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THE EFFECT OF IRRELEVANT SURROUNDING LETTERS ON FOCAL LETTER IDENTIFICATION

The Ohio State University
Ph.D. 1981

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THE EFFECT OF IRRELEVANT SURROUNDING LETTERS
ON FOCAL LETTER IDENTIFICATION

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Ronald Gary Shapiro, B.A., M.A.

****

The Ohio State University
1981

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Dedicated in memory of my father Nathan Shapiro and to my mother Raquel Shapiro.
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extraction. Journal of Experimental Psychology: Human Perception &
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slow (and careful!): The more targets there are, the more likely you
are to miss one. Journal of Experimental Psychology: Human Perception
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CHAPTER 1
INTRODUCTION

Oftentimes, it is necessary to respond to the contents of a well-specified position in physical space. Since the visual world is not perfectly redundant, we must isolate this position from the surround in order to respond accurately. It is not always possible to do this (e.g., Bjork & Murray, 1977). Furthermore, Eriksen and Hoffman (1973) found that all items which fall within 1 deg of visual angle are processed as a single chunk. Thus, it is not possible to identify an item in the specified position, yet completely ignore others which fall within 1/2 deg of visual angle on either side of it. Thus, the response may be based upon: 1) the focal item, i.e., the item in the specified position; 2) the immediate surround, i.e., items which are included in the same chunk as the focal item; and 3) the distant surround, i.e., items which are not included in the same chunk as the focal item.

The surround interferes with focal item processing in many routine tasks. A traffic reporter in a police helicopter, for example, may need to report on the status of a particular traffic light. A neighboring traffic light in his line of sight might confuse him so that he responds more slowly or less accurately. Similarly, a computer repairman may need to find out if the bulb located in the fourth position of the third row on a display is defective. He may be confused by the status of the light in the fourth position of the second row. The repairman must
recheck his decision or risk making an error. An automobile driver who is waiting at an intersection for a traffic light to turn green might think that it did, when in reality the light at the next intersection had turned green. Thus, an accident may result.

Plan of the paper

The experiments in this report are designed to examine the effects of an immediate surround upon responses to the focal item when the surround is: 1) identical to the focal item; 2) similar to the focal item; or 3) quite different from the focal item. Items which are identical, or similar to one another belong to the same family. Items which are quite different from one another belong to different families.

The next section presents data from the literature to illustrate the diverse ways in which the surround affects focal-item processing. Then, some theories which attempt to explain the diverse findings will be presented. A second purpose of the experiments in this report is to determine whether intact focal items are processed more rapidly and accurately than distorted focal items, and why. A discussion of focal item processing will follow the discussion of the surround.

Effects of the surround

There are several ways in which the surround might influence focal item processing. A similar surround might affect focal item processing by increasing or decreasing the sensitivity of the perceptual system (d') or by biasing the perceiver to report seeing what he just saw (beta). Any type of surround might influence focal item processing by serving as a warning signal, by competing with the focal item for use of a limited capacity perceptual system, or by competing with the focal item for use of a single response system. We will first examine
the effects of a similar surround upon focal item processing. Then we will look at the more general effects of having a surround.

The literature shows that a focal item is processed more rapidly when it is identical to, rather than quite different from, the items which surround it, both with intact displays (e.g., Krueger & Shapiro, 1980; Posner & Snyder, 1975a, 1975b; Taylor, 1977) and with brief and masked displays (Bjork & Murray, 1977). The error data, on the other hand, go both ways. With a brief display which is forward and backward masked, identical and similar items tend to be processed less accurately than very different items (Bjork & Murray, 1977; Santee & Egeth, 1980). With a clear display, identical items are processed more accurately than very different items (Posner & Snyder, 1975a, 1975b; Taylor, 1977).

There are two potential explanations for these findings. First, surround similarity could affect \( d' \), the sensitivity of the perceptual system, either increasing it (Proctor, 1981; Wold, 1975) or decreasing it (Bjork & Murray, 1977). Second, the surround might bias (a change in beta) the perceiver to report seeing again the item which he just saw (Krueger & Shapiro, 1981). These two explanations will now be examined in more detail.

**Sensitivity (\( d' \)) changes**

The visual world contains a great deal of repeated information. There are two opposing ways in which the sensitivity of the visual system could have evolved to handle repeated as contrasted with non-repeated information. First, the perceptual system might be desensitized or inhibited when an identical item is shown again (Bjork & Murray, 1977; Estes, 1972, 1974). Posner (1978) has shown evidence that brain activity to the second of two identical stimuli is reduced. In
this case, repeated information, but not non-repeated information
would be masked or attenuated. Thus, non-repeated information would be
seen more clearly or more quickly than repeated information (Bjork &
Murray, 1977; Briggs, Johnsen & Shinar, 1974). Conversely, the
perceptual system could be tuned to be extremely sensitive to repeated
information. Thus, repeated information would be processed more
rapidly or more accurately than nonrepeated information (Eguth &
reduction in d' will now be discussed, followed by a discussion of the
possibility of an increase in d'.

Reduction in d' with repeated information. The feature-specific
inhibition model (Bjork & Murray, 1977) offers, perhaps, the most
direct explanation of how a surround might interfere with processing a
same-family focal item. According to the feature-specific inhibition
model, when a particular feature in a visual display is detected, the
detector for that feature becomes occupied encoding the location in the
visual field from which the particular feature was transmitted. As a
result of this encoding, identical features which appear elsewhere are
likely to be missed.

