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Do Reaction Time and Accuracy Measure the Same Aspects of Letter Recognition?

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Two experiments indicate that reaction time and accuracy are not always equivalent measures of the underlying processes involved in the recognition of visually presented letters. In conjunction with the results of previous work, our research suggests the following generalizations: (a) Under data-limited viewing conditions (the short exposure durations of the typical tachistoscopic task), response accuracy is sensitive to early perceptual interference between target and noise items, whereas reaction time is more sensitive to later processes involved in response interference. (b) Under resource-limited viewing conditions (the long exposure durations of the typical reaction time task), both accuracy and reaction time appear to be sensitive to processes occurring in the later rather than the earlier stages of processing. Since the two dependent measures do not always reflect the same perceptual processes, we suggest that the convergence of reaction time and accuracy within the context of a specific information processing model should be demonstrated empirically rather than assumed a priori.

In the 1960s, when the field now known as cognitive psychology was still quite new, two psychologists met at a convention. When asked what kind of research he did, the budding young cognitive psychologist said, with obvious pride, that he studied reaction time. Whereupon the more traditional psychologist replied, summoning all the scorn he could muster, that *he* studied percentage correct!

Part of what is humorous about this story is the absurdity of proclaiming an abiding interest in what is really nothing more than a dependent variable. In addition, however, it seems funny that the two psychologists, at least in this snippet of conversation, show no awareness of the obvious point that accuracy and reaction time are simply alternative ways of studying the same underlying processes.

The essential equivalence of time and accuracy measures of performance seems to be accepted implicitly by most experimental psychologists; it seems to be so well accepted that it surfaces explicitly only occasionally (e.g., Eriksen & Eriksen, 1979; Lappin, 1978; Smith & Spoehr, 1974). It is our purpose in this article to argue, however, that reaction time and accuracy are *not* necessarily interchangeable measures of the same underlying process. In support of this argument we show that the pattern of a set of results depends upon how performance is measured. Before we turn to the experiments proper, it will be helpful to provide some

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background concerning the subject matter of our research.

Two Models of Letter Recognition

Bjork and Murray (1977) have recently extended Estes's (1972, 1974) interactive channels model of visual processing by emphasizing feature-specific inhibition among visual input channels. According to their model, information about the features contained within visually presented stimuli is extracted over parallel, but interactive, input channels that lead to feature detectors. The excitation of a particular input channel caused by the presence of a particular feature contained within a letter results in both feature-specific inhibition of other channels leading to the *same* feature detector and a more generalized inhibition of all input channels (see Estes, 1972). Thus, the feature-specific inhibition model predicts perceptual interference between two letters to be a function of the degree of their feature overlap.

Evidence in support of feature-specific inhibition comes from a task in which two letters are presented briefly side by side and are followed by a poststimulus cue that indicates which of the two letter positions is to be reported. Subjects know that the cued position will contain one of the two target letters, for example, B or R, and that the uncued position will contain B or R or a nontarget letter such as P or K. Bjork and Murray (1977) found that the accuracy of report was lower when a target letter was flanked by an identical letter than when flanked by the other target letter or by a nontarget letter. For example, they found that if a poststimulus cue indicated that the left-hand member of a letter pair was to be reported, then report of B from the pair BB was less accurate than report of B from the pair BR or the pair BK.

Bjork and Murray's (1977) basic findings have recently been replicated and extended (Santee & Egeth, 1980). Furthermore, some plausible alternative explanations (e.g., response bias) of the crucial difference between the noise-same-as-target condition (e.g., BB) and noise-alternative-target condition (e.g, BR) were ruled out. These results provide strong evidence that the basic phenomenon is robust.

However, there is a problem. Predictions of the feature-specific inhibition model are inconsistent with predictions of the continuous flow model (Eriksen & Eriksen, 1979; Eriksen & Schultz, 1979), which emphasizes interference between target and noise items at the response selection stage of processing. The continuous flow model is based on the premise that subjects are unable to restrict their visual attention to a target item, particularly when the target and noise items are contained within 1 degree of visual angle (see Eriksen & Hoffman, 1972). Such a limitation in selective attention means that as information about the target and noise items accumulates gradually in the visual system, their associated responses will become activated, requiring the inhibition of responses to the noise until the target response reaches threshold. This creates a problem when the target and noise items evoke competing internal recognition or overt responses as in the noise-alternative-target condition. In this condition, the subject must determine that the response that is made is appropriate to the item that appeared in the cued position. In the noise-same-as-target condition, the same correct response would be initiated on each trial even if the subject mistakenly processed the noise letter rather than the target letter. Therefore, the continuous flow model leads to the prediction that performance should be worse in the noise-alternative-target condition than in the noise-same-as-target condition due to response competition between inputs.

