and 40 *different* pairs, 40 *same* and 60 *different* pairs, or 20 *same* and 80 *different* pairs. These conditions will hereafter be referred to as the 80/20, 60/40, 40/60, and 20/80 conditions, respectively. Each block of trials was preceded by two warm-up trials involving the predominant type of pair in the two extreme sets and one pair of each type in the two intermediate sets. The order in which the blocks were presented was counter-balanced across subjects.

Subjects and Procedure

The subjects were 32 students, enrolled in undergraduate classes, who participated for extra credit. Each subject participated in two sessions on successive days, with the method of presentation and the order of the four proportion blocks being the same for both sessions. The first 16 subjects were tested with sequential presentation of the stimuli, whereas the last 16 subjects were tested with simultaneous presentation.

The fixation spot remained on at all times other than when it offset for 250 msec as a warning for the upcoming trial. Two hundred and fifty milliseconds after it reappeared, the two letters were presented. With sequential presentation, the letter to the left of fixation appeared for 500 msec, and 500 msec after its offset, the letter to the right of fixation appeared. This letter was terminated when the subject responded. With simultaneous presentation, both letters onset 250 msec after the reappearance of the fixation spot and remained in view until the subject responded. For both methods of presentation, 1 sec elapsed between the subject's response and the flicker of the fixation spot that signaled the start of the next trial.

Prior to the first session, subjects were given general instructions regarding the matching task that stressed responding rapidly at the expense of making some errors. They were also told that the proportion of *same* and *different* pairs would vary between blocks, and they were instructed to take advantage of this knowledge. Prior to the start of each block, the proportion of *same* and *different* pairs was indicated on the display screen. This information remained on the screen until the subject initiated the block of trials.

RESULTS

The proportion of errors and mean correct reaction times were obtained for each subject as a function of type of pair (*same* or *different*), proportion block (80/20, 60/40, 40/60, and 20/80), and session (1 or 2). Because similar patterns were evident in both sessions, the data were pooled across sessions.

The means of these data are shown in Table 1. Separate three-factor analyses of variance, with one between-subjects variable (method of presentation) and two within-subjects variables (type of pair and proportion block), were performed on the error rate and reaction time data.

Error Rate

One important outcome shown by the analysis of the error rate data was that type of pair interacted significantly with proportion block [$F(3,90) = 29.0$, $p < .001$]. As is apparent from examining the mean data, this interaction indicates the effectiveness of the response bias manipulation. False-*same* errors decreased as the proportion of *different* pairs increased, whereas false-*different* errors increased. The three-way interaction of type of pair $\times$ proportion block $\times$ method of presentation was also significant [$F(3,90) = 7.65$, $p < .001$], indicating that the relative change in errors produced by the proportion block manipulation was greater with simultaneous presentation than with sequential presentation. However, separate analyses showed that the proportion block manipulation was effective at altering the relative number of false-*same* and false-*different* errors for sequential presentation [$F(3,45) = 5.72$, $p < .005$] as well as for simultaneous presentation [$F(3,45) = 24.4$, $p < .001$].

The only remaining effects that were significant were the main effect for proportion block [$F(3,90) = 4.13$, $p < .025$], the proportion block $\times$ method of presentation interaction [$F(3,90) = 4.09$, $p < .025$], and the main effect for type of pair [$F(1,30) = 7.87$, $p < .025$]. The former two effects reflect a U-shaped pattern to the effect of proportion block on the proportion of errors that was evident with simultaneous presentation [$F(3,45) = 4.75$, $p < .001$], but not with sequential presentation ($F < 1.0$). This U shape for simultaneous presentation is a by-product of the proportion manipulation inducing a large proportion of incorrect responses to the less frequent pair type in the two extreme proportion blocks.

Of greater importance is the significant main effect for type of pair. This effect is attributable to the fact that false-*different* errors outnumbered false-*same* errors, overall. Thus, even though the proportion manipulation was effective at inducing a bias to respond *same* or *different*, there was an overall tendency to make more false-*different* responses. This pattern of errors is often obtained (e.g., Krueger, 1983), although we have not consistently obtained it (e.g., Proctor & Rao, 1983b). The major importance of this error pattern is that it indicates that, if anything, subjects are biased toward making the *different* response and not the *same* response. Thus, if correct *same* responses are faster than correct *different* responses, the difference cannot be attributed to response bias.