If it happens that the feature in the surround is detected first,
processing of the feature in the focal item would be preempted. As the
number of features common to both the focal item and the surround
items increases, the opportunity to lose features in the focal item also
increases. Thus, the more physically similar the focal item is to the
surround, the worse performance ought to be. This model predicts that
performance ought to be best if the focal item and surround share no
features in common, somewhat worse if they share many features in common,
and worst of all if they are identical. This model can explain why more errors are made in identifying a focal item in a brief display if the focal item is surrounded by an identical item as Bjork and Murray (1977) found. However, it cannot explain why fast RTs were found by Bjork and Murray in the same case. On the other hand, the perturbation and priming models which posit an increase in $d'$ can explain the fast-response time (RT), but not the large number of errors on similar items.

**Increase in $d'$ with repeated information.** The perturbation model (Wolford, 1975) predicts that performance will be better when the focal item and surround are more similar. Wolford claims that focal items are seen clearly, but features from surrounding items are perturbed towards the focal item. When these items are not identical, performance is hurt. Thus, change between the focal item and the surround inhibits processing. A similar surround does not facilitate processing. Wolford is careful to specify that his perturbations do not occur until after feature extraction has been completed. They do, however, occur prior to naming the focal item.

If all of the letters in a particular display were identical, Wolford would predict that perturbations would not affect performance. Thus, a single letter would be processed no more rapidly, nor more slowly, than 4 or 7 identical letters in a row. This prediction is consistent with the findings of Krueger and Shapiro (1980), and Eriksen and Eriksen (1979).

If the focal and surrounding letters in a multi-letter display were similar, but not identical, then, according to Wolford, performance ought to be slightly impaired because the perturbation of a limited number of features would disrupt performance. If, on the other hand,
many of the features in the focal and surrounding locations were different, the perturbation of most any feature ought to interfere with processing, because most perturbed features would distort the focal item. Thus, the perturbation model would predict worse performance when the focal item was not similar to the surround (Krumhansl, 1977). This prediction is consistent with various experimental findings when RT is the dependent variable (e.g., Bjork & Murray, 1977; Krueger & Shapiro, 1980; Taylor, 1977), but not when errors are the dependent variable (Bjork & Murray, 1977). If the focal item and surround were completely different, a given feature could be part of one and only one display item, so that any feature which happened to be perturbed could be reassigned to its correct location without difficulty. Thus, performance ought to be better when the focal item and surround share no features in common, rather than when they share relatively few features.

Krumhansl (1977; Krumhansl & Thomas, 1977) has proposed combining the feature-specific inhibition model with the perturbation model to fully explain interference. According to Krumhansl, when a surround appears at the same time as a focal item, feature detectors might be very busy encoding the surround, causing some features of the focal item which are identical to features in the surround to escape uncoded, making performance suffer (feature-specific inhibition). When the focal item is presented long after the onset of the surround, features from the surround may have traveled to the focal item. Thus, perturbations would explain these findings. Taylor (1977) has, however, found that focal item-surround matches are not processed more slowly than mismatches when the focal item and surround appear simultaneously.
Thus, this hybrid model cannot explain Taylor's findings. Let us now look at a different model to explain increases in $d'$. Proctor (1981) explained that repeated items are processed more rapidly than non-repeated items because they are primed or encoded more efficiently. Although this facilitation principle contrasts with the perturbation model (Wolford, 1975), which explains that the higher $d'$ to repeated rather than to novel items is due to less interference on repeated items, it is not a completely new or novel idea. Indeed, Külpe (1904) first studied how a person could selectively attend to a repeated display. Haber (1966, 1968) and Egeth (1967) attempted to explain an increase in $d'$ but, like Proctor, they neglected to discuss or allow for the possibility of decreases in $d'$ with repeated displays. Although Krueger and Shapiro (1980) found that $d'$ did not change with repeated surrounds, when their focal item and surround were different they always differed considerably. Consequently, their design may not have been sensitive to small changes caused by feature-specific inhibition, and feature-specific inhibition may yet occur with similar displays, producing a decrease in $d'$. Thus, Proctor's theory, which only allows for increases in $d'$, may not explain all of the ways in which a previous display may influence the encoding of a current display.

In addition to being incomplete, Proctor's theory faces a more serious problem. Proctor explained that repeated items are processed more efficiently than non-repeated items. There are two ways in which this could happen: 1) sensory tuning or 2) more efficient cognitive coding. Krueger and Shapiro (1981) explained that neither of these possibilities is very likely.
Facilitation at the feature-extraction stage is not likely because there is as much reason to expect stimulus repetition to hinder processing as to help it (Dember, 1960; Kraut & Smothergill, 1978; Sokolov, 1963), and because many findings show that context does not improve feature extraction. For example, Krueger and Shapiro (1979) found that a word context did not make it easier to decide if a target was distorted. Krueger and Shapiro (1980) found that detection of a focal item was no faster with a string of repeated letters than with a single letter in isolation.

Cognitive facilitation is not likely either. Since letter naming is a relatively automatic process which offers little room for further improvement, showing the same display item twice in a row could hardly be expected to facilitate naming or interpretation.

In spite of Krueger and Shapiro's (1981) arguments that repeated display elements should not facilitate encoding, in a perceptual matching task same responses are often faster than different responses, especially when pairs of items are presented successively rather than simultaneously (e.g., Nickerson, 1967, 1975; Peeke & Stone, 1973; Exp. 1; Proctor, 1981; Snodgrass, 1972). Thus, it may be that same responses with successive presentation are faster than same responses with simultaneous presentation because the first item facilitates the encoding of the second item (Proctor, 1981). Before concluding that Proctor is right, let us look at error data for both simultaneous and successive matching tasks.