Results from several studies conducted by Eriksen and his associates support the continuous flow model (e.g., Eriksen & Eriksen, 1974, 1979; Eriksen & Schultz, 1979). In these studies subjects responded as quickly and accurately as possible to a centrally located target letter when it was flanked by different types of noise elements. For example, if the target letters H and K were assigned to different responses, then performance was measured in two types of noise conditions relevant to the present discussion: (a) a compatible-noise condition (e.g., HHHHHHH), and (b) an incompatible-noise condition (e.g., KKKHKKK). In every study, reaction time (RT) to a target letter was longer in the incompatible-noise condition than in the compatible-noise condition (see also Taylor, 1977).

Eriksen and Eriksen (1979) have recently investigated the possibility that the overpowering effects of response competition may have obscured or masked the weaker effects of perceptual interference in their RT measures. They attempted to reduce the effects of response competition by using noise letters that were from the same response set as the target. For example, with the target letters H and S in one response set and the targets K and C in the other, performance could be compared when the noise was either identical to the target (e.g., HHHHHHH) or was the other member of the same response set (e.g., SSSHSSS). They reasoned that there should be little difference in overt response competition between these two conditions, since the same lever-pressing response was required when either H or S was the target letter in the middle position. Clearly, the feature-specific inhibition model predicts worse performance when the noise is identical to the target. The RT results, however, did not support this prediction. Eriksen and Eriksen (1979) argued that even when target and noise items are from the same response set, response competition persists between internal recognition responses to the stimuli.

Are Interference Effects Task Related?

One possible resolution of the conflict between the two models stems from the following observation: When stimuli have been presented briefly and the accuracy of unspeeded responses measured, the results have been consistent with the feature-specific inhibition model, whereas when displays were presented for a relatively long time and the reaction time of speeded responses measured, the results have been consistent with the continuous flow model. This observation has prompted the suggestion that response accuracy may be more sensitive to processes occurring during the early perceptual stages of processing, whereas RT may be more sensitive to later decision and response processes (Bjork & Murray, 1977; White, 1981). This conclusion deserves further consideration in view of the fact that it is commonly assumed within cognitive psychology that RT and accuracy reflect the *same* underlying processes (e.g., Eriksen & Eriksen, 1979; Lappin, 1978, Smith & Spoehr, 1974). Eriksen and Eriksen (1979) for example, assumed that any experimental condition that increases the inhibitory effects among input channels, as reflected in response accuracy, should also delay recognition responses. Underlying this assertion is the fundamental assumption that RT and accuracy are converging measures of the amount of time required for information processing (cf. Smith & Spoehr, 1974). Thus, if either accuracy is lower or RT longer in Task A than in Task B, it is routinely assumed that successful completion of processing requires more time in A than in B.

One of the most common ways of manipulating performance in a task in which the dependent variable is accuracy is by means of adjusting exposure duration. Brief stimulus exposures, however, not only limit the amount of time that a stimulus is available for processing but also reduce the quality of the stimulus information available to the subject. The brief exposures used in accuracy tasks produce data limitations (Norman & Bobrow, 1975; state limitations, according to Garner, 1970) that reflect whether or not stimulus information gets into the processing system. The long exposures used in the typical RT task, however, result in resource limitations (Norman & Bobrow, 1975; process limitations, according to Garner, 1970) that reflect whether sufficient cognitive resources have been allocated for the processing of a high-quality stimulus. The potential fruitfulness of this kind of task analysis has been demonstrated by some important recent studies of letter perception that have shown that different processing strategies may be involved in data-limited and resource-limited conditions (e.g., Pachella, Smith, & Stanovich, 1978; Stanovich, 1979). These studies indicate, based on error analyses, that under brief-exposure/data-limited conditions the identification of a single letter is more likely to be based on partial visual information. However, under long-exposure/resource-limited conditions, subjects are more likely to process a letter completely, or not at all. (Errors were obtained in the resource-limited condition by requiring subjects to make speeded identifications.)

If subjects encode stimuli differently under data-limited and resource-limited conditions, then accuracy and RT tasks may yield qualitatively different results. Thus, the apparent theoretical discrepancies between the feature-specific inhibition model, which is based on data-limited accuracy results, and the continuous flow model, which is based on resource-limited RT results, may reflect nothing more (nor less) than that accuracy and RT reflect different aspects of information processing.

Two experiments are reported that make a direct comparison between the feature-specific inhibition and continuous flow models when the same stimuli are presented in a data-limited accuracy task and a resource-limited RT task. A poststimulus cuing procedure similar to that of Bjork and Murray (1977) is used in Experiment 1, whereas the identification task introduced by Eriksen and his colleagues is used in Experiment 2. Support of feature-specific interference in the data-limited accuracy task in conjunction with support of response interference in the resource-limited RT task would suggest that (a) both types of interference are present in the letter identification process, and, (b) recognition accuracy and RT are differentially sensitive to perceptual and response interference effects. Furthermore, a different pattern of results across stimulus conditions in the two tasks, regardless of whether response or perceptual interference is implicated, would provide further evidence that RT and accuracy tasks reflect qualitatively different processes.