Reaction Time

The mean reaction time data also show that the proportion manipulation was effective in altering the relative bias to respond *same* or *different*, as indicated by the significant interaction of proportion block $\times$ type of pair [$F(3,90) = 153.3$, $p < .001$]. Unlike the proportion of errors, this effect of proportion block at altering the relationship between *same* and *different* responses did not interact with method of presentation ($F < 1.0$).

The most important outcome was the significant main effect for type of pair [$F(1,30) = 19.9$, $p < .001$]. This outcome was attributable to the fact that *same* responses were faster than *different* responses. Type of pair interacted significantly with method of presentation [$F(1,30) = 4.13$, $p < .05$], indicating that the disparity between *same* and *different* response latencies was greater with sequential presentation (26.4 msec) than with simultaneous presentation (9.8 msec). However, separate analyses indicated that the reaction time advantage for *same* pairs was reliable for simultaneous presentation [$F(1,15) = 5.01$, $p < .05$] as well as for sequential presentation [$F(1,15) = 14.9$, $p < .005$]. The finding of a greater *same-different* reaction time disparity with sequential presentation than

Table 1
Proportion of Errors as a Function of Type of Pair, Proportion Block, and Method of Presentation

Presentation		Proportion Block			
		80/20	60/40	40/60	20/80
		Proportion of Errors			
Simultaneous	Same	.020	.035	.062	.155
	Different	.114	.065	.032	.015
Sequential	Same	.023	.042	.061	.071
	Different	.045	.033	.030	.016
		Reaction Time			
Simultaneous	Same	433.7	472.8	492.5	462.3
	Different	500.0	497.8	493.0	409.9
Sequential	Same	412.3	451.9	477.8	481.5
	Different	492.7	493.6	493.1	449.7

with simultaneous presentation is common (Krueger, 1983; Proctor, 1981) and is likely attributable to priming or facilitation that occurs with sequential presentation.

The only remaining effects that were significant were the main effect for proportion block [$F(3,90) = 16.4$, $p < .001$] and the interaction of proportion block with method of presentation [$F(3,90) = 5.73$, $p < .005$]. These interactions reflect basically the same characteristic that was apparent in the error data. Although errors were fewer for the intermediate proportion blocks than for the two extremes, responses were slower. As for the error-rate data, this inverted U-shaped function was accentuated with simultaneous presentation, particularly for the 20/80 condition, in which *different* pairs predominated.

DISCUSSION

The present experiment demonstrates clearly that the *same-different* disparity in reaction time obtained when matching single-letter pairs is not attributable solely to response bias. Although the experimental manipulation of bias was effective in altering the relationship between *same* and *different* reaction times and error rates, an advantage for *same* reaction times was evident over and above the effect of the bias manipulation. Moreover, this overall latency advantage for correct *same* responses was paired with an overall preponderance of false-*different* errors, indicating that any residual response bias beyond that induced by the experimental manipulation was toward responding *different*, rather than toward responding *same*.

The results from our experiment, in which bias was directly manipulated, are in agreement with the findings from studies in which bias was not manipulated. In the latter studies, the reaction time disparity is also often accompanied by greater false-*different* errors, rather than the preponderance of false-*same* errors predicted by the response bias account (Krueger, 1978). Thus, the case is quite strong against the hypothesis that the *same-different* reaction time disparity for single-letter pairs is due to response bias alone and nothing more.

The present study is also in agreement with the general finding that the reaction time disparity is greater for sequential presentation than for simultaneous presentation (Krueger, 1983; Proctor, 1981). The magnitude of the disparity obtained with sequential presentation was approximately 2.5 times as large as that obtained with simultaneous presentation. This greater disparity for sequential presentation has been attributed by Proctor (1981) to facilitation in the encoding of the second letter when it is the same as the first. That it was obtained in the present study without an increase in the relative proportion of false-*same* errors indicates that the facilitation re-

flects a change in sensitivity, as Proctor proposed, and not a change in criterion, as Krueger and Shapiro (1981a) suggested. This finding is consistent with results recently obtained by Krueger (1983).

Although the *same-different* disparity obtained with simultaneous presentation was small, the effect was statistically reliable. This outcome is also of importance because it has previously been suggested that the disparity might be reliable only for sequential presentation (Nickerson, 1978; Proctor, 1981). Although small, the disparity obtained with simultaneous presentation is apparently real and is not a response bias phenomenon (see also Proctor & Rao, 1983a).