In the case of simultaneous matching, more errors are typically made on same than on different trials (due apparently to the fact that internal noise makes same pairs appear to be different more often than
vice versa; see Krueger, 1978). The same-different error disparity typically decreases when displays are presented successively rather than simultaneously. This decrease in the error disparity suggests that priming which caused the extremely rapid same RT with successive presentation may have been due to a bias or disposition to see repeated displays rather than to encoding facilitation. Let us now examine the matter of bias more fully.

Criterion (beta) changes.

The criterion change (bias) model of priming specifies that the first item seen does not affect the clarity of subsequent items. Instead, the first item biases the subject to ignore minor differences between it and the second item in order to assign the same name to a visually-similar second item. Perhaps, priming cuts short the encoding process before it becomes highly accurate (McClelland, 1979). In the perceptual matching task, this priming would result in faster processing of same trials, combined with a decrease in the same-different error disparity, because internal noise increases false-different responses, while priming increases false-same responses with successive presentation. In other tasks, priming would still result in faster processing of repeated items. The fast responses would typically be accompanied by an increase in misidentifying items as being identical to their predecessor. In addition to changes in either d' or beta caused by a similar surround, the mere presence of any surround might also affect focal item processing. Let us now consider such general effects.

General Effects

If the perceptual system has an unlimited capacity, a surround
which appears before the onset of the focal item ought to facilitate focal item processing by signaling that the focal item is about to arrive (Posner & Boies, 1971). If, on the other hand, the perceptual system has only a limited capacity (Kahneman, 1973), in addition to facilitating focal item processing by serving as a warning signal, the surround may inhibit focal item processing by demanding attention at the same time as the focal item. Unfamiliar items, which are usually processed more slowly than familiar items (Krueger, 1975) would cause more interference than familiar items. In either case, since the perceiver has only one response system, response competition may account for much of the interference caused by a surround which has a different response tendency than the focal item (Eriksen & Eriksen, 1979; Eriksen & Schultz, 1979; Krueger & Shapiro, 1980; Proctor, 1981).

Let us consider it next.

Response competition. According to Eriksen and Schultz's continuous flow model, all of the items in a display are encoded independently. Thus, the presence vs. absence of a given display item would not influence the encoding of neighboring display items. Neighboring display items may serve, however, to activate a competing response. Thus, the presence of a surround may cause a second, competing response to become activated. The activation of the second response would cause response uncertainty, which the subject would reduce by performing additional processing. Response time thus would increase. Proctor (1981) would not agree that all display items are processed independently. However, his inhibition principle affirms the presence of response competition.
Data from various RT studies (e.g., Eriksen & Schultz, 1979; Taylor, 1977) support this explanation. Slower responses are made when a focal item is surrounded by members of the opposite response set. Studies with brief, masked displays in which errors are the primary dependent variable do not support this model (Bjork & Murray, 1977; Santee & Egeth, 1980). The error studies show that performance is less accurate when the focal item and surround are identical. However, the error studies may not be a fair test of the response competition model. Indeed, there may be some response competition even in these studies which is overridden by feature-specific inhibition. Thus far, however, there is evidence to support the response competition model only when the display is clear and RT is the primary dependent variable.

In summary, there are several ways in which the surround can influence focal item processing. First, focal-surround similarity could increase or decrease d', the sensitivity of the perceptual system. Second, the surround might bias the perceiver to report seeing again the item which he just saw. Third, the surround might serve as a warning signal, informing the subject that the focal item is about to appear. Fourth, the surround could interfere with focal item processing by demanding attention while the focal item is being processed. Finally, the surround could compete with the focal item for use of a single response system. Now that we have seen how surrounds might influence focal item processing, let us turn to the more general issues of focal letter processing.
Focal Letter Processing

Familiar focal items are often processed more rapidly and accurately than unfamiliar focal items. Typically, this finding is called a familiarity effect (Krueger, 1975). Wandmacher, Shapiro, and Mohr (1981) have shown that familiarity does not improve feature extraction when the focal item is an intact letter vs. a rotated letter. Krueger and Shapiro (1979) and Massaro (1979) offered similar evidence when the focal item is an English word or nonword. There has, thus far, been no adequate theoretical explanation of how familiarity does affect the naming of a single focal item.

The noisy-operator theory (Krueger, 1978), according to which processing is often noisy or imperfect, can be adapted to offer an adequate explanation of this finding. Perhaps some of the noise in processing is caused by feature-specific inhibition (Bjork & Murray, 1977). In any case, there are many features in a familiar item (e.g., an intact English letter) which have the potential to become distorted. If any one of these features does become distorted, the focal item will appear to be unfamiliar or distorted. There are, however, very few ways in which a familiar or an unfamiliar focal item could be distorted to appear to be a familiar item. This type of change would, therefore, occur most infrequently. Thus, it would be safe for the perceiver to assume that any item which looked familiar was properly encoded. Additional rechecking would not be necessary. If the item did not appear to be familiar, the subject could not conclude that it had been encoded properly. Thus, additional processing might be necessary. Since it is relatively easy to determine that a familiar item is properly encoded, familiar items ought to be identified more rapidly and more
accurately than unfamiliar focal items.

If the task is changed from focal-item identification to normality detection, the perceiver would still be able to assume that any item which appeared to be familiar was properly encoded. Additional rechecking would not be necessary. Unfamiliar appearing items could either be noisy intact items or distorted items. In order to avoid making an excess of false-distorted responses, many distorted items would be rechecked. Thus intact (familiar) items ought still to be processed more rapidly than distorted (unfamiliar) items. If the rechecking process were imperfect, false-distorted responses would be made.