Experiment 1

A poststimulus cuing procedure was adopted in Experiment 1. On each trial, two letters were presented, one on each side of the central fixation point. The letters were then followed by an upward pointing arrow directly underneath one of the two letter positions. The subject's task was to indicate which one of the two target letters, A or E, was present in the cued position by pressing the appropriate button. This procedure differed from that in previous studies supporting feature-specific inhibition (Bjork & Murray, 1977; Santee & Egeth, 1980) in that premasks, postmasks, and extraneous background characters in the stimulus displays were not used. These changes permitted us to determine if the feature-specific inhibition model could be generalized to an importantly different set of stimulus conditions.

Three types of display conditions were used in Experiment 1. The nomenclature for these conditions has been borrowed from Bjork and Murray (1977). In the noise-same-as-target condition (AA), the two letters were identical, but only the cued letter served as the target. In the noise-alternative-target condition (AE), both target letters were presented. Again, only one of the target letters was cued. Finally, the noise-nontarget condition (AK) contained a target letter in the presence of one of the two nontarget letters, K or L. Note that the noise letters were compatible with the correct response in the AA condition, incompatible with the correct response in the AE condition, and neutral with respect to the correct response in the AK condition. All three stimulus conditions were presented in a data-limited accuracy task and a resource-limited RT task.

According to the feature-specific inhibition model, input channels leading to the *same* feature detector inhibit each other more than channels leading to other feature detectors. Thus, the mutual inhibition between two elements should be a function of the degree to which these elements have the same features. This means that the worst performance should be obtained in the AA condition. The AE and AK conditions should generate approximately equal levels of performance, because the degree of feature overlap among the target and noise letters is approximately the same in both conditions—see Townsend's (1971) interletter confusion matrices.

According to the continuous flow model, interference between target and noise elements is a function of the extent to which they prime incompatible responses. Different motor responses are incompatible in the sense that they are difficult to perform simultaneously. Eriksen and Schultz (1979) have also argued that internal recognition responses are serial in nature and therefore are also subject to inhibition from competing responses. This means that performance should be (a) worst in the AE condition, since the two letters will prime different manual responses; (b) best in the AA condition, since the two letters will prime the same responses; (c) intermediate in AK condition, since the nontarget letter will usually prime only an internal recognition response that competes with the recognition response for the target letter. (In the AK condition incompatible manual responses will also be primed from time to time when, for example, a K is misperceived as an E.)

Method

Subjects. Sixteen undergraduates at the Johns Hopkins University served as paid subjects. All had normal or corrected-to-normal vision. Eight subjects were randomly assigned to a data-limited accuracy task; the remaining eight subjects were assigned to a resource-limited RT task. Each subject was tested individually in a 1-hour experimental session.

Apparatus. All aspects of the two tasks were identical except where otherwise indicated. Displays were presented in two channels of an automated four-channel Iconix tachistoscope. The luminance of both fields was 41 cd/m^2, as measured with a Spectra brightness spot meter. The fixation field contained a centrally located black dot on a white background. Stimulus displays consisted of two black letters positioned horizontally, one .13° to the right of the fixation point and one .13° to the left of the fixation point. The letters were typed on white cards with an IBM Selectric typewriter with an Artisan-12 element. Each letter subtended approximately .20° in height and .15° in width. Each of the poststimulus cues contained the central fixation point and an upward-pointing arrow .45° below one of the letter positions.

Procedure. The target letters A and E appeared equally often in each of the three stimulus conditions and as the cued letters in each of the two display positions. Also, the nontarget letters K and L appeared equally often with each of the target letters in the AK condition. Displays were presented in 12 blocks of 24 trials each during the experimental session of both the accuracy and RT tasks. Within each block, both target letters and each of the three display conditions appeared equally often and in a randomized order. Each of the two positions was also cued an equal number of times within each block of trials. Subjects responded by pressing one button with the index finger and another button with the thumb of the preferred hand.[1] The two target-response assignments were counterbalanced across subjects in both tasks.

In the data-limited accuracy task, the exposure duration of the stimulus displays was adjusted until each subject performed at approximately 75% accuracy, averaged across all stimulus conditions during four blocks of practice trials. Duration was adjusted at the end of each block of trials if necessary in order to maintain 75% accuracy throughout the experimental session. The duration for individual subjects ranged from 8 to 20 msec. In the RT task, the exposure duration was 100 msec, to maintain an overall high level of accuracy. Four blocks of practice trials also preceded the experimental blocks of trials.

At the beginning of both tasks, subjects were told that either an A or an E would be cued on each trial. They were also informed that the two target letters as well as the left and right positions would be cued with equal probability no matter what appeared in the uncued position. Responses were to be based on only the information in the cued positions. In other words, they were informed that information in the uncued position would not provide them with any information about the letter present in the cued position.