Although the *same-different* disparity in reaction time obtained with single-letter pairs is not attributable to response bias, the role of response bias in the disparity obtained with multiletter strings is more open to question. As Ratcliff and Hacker (1981) have noted, false-*same* errors predominate in studies of multiletter matching, with the error rate being particularly great for strings that differ only minimally. The high error rates obtained for *different* strings are problematical for interpretation of the reaction time advantage for *same* strings, as Ratcliff and Hacker have indicated. However, a simple response bias explanation is likely to be inadequate as a complete account of the data.

In conclusion, Ratcliff and Hacker (1981, 1982) have correctly emphasized that differences in error rate can confound comparisons of *same* and *different* reaction times, particularly in studies of multiletter matching. However, they have incorrectly concluded that the latency advantage for *same* pairs is likely to be entirely attributable to response bias. The evidence clearly indicates that such is not the case for the *same-different* disparity obtained with single-letter pairs.

REFERENCE NOTE

1. Krueger, L. E. *A theory of perceptual matching* (Tech. Rep. 1). Columbus: Ohio State University, Human Performance Center, June 1977.

REFERENCES

- BAMBER, D. Reaction times and error rates for "same-different" judgments of multidimensional stimuli. *Perception & Psychophysics*, 1969, 6, 169-174.
- BINDRA, D., WILLIAMS, J. A., & WISE, J. S. Judgments of sameness and difference: Experiments on decision time. *Science*, 1965, 150, 1625-1627.
- EGETH, H. Parallel versus serial processes in multidimensional stimulus discrimination. *Perception & Psychophysics*, 1966, 1, 245-252.
- ERIKSEN, C. W., O'HARA, W. P., & ERIKSEN, B. A. Response competition effects in *same-different* judgments. *Perception & Psychophysics*, 1982, 32, 261-270.
- KRUEGER, L. E. A theory of perceptual matching. *Psychological Review*, 1978, 85, 278-304.

- KRUEGER, L. E. Probing Proctor's priming principle: The effect of simultaneous and sequential presentation on *same* and *different* judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1983, 9, 511-523.
- KRUEGER, L. E., & SHAPIRO, R. G. A reformulation of Proctor's unified theory for matching-task phenomena. *Psychological Review*, 1981, 88, 573-581. (a)
- KRUEGER, L. E., & SHAPIRO, R. G. Intertrial effects of same-different judgements. *Quarterly Journal of Experimental Psychology*, 1981, 33A, 241-265. (b)
- NICKERSON, R. S. On the time it takes to tell things apart. In J. Requin (Ed.), *Attention and performance VII*. Hillsdale, N.J.: Erlbaum, 1978.
- PROCTOR, R. W. A unified theory for matching-task phenomena. *Psychological Review*, 1981, 88, 291-326.
- PROCTOR, R. W., & HURST, P. W. A parametric investigation of multiletter matches. *Perception & Psychophysics*, 1982, 32, 75-84.
- PROCTOR, R. W., & RAO, K. V. On the "misguided" use of reaction-time differences: A discussion of Ratcliff and Hacker (1981). *Perception & Psychophysics*, 1982, 31, 601-602.
- PROCTOR, R. W., & RAO, K. V. Null effects of exposure duration and heterogeneity of difference on the *same-different* disparity in letter matching. *Perception & Psychophysics*, 1983, 33, 163-171. (a)
- PROCTOR, R. W., & RAO, K. V. Reinstating the original principles of Proctor's unified theory for matching-task phenomena: An evaluation of Krueger and Shapiro's reformulation. *Psychological Review*, 1983, 90, 21-37. (b)
- RATCLIFF, R., & HACKER, M. J. Speed and accuracy of same and different responses in perceptual matching. *Perception & Psychophysics*, 1981, 30, 303-307.
- RATCLIFF, R., & HACKER, M. J. On the misguided use of reaction-time differences: A reply to Proctor and Rao (1982). *Perception & Psychophysics*, 1982, 31, 603-604.
- TAYLOR, D. A. Effect of identity in the multiletter matching task. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, 2, 417-428.

NOTE

1. Although Ratcliff and Hacker have most forcefully raised the issue of response bias as an account of the *same-different* reaction time disparity in letter matching, concern with response bias when comparing *same* and *different* reaction times dates back to Bindra, Williams, and Wise (1965) and Egeth (1966). (See Krueger, Note 1, pp. 36-51, for a thorough discussion of response bias in matching.)

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