Now that we have examined the theories to explain the effect of the surround upon focal item processing, and focal item processing itself, let us turn to Experiments 1 to 5 to find out what effect identical, similar, and quite different surrounds have on focal-item processing; and to see whether the noisy-operator theory can explain familiarity effects in a task other than perceptual matching.
CHAPTER 2
EXPERIMENTS 1 TO 5

The introduction presented several ways in which a particular surround could affect the processing of a focal item. First, the surround could change the clarity (d') of the focal item (i.e., direct effects). In this case, the locus of the effect would most likely be at feature extraction. Second, the surround could bias (via beta) the subject to demand more or less evidence from the focal item, depending on whether or not it matched the expected representation. In this case, the locus of the effect would most likely be at the interpretation or naming stage. Third, the surround could serve as a warning that the focal item is about to appear. Fourth, the surround might merely compete with the focal item for use of a limited capacity perceptual system. Finally, the surround could either compete with the focal item for use of the response system, or it could preactivate the response system. These models will be examined in Experiments 1 to 5.

According to an adaptation of the noisy-operator theory presented in the introduction, a normal focal item might be encoded more rapidly than a distorted focal item. The accuracy of encoding normal vs. distorted focal items would vary with tasks. This adaptation of the noisy operator theory also will be examined in the experiments.

The tasks

In Experiments 1, 2, 3, 4, and 5, a focal item was presented either concurrently with or shortly after the onset of two identical
surround letters. The core set of focal items included in all five experiments were an uppercase A (square form; see Figure 1) and an uppercase E. Additional focal items in Experiment 1 included an uppercase A with an added line connecting the middle of the two horizontal lines, and an uppercase E with an added diagonal line in the bottom segment (see top row of Figure 1). Additional focal items in Experiment 2 included an uppercase A with one of the vertical line segments missing, and an uppercase E with one of the vertical line segments missing (see second row of Figure 1). In Experiments 3 and 4, the additional focal items included two different incomplete E forms and two different incomplete A forms. A and E were the only focal items used in Experiment 5.

In each of the studies, the focal items could appear as surround items. In addition, an uppercase H, C, or X could appear as a surround item in Experiments 3 and 4. An uppercase H, C, X, R, K, F, or T could appear as a surround item in Experiment 5.

The A letter differed from the H, R, and the distorted A forms by only one line segment, so these were considered to be members of the A family. Similarly, the E differed from the C, F, and the incomplete E forms by only one line segment, so these were considered to be members of the E family. All other forms differed from each other by more than one line segment, so their differences were between family rather than within family. An X is sufficiently different from other items so that it will merely be called a member of the X family.

Taylor (1976) has shown that items which are physically very similar to one another are also psychologically very similar. In a same-different comparison task employing successive presentation, Taylor
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<th>Experiment</th>
<th>Task</th>
<th>Focal Family</th>
<th>Surround Family</th>
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<td>Identification</td>
<td>A  A E  E</td>
<td>A  H R K E  C  F  X</td>
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</tbody>
</table>

Figure 1. Display letters and tasks in Experiments 1 to 5.
showed subjects various block-form letters, such as A, O, E, F, and U. He found that RT to different letters increased as the number of segments differing between the successive letters decreased, indicating that the items were more similar psychologically. Thus, Taylor has shown that the number of differing line segments is a valid measure of psychological distance between letters.

In all five of the present experiments the basic idea was to study the effects of focal-surround similarity upon processing a focal item, and to reproduce the interference effects observed by Bjork and Murray (worse performance on very similar items), using RT as well as errors as dependent variables. Experiments 1, 2, and 3 used a distortion detection task in which the observer pressed one button if the focal item was a normal A or E, and another button if it was not (i.e., a distorted A or E; see Figure 1). Experiments 4 and 5 used an identification task in which the observer pressed one button if the focal item was an A (normal or distorted), and another button if the focal item was an E (normal or distorted) (see Figure 1). Displays were bright and remained on for a long period of time. If the pattern of performance does not change between seemingly very different tasks, the effects of the surround can more readily be attributed to early (pre-response) processing involving either feature extraction or identification of the focal item rather than response competition. If, on the other hand, the pattern of performance does change, the effects of surrounding items may be more readily attributed to response processing rather than to feature extraction. The various predictions for the task variable are discussed in detail in the introduction to Experiments 3 and 4.
Predictions

Now, let us formulate a model to explain performance in these tasks for each of the theories mentioned in the introduction.

**Sensitivity (d') changes.** The feature-specific inhibition model (Bjork & Murray, 1977) explains that the presence of a particular feature in the surround will, on occasion, inhibit one's ability to perceive the same features in the focal item. Thus, redundant information is ignored. Unfortunately, the subject does not have the opportunity to select whether to ignore features in the surround or features in the focal item. Thus, the subject may end up fully encoding the surround, and ignoring focal-item features which happen to be identical to the features in the surround, rather than vice versa. With a brief display, focal items which share the most features with items in the surround ought to be processed less accurately than focal items which share few features with items in the surround. When the display is on for a long period of time, the subject might try to reduce errors by rechecking those focal items which seemed to be somewhat similar but not identical to items in the surround.