In the data-limited accuracy task, subjects were told to respond as accurately as possible and not to worry about how fast they responded. Reaction time was not measured in this task. However, in the resource-limited RT task, subjects were told to respond as quickly and accurately as possible. Reaction time was measured to the nearest millisecond from the onset of a stimulus display.

The first trial in each block was initiated by the experimenter. Each trial began with the central fixation point in view during which time an auditory warning signal was presented. A stimulus display appeared 1 sec later and was followed by a poststimulus cue containing an upward-pointing arrow underneath one of the two positions. The cue stayed in view until the subject made a response, at which time it was replaced by the fixation point. The subject initiated the next trial by pressing a button. A 5-min rest period was given midway through each experimental session.

Results and Discussion

Table 1 presents the mean proportions of correct identifications in the data-limited accuracy task along with the mean reaction times and proportions of correct responses in the resource-limited RT task. Since the experiments reported in this article were designed to test the predictions of the feature-specific inhibition and continuous flow models, the statistical analysis consisted of planned comparisons.[2]

Performance under data-limited conditions. The accuracy data presented in Table

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[1] The response buttons were arranged one in front of the other in order to eliminate any left-right/cue-response compatibility effects.

[2] Although the planned comparisons were not orthogonal, they were treated as such. Keppel (1973, p. 93) and Winer (1962, p. 69) argue that all planned comparisons, regardless of whether they are orthogonal, should be evaluated with the same *per comparison* error rate.

Table 1
Performance in Data-limited Accuracy Task and Resource-limited RT Task in Experiment 1

	Task					
	Data-limited		Resource-limited			
Display	%C	*SE*	%C	*SE*	RT	*SE*
Noise same as target (AA)	67	2	99	1	523	22
Noise alternative target (AE)	81	3	95	1	645	38
Noise nontarget (AK)	79	1	98	1	559	24

Note. %C = mean percentage correct. *SE* = standard error. RT = reaction time to nearest millisecond.

1 are in close agreement with other evidence that has been taken to be consistent with the predictions of the feature-specific inhibition model (Bjork & Murray, 1977; Santee & Egeth, 1980). Performance was significantly lower in the AA condition than in either the AE or AK conditions, $F(1, 14) = 6.55$, $p < .025$, and $F(1, 14) = 4.87$, $p < .05$, respectively; virtually the same level of performance was attained in the latter two conditions. Results from these mask-free stimulus conditions indicate that previous evidence supporting feature-specific inhibition did not result from interactions between the target letters and masking characters.

These accuracy data implicate perceptual interference, which is consistent with the feature-specific inhibition model proposed by Bjork and Murray (1977). In this model, which essentially elaborates on Estes's (1972) interactive channels model, two forms of inhibition have been proposed: (a) general inhibition among all input channels leading to neighboring feature detectors; and (b) specific inhibition among input channels leading to the same feature detector. Moreover, feature detectors are assumed to be of limited capacity (Bjork & Murray, 1977) and arranged in a hierarchical fashion (Hubel & Wiesel, 1962, 1965). Inhibition does not imply that one channel prevents the activation of any other channel, but that the arrival of information over one channel at a common feature detector prevents the simultaneous use of information arriving over the other channels due to the limited capacity of feature detectors (see Pomerantz, Sager, & Stoever, 1977, for a similar argument). A delay in the utilization of information arriving over some input channels increases the likelihood that that information will be lost. This is particularly evident when the exposure of the stimulus is very brief.

Recognition accuracy, which is manipulated by varying stimulus duration, appears to reflect whether or not sufficient information has entered the visual processing system in order to correctly recognize a target letter. The feature-specific inhibition model provides a reasonable account of how the amount of information concerning a target letter can vary under different noise conditions. As we noted earlier, the delay and subsequent loss of information arriving over input channels (due to capacity limitations of feature detectors) plays a critical role in determining recognition accuracy when information is no longer coming into the visual system from the stimulus display. Furthermore, since subjects are not under time pressure to respond, the priming of competing response tendencies is not reflected in the accuracy measures.

The fact that evidence consistent with the principles of feature-specific inhibition was obtained without any masking stimuli deserves some further comment. In previous studies using Bjork and Murray's (1977) poststimulus cuing paradigm, masking stimuli have always been used. The present data suggest that masks are not necessary. However, using a different paradigm with no poststimulus cue, Santee and Egeth (1982) found the pattern of results indicative of feature-specific inhibition only when a premask and/or postmask was used. Taken together these facts suggest that to obtain feature-specific inhibition it may not be enough to limit processing by brief exposure alone; it may also be necessary to make available an explicit stimulus (a mask, a cuing stimulus) to reduce effective processing time (see also Santee and Egeth, 1982, Experiment 4, for a related discussion). Alternatively, uncertainty about target location may be an important factor. This point will be considered further in the discussion of Experiment 2.

Performance under resource-limited conditions. The mean RTs for correct responses presented in Table 1 conform, for the most part, to the predictions of the continuous flow model. Reaction time was significantly longer in the AE condition than in either the AA or AK conditions, $F(1, 14) = 21.00, p < .001$, and $F(1, 14) = 10.44$, $p < .01$, respectively. Although performance in the AA and AK conditions did not differ significantly by parametric test, all eight subjects responded faster in the AA condition, as was predicted by the continuous flow model ($p < .01$). Too few errors were made to warrant analysis of the reaction times for incorrect responses. The accuracy data closely parallel the RT data for correct responses. Significantly more errors were made in the AE condition than in either the AA or AK conditions, $F(1, 14) = 8.13, p < .025$ and $F(1, 14) = 4.70$, $p < .05$, respectively. The latter two conditions did not differ significantly.

In a speeded-response task, stimulus displays typically are presented long enough for the target and noise elements to be seen clearly. Under such conditions, the target and noise letters prime competing internal recognition responses and overt motor responses (Eriksen & Eriksen, 1979), and time is required to inhibit the competing response tendencies. In order to minimize response errors, subjects under pressure to respond quickly but accurately are likely to adopt response criteria so high that the effects of perceptual interference among input channels during the early stages of processing are essentially undetectable. In other words, when a display is presented long enough for a subject to recognize the target and noise letters, each stimulus has the opportunity to activate its respective response. Under such circumstances, any further interference among input channels has little or no effect on a subject's response time or accuracy. Whatever initial delay is incurred from the interference among input channels *before* target recognition appears to be masked by the overpowering effects of response competition on response time.

Bjork and Murray (1977) report some results that support the preceding argument. They measured both RT and accuracy under data-limited conditions. On the one hand, they found that accuracy was lower in the AA condition than in the AE condition. This indicates that on the average, less information was available for target recognition in the former condition due perhaps to feature-specific inhibition. On the other hand, a longer mean RT for correct responses was obtained in the AE condition than in the AA condition. This suggests that when enough information is available to recognize the target and noise letters, reaction time is reflective of the processes involved in response interference. (It is unlikely that Bjork and Murray's results can be explained in terms of a speed–accuracy trade-off between the AA and AE conditions, since the conditions appeared randomly from trial to trial.) Similar results have been reported by White (1981).

Experiment 2

The results of Experiment 1 suggest that (a) both perceptual and response interference are involved in letter identification; and (b) accuracy under data-limited conditions is particularly sensitive to early perceptual interference, whereas performance (both speed and accuracy) in a resource-limited speeded response task is sensitive to later response interference. On a more general level, the results of Experiment 1 challenge the assumption that accuracy and RT reflect the same processes and that results based on the two measures can be interchanged in support of the same theoretical position (cf. Eriksen & Eriksen, 1979; Lappin, 1978; Smith & Spoehr, 1974).

However, one might dispute the results of Experiment 1 by arguing that the poststimulus cuing procedure does not provide an adequate setting in which to test the continuous flow model in the long-exposure RT task. A longer mean response time may have been obtained in the AE condition simply because subjects had to process the poststimulus cue in order to determine which response was appropriate, whereas in the AA and AK conditions subjects did not need to process the cue in order to respond appropriately. (In both cases there is only one permissible response that could be made.) Thus, the longer latencies in the AE condition may reflect the extra time that is required to process a poststimulus cue, or the extra time to inhibit competing response tendencies, or both.

Experiment 2 eliminates the poststimulus cuing problem by employing Eriksen's identification paradigm, in which a target letter is presented in the same location on each trial. This task also provides an opportunity to test the feature-specific inhibition model when a subject's attention is directed toward only one location during the initial stages of feature extraction instead of being distributed across two or more locations. In this experiment the same subjects served in both the data-limited accuracy and resource-limited RT tasks. Both RT and accuracy were measured in both tasks.[3]

On each trial, the centrally located target letter was flanked on each side by a noise letter which was either (a) the same as the target letter (AAA); (b) the alternative target letter (EAE); or (c) a nontarget letter (KAK). Two single-target control conditions were also employed in which a target letter appeared alone in the display. In the single-target mixed control, a target letter was presented alone during blocks of trials in which the three noise conditions were presented. In the single-target blocked control, the target letters appeared alone in a separate block of trials. Subjects were instructed to attend to only the central target letter, and to ignore the flanking noise letters.

Predictions concerning performance in the three noise conditions for the feature-specific inhibition and continuous flow models are the same as in Experiment 1. The feature-specific inhibition model also predicts better performance in both of the single-target conditions than in the three noise conditions, because in the former condition adjacent noise letters are not present to create competition between input channels leading to the same or different feature detectors. Predictions by the continuous flow model concerning performance in the single-target conditions are somewhat more complicated. First, single-target blocked performance should be superior to performance in all other conditions, including the single-target mixed condition, because in the blocked condition subjects know beforehand that they will not need to inhibit responses to any noise letters. Second, single-target mixed performance should be better than performance in the noise-alternative-target and noise-nontarget conditions, because the noise letters in the latter two conditions will activate competing responses. Finally, performance in the single-target mixed and noise-same-as-target conditions should be equal (Eriksen & Eriksen, 1979).