In the current experiments, the feature-specific inhibition model predicts that performance ought to be worst on a focal item if it is surrounded by an identical letter, somewhat better if it is surrounded by a non-identical letter member of the same family, and considerably better if it is surrounded by a member of a different family. Thus, this model predicts that an A focal item, say, ought to be processed most slowly with an identical A in the surround, slightly faster with a distorted A, an H, or an R (i.e., same family) in the surround, and fastest of all with a member of the E or X families in the surround.
Similarly, an E focal item ought to be processed most slowly with an identical E in the surround, slightly faster with a distorted E, a C, or an F in the surround, and fastest of all with a non-E-like letter in the surround. When the focal item is distorted rather than normal, processing ought to be slowest when the focal and surround items are identical, slightly faster when the focal item and surround have the same general shape, but are not identical, and fastest of all when the focal item and surround are quite different.

The Wolford perturbation model (1975) predicts that performance will be best when the focal item and surround are identical. Performance will decline steadily as the focal item and surround become less similar. Wolford explains that the change in performance is due to features drifting from the surround to the focal items. When the drifted features are not identical to features in the focal item, the subject becomes confused and performance is inhibited. When the focal item and surround share no features in common, however, perturbations may be straightened out, since a given feature could be a part of one and only one display item. Thus, increased errors would not be expected if the focal item and surround were completely different.

The priming facilitation model of Proctor (1981) and Posner (1978) explains that processing of the second of two identical items is faster than processing of a different second item. Evidently, the first item leaves the encoding pathways in an "activated" state, so that an identical second item will be facilitated. However, processing of any other items would not be affected. Thus, this model predicts fast performance whenever the focal item and surround are identical or virtually identical, but equally slow performance when the focal item
and surround are noticeably different, regardless of whether they are relatively similar or very different items. Now, we will examine the predictions for Krueger and Shapiro's (1981) bias model of priming.

**Criterion (beta) changes.** The bias model of Krueger and Shapiro (1981), like Proctor's model, posits that subjects are able to use repetition in the world. The repetition does not, however, help them to see more clearly. Instead, it prompts observers to shift their criterion for identifying a focal item, so that less evidence would be required to give a focal item a particular label if that label were evoked (and thus preactivated) by the surround. Thus, processing on repeated items would be very fast, but there would be some risk of misidentifying items which did not merely repeat the surround. The risk of misidentifying a distorted focal item as being normal is less than the risk of identifying a normal focal item as being distorted since noise is more likely to make a normal item look distorted than vice versa. Thus, subjects might be more willing to relax their criterion for labeling a particular item as being normal after seeing an identical item than they would be willing to relax their criteria for labeling a particular item as being distorted after seeing an identical distorted item, and bias might only show up on normal focal item trials.

If the naming or identification process is similar regardless of task, this model would predict fast responses to repeated normal items in the naming task as well. If, however, subjects use less stringent criteria for identifying A and E items in the identification task, fast performance would be expected on any family match trials in which the focal item and surround look similar.
The name similarity between the focal item and the surround will be varied in Experiments 3, 4, and 5 to determine whether name similarity biases the interpretation process. In addition to bias at the perceptual level, the surround may bias the subject to respond in a given way. Thus, the focal item and surround compete with one another for use of a single response system.

Response competition. When the focal item and surround point towards opposite responses, response competition (Eriksen & Schultz, 1979) might slow RT and increase errors. In a distortion detection task, if response competition were the only factor affecting performance, a distorted A focal item with a normal A surround ought to be processed more slowly than a normal A focal item with a normal E surround. In an identification task a normal A focal item with a distorted A surround ought to be processed more rapidly than with a normal E surround.

In the ordinary world, a focal item is highly correlated (i.e., redundant) with the items which surround it. Although it seems as if the presence of these surround items makes it easier to see the focal item their presence may have no such effect (Krueger & Shapiro, 1979). However, the focal item is usually predictable from the surround so that subjects may merely respond to the surround (which may appear prior to the focal item) on the more difficult items. Thus, it might only seem as if the focal item had been encoded readily. When the surround and the focal item point towards the same response on most trials, this guessing procedure would cause relatively few errors: virtually no errors would be made on focal-predictable trials, though many errors would be made on the relatively infrequent focal-prediction-violated trials. In Experiments 1 and 2 the probability of the surround matching
the focal item will be varied to determine whether subjects do, indeed, tend to respond to the surround instead of the focal item when the surround is a reliable predictor. The stimulus-onset-asynchrony (SOA), i.e., the amount of time between the onset of the surround and the onset of the focal item, will be increased from 0 to 800 msec to decrease the amount of response competition. Let us now look at an alternative way in which the surround could interfere with focal-item processing.

**Surround familiarity.** Displays which contain familiar items such as words or intact letters are processed more readily than displays which contain unfamiliar items such as nonwords or rotated letters (Egeth & Blecker, 1971; Krueger, 1975; LaBerge, 1973; Mewhort, 1967). This effect persists for both focal items which demand a response and for irrelevant surround items which do not. Since intact letters are more familiar than distorted letters, faster processing would be expected when the surround letter was intact rather than distorted.

**Focal letter processing.** In the introduction an explanation of how the noisy-operator theory could be extended to describe performance in a distortion detection task was presented. According to the extended noisy-operator theory, intact focal items ought to be processed more rapidly but less accurately than distorted focal items in a normality detection task. There are many ways in which a normal item could be changed to look distorted, but there are relatively few ways in which a distorted focal item could be changed to appear normal. Thus, the asymmetric effects of noise ought to cause many false-distorted responses on normal items, but few false-normal responses on distorted items.
To reduce the number of false-distorted responses, subjects may recheck all distorted looking items before they respond "distorted." When a display is clear, relatively few normal items will appear to be distorted. Rechecking may be limited to those items which are really distorted, plus a few normal items which were misperceived as distorted. Normal items ought to be processed more rapidly than distorted items. On the other hand, when the display is brief or degraded, most normal items will, after a first glance, appear to be distorted. Thus, normal and distorted items will both need rechecking, and both ought to be processed slowly.