Method

Subjects. Ten undergraduates at the Johns Hopkins University served as paid subjects. All subjects had normal or corrected-to-normal vision. Each participated in two experimental sessions conducted on successive days. One session was devoted to the data-limited accuracy task and the other session was devoted to the resource-limited reaction time task. The order of the two tasks was counterbalanced across subjects.

Apparatus. All aspects of the two tasks were identical except where otherwise indicated. Displays were presented in the same Iconix tachistoscope used in Experiment 1, with luminance set at 41 cd/m^2 in all fields. The fixation field contained three black dots arranged horizontally on a white background. The target stimuli were the letters A and E, and the neutral or nontarget stimuli were the letters K and L. The black letters were typed on white cards with an IBM Selectric typewriter with an Orator Presentor element. Each letter subtended approximately .25° in height and .16° in width.

The single-target control displays contained a target letter centered on the position corresponding to the central fixation point. Three noise conditions were also employed: (a) noise-same-as-target (AAA, EEE); (b) noise-alternative-target (EAE, AEA); and (c) noise-nontarget (KAK, KEK, LAL, LEL). The positions of the flanking noise letters corresponded to the positions of the flanking black dots in the fixation field. The adjacent letters were separated by .25° edge to edge.

Procedure. The single-target mixed displays and the three types of noise displays were presented in 12 blocks of 32 trials each in both tasks. The 32 trials within each block were divided equally between the two target letters

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[3] Due to an oversight, response times were obtained from only 7 of the 10 subjects in the accuracy task.

Table 2
Performance in Data-Limited Accuracy Task and Resource-Limited RT Task in Experiment 2

	Task							
	Data limited				Resource limited			
Display	%C	*SE*	RT	*SE*	%C	*SE*	RT	*SE*
Single target-blocked (A)	80	2	724	17	98	1	414	9
Single target-mixed (A)	81	1	757	28	98	1	441	9
Noise same as target (AAA)	75	3	766	28	99	1	451	9
Noise alternative target (EAE)	76	3	813	28	93	1	525	12
Noise nontarget (KAK)	74	1	816	22	98	1	477	10

Note. %C = mean percentage correct. *SE* = standard error. RT = reaction time to nearest millisecond.

and among the four display conditions, which were presented in a randomized order. Single targets were also presented in two blocks of 32 trials each; one block was presented after the first six experimental blocks of trials, and the other block after the last six blocks of experimental trials. Five of the subjects responded on each trial by pressing the right button if the central target letter was an A and the left button if the target letter was an E. The other five subjects followed the opposite target-response assignment.

In the data-limited accuracy task, the exposure duration of the stimulus displays was adjusted until each subject performed at approximately 75% accuracy, averaged across all stimulus conditions for three blocks of practice trials. This was adjusted at the end of each block of trials if necessary in order to maintain 75% accuracy throughout the experimental session. The exposure durations for the two blocks of single-target trials were set at the averages of the durations used during the first six and the last six blocks of experimental trials respectively. In the resource-limited RT task, the exposure duration was set at 1 sec. Three blocks of practice trials preceded the experimental trials.

At the beginning of both tasks, subjects were instructed to attend only to the central location where the target letters always appeared, and to base their response on only the letter in that location. As in Experiment 1, subjects were fully informed of the nature of the stimulus materials. They were also informed that the information in the noise positions would not provide them with any clues about which of the two targets was present in the target position.

In the data-limited accuracy task, subjects were instructed to respond as accurately as possible and not to worry about how fast they responded. However, in the resource-limited RT task, subjects were given standard instructions to respond as quickly and accurately as possible. Reaction time was measured to the nearest millisecond from the onset of the stimulus display in both tasks.

The first trial in each block was initiated by the experimenter. Each trial began with the fixation field in view, during which time an auditory warning signal was presented. A stimulus display appeared 1 sec later and was then replaced by the fixation field. In the resource-limited RT task, a stimulus display was presented for 1 sec regardless of how long it took the subject to respond. After responding, the subject initiated the next trial by pressing a button. A 5-min rest period was given halfway through each experimental session.

Results and Discussion

Presented in Table 2 are the mean proportions of correct identifications and the mean reaction times for correct responses in both tasks.

Performance under resource-limited conditions: RT. The RT data for correct responses obtained in the speeded-response task are in close agreement with RT results of Experiment 1 and the predictions of the continuous flow model.[4] Responses were significantly slower in the EAE condition than in AAA condition, $F(1, 27) = 70.39$, $p < .001$. Furthermore, RT was slower in the KAK condition than in the AAA condition, $F(1, 27) = 19.99$, $p < .001$. These results clearly demonstrate that more time is required to respond to a central target letter when it is flanked by noise letters that evoke competing overt and/or internal recognition responses.

Faster responses were also obtained in the single-target mixed condition than in the EAE condition, $F(1, 27) = 212.02$, $p < .001$, or the KAK condition, $F(1, 27) = 38.08$, $p < .001$. The effects of flanking noise letters cannot be attributed to general interference due to adjacent contours, since similar re-

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[4] As in Experiment 1, too few errors were made in the resource-limited RT task to warrant analysis of reaction times for incorrect responses.

sponse times were obtained in the single-target and AAA conditions (see Eriksen & Eriksen, 1979, for a similar result). Instead, these results provide further evidence that noise letters impair target processing by evoking interfering responses.

A separate analysis of response time in the two single-target conditions showed that responses were faster in the blocked condition, $F(1, 9) = 14.99, p < .005$. Eriksen and Eriksen (1974) have suggested that faster responses are obtained in the single-target blocked condition because subjects do not need to use the "inhibitory processes" they use in the mixed condition to refrain from responding to flanking noise items.

Performance under resource-limited conditions: Accuracy. An analysis of errors in the speeded response task indicates that the continuous flow model correctly predicted that more errors would be obtained in the EAE condition than in the other conditions ($ps < .001$). However, other predictions of the model were not supported in that no differences were obtained among the remaining conditions. Inspection of the data suggests that this is because the data were subject to a ceiling effect.

Performance under data-limited conditions: Accuracy. Inspection of the data-limited accuracy data presented in Table 2 shows that the predictions of neither the feature-specific inhibition model nor the continuous flow model were supported. In fact, there were no significant differences among the noise conditions.[5] The only trend present in the accuracy data was that of slightly more accurate performance in the two single-target conditions than in the three noise conditions ($p < .10$). This is consistent with other studies that have shown that processing of a target is impaired by the presence of extraneous noise elements (e.g., Eriksen & Eriksen, 1972; Eriksen & Schultz, 1978).

Performance under data-limited conditions: RT. The pattern of mean reaction times for *correct* responses in the accuracy task are very similar to the response times obtained under resource-limited conditions (i.e., the RT task). Although responses did not differ in the EAE and the KAK conditions, responses were slower in each of these conditions than in the AAA condition $F(1, 18) = 4.49, p < .05$, and $F(1, 18) = 5.08, p < .05$ respectively. As in the RT task, faster responses were made in the single-target mixed condition than in the EAE condition, $F(1, 18) = 6.60, p < .025$, or the KAK condition, $F(1, 18) = 7.31, p < .025$, whereas similar response times were obtained in the single-target and AAA conditions. The difference between blocked and mixed performance in the single-target conditions was not significant, although it was in the direction predicted by the continuous flow model. Analysis of the mean reaction times for incorrect responses in the accuracy task revealed no differences among the experimental conditions, $F(3, 18) = 1.46, p > .20$).

The results of Experiment 2 confirm the argument that evidence supporting the feature-specific inhibition and continuous flow models is task dependent. The continuous flow model is, on the whole, supported by reaction time for correct responses in both data-limited and resource-limited tasks. This suggests that if enough information enters the visual processing system to ensure correct recognition of the target and noise items, then reaction time reflects the processes involved in response competition. Data-limited accuracy performance, however, does not reflect the activation of competing response tendencies but may instead reflect whether sufficient information has entered the processing system for correct recognition of the target item.

No evidence of feature-specific inhibition was obtained in Experiment 2, even when accuracy was measured under data-limited conditions. Somewhat similar stimulus conditions in previous studies have resulted in evidence supporting feature-specific inhibition (Bjork & Murray, 1977; Santee & Egeth, 1980; Experiment 1 of this article). What accounts for the difference in results? The answer is by no means clear. However, one highly speculative possibility points to

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[5] One might argue that the failure to obtain any performance differences in the accuracy task is due to a lack of sensitivity in the experimental design. This seems unlikely in view of the fact that the significant accuracy differences obtained in Experiment 1 were based on the same number of trials per condition as the insignificant differences in Experiment 2.

a particular difference between the paradigm used in Experiment 2 and the poststimulus cuing procedure used in the previous studies. In the present paradigm, subjects knew beforehand exactly where a target would be presented; thus, they could direct their attention to that particular location. However, in the poststimulus cuing paradigm, subjects were uncertain about the exact location of a target. Therefore, attention must be divided among two (or, in the case of Bjork and Murray's 1977 study, more than two) equally probable target locations at the moment a display is presented. This may indicate that the allocation of attention to a target's location during the early stages of feature extraction in the nonsearch task can eliminate the inhibitory effects of adjacent noise characters.