Experiments 1 and 2

The purpose of Experiments 1 and 2 was to determine how the presence of a similar surround affects the processing of a focal item. Thus, subjects saw a focal item which was surrounded by either two copies of a member of its own family (e.g., a normal A focal item surrounded by two normal As, or by two distorted As), or by two copies of a member of another family (e.g., a normal A focal item surrounded by two normal or two distorted Es). In Experiments 1 and 2 the delay between the onset of the focal item and the onset of the surround was varied from 0 to 800 msec, and the probability of the focal item and surround pointing towards the same response was varied from 80% to 20% in order to determine whether subjects do, in fact, tend to respond to the surround when it is a reliable predictor of the focal item.

To insure that subjects encoded the entire focal item, the task selected was distortion detection. Subjects had to decide whether the focal item was distorted or normal. If, in this task, subjects failed to encode any part of a normal focal item, the chances of making an
error would be very high.

A second purpose of Experiments 1 and 2 was to study the processing of normal and distorted focal items. Thus, the distorted focal item in Experiment 1 had an added line segment, while that in Experiment 2 had a deleted line segment.

Method

Apparatus. Displays were presented (at 32 cd/m² intensity) on an Imlac PDS-4 graphics computer, whose cathode ray tube had a greenish-tint, fast-decay P31 phosphor (decay to 1% intensity at .25 msec after display offset). Stimulus letters were thin, illuminated lines on a dark screen; they were software generated using short line vectors. Normal letters resembled English uppercase letters. Distorted letters were constructed in the same manner, except that one line segment was deleted or added. Each subject sat alone in a dark room, with the head held fast in a chin rest located 70 cm from the display screen.

Stimulus materials. On each trial, a row containing two identical surround letters was presented. The two surround letters bracketed the focal letter, which was presented either simultaneous with or subsequent to the onset of the surround. Each letter was .25 cm wide by .3 cm high, and .15 cm separated adjacent letters in the three-character display, whose total width thus was 1.05 cm (0.86 deg of visual angle). A .16 cm high by .16 cm wide plus sign centered on the screen served as the fixation point. It was .3 cm below the center of the focal item.

The focal and surround letters were either a normal A (square form), a normal E, an incomplete A, an incomplete E, a supplemented A, or a supplemented E (see Figure 1). The stimulus set in both Experiment 1 and Experiment 2 included the normal A and the normal E letters.
The supplemented letters (Experiment 1) were formed by adding an extra vertical line segment to the top part of the A, or an extra diagonal line segment to the bottom part of the E. The incomplete letters (Experiment 2) were formed by deleting the upper right segment of an A, and the lower left segment of an E.

The 480 trials in the experimental session were grouped into three blocks of 160 trials each. The experimental trials in each block were preceded by 40 practice trials, so there were 600 trials in all. Each experimental block contained 80 A and 80 E focal letters. Half of these focal letters were intact letters and half were distorted (in Experiment 1 the alteration involved supplementing the normal intact letter with an additional line segment; in Experiment 2 the alteration involved the removal of a line segment). On half of the trials in each block the surround letters had the same name as the focal letter (e.g., both focal letter and surround letters were a normal or a distorted A), and on the other half the surround letters did not have the same name as the focal letter (e.g., the surround letter was a normal or a distorted A and the focal letter was a normal or a distorted E).

The focal item and surrounding items pointed towards the same response (i.e., normal or distorted) on 80% of the trials (vs. 20% to the other response) in the 80/20 block, on 50% of the trials in the 50/50 block, and on 20% of the trials in the 20/80 block. The ordering of blocks was counterbalanced between subjects.

Four different levels of delay or stimulus onset asynchrony (SOA) were randomly intermixed within each block: 0, 200, 400, and 800 msec. Each condition appeared equally often within each level of the SOA. Thus, there was one between-subjects factor: distortion type.
(Experiment 1: added features vs. Experiment 2: deleted features) and five within-subject factors: focal normality (distorted vs. normal), surround normality (distorted vs. normal), focal-surround family (name) match, predictive validity of the surround, and SOA (2 X 2 X 2 X 3 X 4 X 5 replications = 480). To minimize the effect of intertrial dependencies, six different (randomly selected) stimulus orderings were used.

Procedure. The two surround letters appeared at the beginning of the trial. The focal letter appeared either simultaneously with the onset of the surround letters (0 msec SOA), or after a delay of 200, 400, or 800 msec. Half of the subjects pressed a "yes" button with their left index finger if the focal item was normal, and a "no" button with their right index finger if it was distorted. The other half had the reverse hand assignment. A response immediately terminated the display, after which the subject received a 1-sec feedback message. Then the next trial began.

Subjects were told not to pay attention to the surround items, but simply to regard them as indicators of the location for the upcoming focal item (cf., Posner & Snyder, 1975). They were asked to respond as rapidly as possible, but to try to make no errors.

Those few trials with RT less than 200 msec or greater than 3 sec were discarded prior to data analysis. Mean RT was computed for correct trials only.

Subjects. Sixty Ohio State University undergraduates participated as subjects (30 in Experiment 1 and 30 in Experiment 2) in order to receive credit in an introductory psychology course. Data from two additional subjects were discarded because their errors exceeded 10%.
All subjects had at least 20/30 vision (corrected) as tested with a Snellen chart.

Results

There was one between-subjects factor: Experiment 1 (added line segment in the distorted condition) vs. Experiment 2 (deleted line segment in the distorted condition). There were five within-subjects factors: focal normality (normal vs. distorted focal item), surround normality (normal vs. distorted surround items), focal-surround family match (same vs. different families), validity (80/20, 50/50, 20/80), and SOA (0, 200, 400, and 800 msec). The RT and error data for Experiments 1 and 2 are shown in Tables 1 and 2, respectively.

Experiment 1 vs. 2. Significantly more errors were made in Experiment 2 (deleted segments) than in Experiment 1 (added segments), 2.16% vs. 1.32%, $F(1, 58) = 5.47, p < .025$. Although performance was somewhat faster in Experiment 2, experiment did not have a significant main effect on RT, 666 vs. 682 msec, $F < 1$. Perhaps, the insignificantly faster RT in Experiment 2 was due to carelessness, as indicated by the higher error rate in Experiment 2.

Focal item. Normal focal items were processed 26 msec faster than distorted focal items, 661 vs. 687 msec, $F(1, 58) = 24.61, p < .001$, but more errors occurred when the focal item was normal rather than distorted, 2.00% vs. 1.49%, $F(1, 58) = 4.03, p < .05$. This might suggest a response-bias explanation of the speed advantage for normal items (i.e., always respond faster on normal or positive items). However, a response bias towards normal would produce more false-normal than false-distorted responses, whereas the present data indicated the opposite. Thus, the response bias explanation is not tenable.
<table>
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<tr>
<th>Family, Match, Predictive Validity, and SOA</th>
<th>Normal Focal Item Surround</th>
<th>Distorted Focal Item Surround</th>
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### TABLE 2

Experiment 2: Mean Response Time and Percentage of Error Rate by Focal Type, Surround Type, Family Match, Predictive Validity, and SOA

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<th>Family Match, Predictive Validity, and SOA</th>
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<td>589</td>
<td>0.56</td>
</tr>
<tr>
<td>800</td>
<td>611</td>
<td>1.11</td>
<td>583</td>
<td>1.39</td>
</tr>
<tr>
<td>20/80 cond.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>697</td>
<td>5.00</td>
<td>738</td>
<td>2.08</td>
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<tr>
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<td>1.67</td>
<td>616</td>
<td>1.25</td>
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<tr>
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<td>603</td>
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<td>2.08</td>
</tr>
<tr>
<td>800</td>
<td>617</td>
<td>5.00</td>
<td>599</td>
<td>1.25</td>
</tr>
</tbody>
</table>
Focal normality interacted significantly with experiment (distortion type) on both RT, $F(1, 58) = 27.44, p < .001$, and errors, $F(1, 58) = 6.01, p < .025$, as shown in Table 3. Tukey tests revealed that distorted focal items were processed more slowly ($p < .001$) and more accurately ($p < .001$) than normal focal items only in Experiment 2. Subjects in Experiment 1 showed no difference in performance between normal and distorted focal letters.

Surround effects. Overall performance was significantly (20 msec) faster, $F(1, 58) = 68.54, p < .001$, and somewhat more accurate, $F(1, 58) = 3.76, p < .10$, when the surround was normal rather than distorted. The main effect of family match was not significant on either RT or errors.

Focal normality interacted significantly with surround normality, $F(1, 58) = 17.75, p < .001$, on RT, and $F(1, 58) = 6.27, p < .025$ on errors, as shown in Table 3. A Tukey test indicated that on focal normal trials, performance was significantly faster ($p < .01$) and more accurate ($p < .05$) when the surround also was normal. On focal distorted trials, by contrast, surround normality had no effect on either RT or errors. It is interesting to note (in Table 3) that having a distorted surround with a normal focal item slowed RT about as much as did having a distorted focal item. A Scheffé test showed that performance was significantly ($p < .01$) faster (13 msec) when the focal item and surround had the same response tendency, i.e., both items were normal or both were distorted, than when they had conflicting response tendencies, i.e., one was normal and the other was distorted.

The Family Match X Surround Normality interaction was significant on errors, $F(1, 58) = 4.97, p < .05$, reflecting the fact that .65% more
### TABLE 3
Experiments 1 and 2: Mean Response Time and Percentage of Error Rate by Experiment, Surround Type, Focal Type, and Family Match

| Focal Item and Family Match | Experiment 1 | | Experiment 2 | | |
|-----------------------------|--------------|-----------------|-----------------|-----------------|
|                             | Surround | MRT | PE | Surround | MRT | PE | Surround | MRT | PE | Surround | MRT | PE |
| Normal Focal Item Match     | 660 (0.91) | 706 (1.86) | 606 (1.60) | 668 (4.58) |
| Mismatch                    | 675 (1.00) | 690 (1.28) | 637 (2.41) | 646 (2.34) |
| Distorted Focal Item Match  | 689 (1.37) | 679 (1.23) | 689 (1.98) | 691 (1.45) |
| Mismatch                    | 669 (1.42) | 689 (1.49) | 685 (1.53) | 703 (1.42) |
errors were made when a distorted surround was a member of the same family as the focal item rather than a member of a different family (2.28% vs. 1.63%; Tukey, \( p < .01 \)). The presence of a distorted surround increased errors on same-family focal items.