Interestingly, Estes (1982) also failed to obtain evidence of feature-specific inhibition when subjects had to report the center of three letters. However, in his experiment the locations of the triads varied from trial to trial. If the crucial factor does in fact have anything to do with certainty of target location, it must be relative rather than absolute location that is relevant.

General Discussion

The major conclusion we draw from our research is that two popular experimental paradigms that are usually assumed to yield comparable results do not, in fact, do so. Specifically, it is not a matter of indifference whether one assesses performance by measuring accuracy under data-limited conditions or reaction time under resource-limited conditions. The evidence for this is that the ordering of our stimuli with regard to their "perceptibility" differed depending on the circumstances under which performance was measured. For example, in Experiment 1, when accuracy was measured under data-limited conditions, the order from good to bad was AE, AK, AA. However, when reaction time was measured under resource-limited conditions, the order was precisely reversed: AA, AK, AE. The situation in Experiment 2 was a bit different, but the general point is the same. Under data-limited conditions, there were no significant differences in accuracy among the three noise conditions; under resource-limited conditions, however, there were clear differences in RT among them.

Generally speaking, our results fail to support the assumption that accuracy and reaction time are converging measures of the same processes. We are not suggesting that the two dependent measures will always reflect different processes, however. We wish to argue that the convergence of reaction time and accuracy within the context of a specific information processing model should be demonstrated empirically rather than assumed a priori.

Status of the Two Models of Letter Recognition

To summarize the implications of our results for the models of letter recognition under investigation, we can consider the four cells resulting from the combination of response measure (RT vs. accuracy) and processing limitation (data vs. resource). Data consistent with the feature-specific inhibition model were found only when accuracy was measured under data-limited conditions (Experiment 1; Bjork & Murray, 1977; White, 1981; but *not* Experiment 2). In all three remaining cells the data provide at least partial support for the continuous flow model. Thus, under data-limited conditions accuracy frequently appears to be sensitive to early perceptual interference between target and noise items, whereas RT appears to be sensitive to later processes involved in response interference. Under resource-limited conditions both RT and accuracy measures appear to be more sensitive to processes occurring in the later rather than the earlier stages of processing.

Our data, in conjunction with the previous results of Eriksen and his colleagues (e.g., Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979), show that there are several circumstances in which the continuous flow model correctly predicts performance. In the present experiments those circumstances were when RT was measured in both the data-limited accuracy task and the resource-limited RT task and when accuracy was measured in the resource-limited RT task. The major failure of the model is its inability to predict accuracy levels under data-limited conditions. (There were some minor failures that may simply be Type II errors; for example, in the data-limited accuracy task of Experiment 2, EAE did *not* yield longer mean RT than KAK). On the whole, then, the continuous flow model is well established in that it can account for an impressive range of results.

The status of the feature-specific inhibition model is not as clear at the time of this writing. Data consistent with the model have been obtained in numerous experiments in which accuracy has been measured under data-limited conditions (e.g., Experiment 1; Bjork & Murray, 1977; Santee & Egeth, 1980; see also Pomerantz, et al., 1977). However, it did not obtain in Experiment 2 of the present paper. In addition, some recent papers cast doubt on the theoretical interpretation of the data taken as evidence in support of feature-specific inhibition.

One such problem is whether the inhibition in question can properly be described as "feature specific." Egeth and Santee (1981) found substantial interference within letter pairs made up of conceptually similar elements (e.g., Aa) as well as within pairs made up of physically similar elements (AA). More interference was found for physically similar pairs than for conceptually similar pairs, and thus it is possible that there is some degree of feature-specific inhibition above and beyond the inhibition due to conceptual similarity. Further research will be needed to determine if this is a plausible account.[6]

Another problem is that Estes (1982) has argued that the data cited by Bjork and Murray (1977) and others as establishing the existence of feature-specific inhibition may actually reflect a subtle form of response bias rather than a shift in the discriminability of targets as a function of the nature of noise elements. Although Estes's argument is compelling, Santee and Egeth (1982) appear to have found further evidence consistent with feature-specific inhibition in a paradigm to which the response-bias explanation does not readily apply.

Clearly, further research is needed to determine under what conditions (if any) the principle of feature-specific inhibition obtain. However, the uncertainty surrounding the status of that model should not obscure the main point of our article, which is that the nature and conditions of performance measurement are crucial.

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[6] This point is related to another issue that is at present only potentially a problem. According to the principle of feature-specific inhibition, perceptual interference is a function of the degree of overlap among the features of simultaneously presented stimuli. The degree of feature overlap also ought to predict the speed of same-different judgments. Although on the whole this *is* the case, Crist (1981) has recently pointed out that the speed of a same-different judgment is affected not only by the featural similarity of the stimuli being compared, but also by the composition of the set from which stimuli are drawn. It is an interesting question for future research whether such a context effect might also be present in the paradigms that have lent support to the feature-specific inhibition model. If it was, this would cast further doubt on the proposition that the interference observed should be called feature-specific.

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