The Focal Normality X Surround Normality X Family Match interaction was significant on both RT, \( F(1, 58) = 28.85, p < .001 \), and on errors, \( F(1, 58) = 7.90, p < .01 \), as shown in Figure 2. When the focal item and surround were both normal, performance was significantly faster if both were members of the same family (Tukey test, \( p < .01 \)). When the focal item was normal, but the surround was distorted, however, RT was significantly slower and performance significantly less accurate if both focal item and surround were from the same family (Tukey test, \( p < .05 \)). Thus, with a normal focal item, performance is fastest when the focal item and surround are identical, slower when they are from different families, and slowest of all when they are from the same family, but are not identical. There were no effects of family match with distorted focal items.

**Predictive validity.** The main effect of predictive validity, that is the likelihood (80/20, 50/50, 20/80) of having the focal item and surround point towards the same response, was not significant on either errors or RT. The Validity X Focal Normality interaction was significant on RT, \( F(2, 116) = 5.59, p < .01 \), as shown in Figure 3. The RT to respond distorted increased steadily and significantly as the probability of having the focal item and surround point toward the same response decreased (Tukey test, \( p < .01 \)). The RT to respond normal was not affected by this response tendency (see Figure 3). The Validity X Focal Normality X Surround Normality interaction was also significant.
Figure 2. Experiments 1 and 2: Mean response time and percentage of error rate for surround normality (abscissa) and family match by focal normality (parameter).
Figure 3. Experiments 1 and 2: Mean response time and percentage of error rate for predictive validity (abscissa: 80/20, 50/50, 20/80) and experiment by focal normality (parameter).
on RT, \( F(2, 116) = 19.18, p < .001 \). As Figure 4 shows, RT was significantly faster on those trials in which the focal item and surround pointed towards the same response (vs. opposite responses) in the 80/20 condition.

The Validity X Family Match interaction was significant on errors, \( F(2, 116) = 3.26, p < .05 \). More errors occurred in the 50/50 condition when the focal item and surround had the same name (versus different names) (Tukey test; \( p < .05 \)). This suggests that people had a greater tendency to respond to the surround when the focal item and surround were similar in name, in spite of the fact that their response tendencies were not correlated.

**Time delay.** Both RT, \( F(3, 174) = 298.60, p < .001 \), and errors, \( F(3, 174) = 3.65, p < .025 \), decreased significantly as the SOA increased from 0 to 800 msec (see Figure 5), apparently because the surround warned the subject that the focal item would be arriving soon. Thus, the subject was better prepared for the focal item. A significant SOA X Focal Normality interaction on RT revealed that the advantage for having a normal focal item increased with increasing SOA, \( F(3, 174) = 7.32, p < .001 \), in this distortion detection task. On the other hand, the SOA X Focal Item Normality X Surround Normality interaction indicated that response competition was greatest at the 0 SOA, and decreased monotonically and significantly as the SOA increased, both on RT, \( F(3, 174) = 3.81, p < .01 \) and on errors, \( F(3, 174) = 3.90, p < .01 \) (see Figure 6).

**Discussion**

**Focal item.** In Experiment 1 (supplemented alteration), RT and errors were virtually identical regardless of whether the focal item
Figure 4. Experiments 1 and 2: Mean response time and percentage of error rate for predictive validity (abscissa: 80/20, 50/50, 20/80) by normality matches and mismatches (parameter).
Figure 5. Experiments 1 and 2: Mean response time and percentage of error rate at each delay interval (abscissa) by focal normality (parameter).
Figure 6. Experiments 1 and 2: Mean response time and percentage of error rate at each delay interval (abscissa) for response matches and mismatches (parameter).
was normal or distorted. In Experiment 2 (deleted alteration), on the
other hand, more errors were made in identifying normal focal items,
yet normal focal items were identified more rapidly than distorted ones.
Why should deleting a feature from a display affect performance more
than adding a feature to the display? Konorski (1967) and Massaro and
Schmuller (1975) said that it should not.

An added line segment may be separable from the letter in which it
occurs, whereas a deleted line segment may not be processed independently
of the basic letter. In Experiment 1, subjects may actually have encoded
the distorted display as a normal focal item and a separate line segment
rather than as a schema (letter) with correction (cf. Woodworth, 1938).
In Experiment 2 the deletion apparently was not encoded independently
of the basic focal letter. Thus, added and deleted features may be
processed differently.

In Experiment 1 since the added line segments may have been concep-
tually separable (Garner, 1974) from the remainder of the focal item,
subjects may have responded to the presence or absence of an added
segment, ignoring the remaining structure of the focal item. Their
task, in this case, would have been a binary decision, i.e., they would
have decided whether the focal item contained a particular single line
segment. The probability of this line segment appearing or disappearing
would be nearly equal. Thus, an equal number of false-distorted and
false-normal responses would be expected. Equal RT on normal and dis-
torted focal items would also be expected. This is what was found.

In Experiment 2, the deleted line segments may not have been con-
ceptually separable from the remainder of the focal item. Thus, the
subjects may have had no choice but to process the entire focal item.
In focal item processing, features may on occasion be overlooked during the encoding process so that normal items may appear to be distorted (Krueger, 1978; Bjork & Murray, 1977). In some tasks subjects may be able to fill in the missing segments, without even noticing the defects. If filling in were done in this distortion detection task, subjects would always respond incorrectly on distorted items. If, on the other hand, subjects were to respond "distorted" as soon as they detected a single distortion or made a single examination of the focal item, subjects would respond incorrectly on many normal items.

To respond relatively accurately in the distortion detection task, subjects do not fill in missing segments, and they do not respond "distorted" after making a single examination of the focal item. Instead, subjects may reexamine the relatively small number of normal displays which appear to be distorted, and most of the distorted displays to reduce the chances of making false-distorted responses. Thus, overall distorted focal RT is much slower than overall normal focal RT. The rechecking process may, on occasion, have been unsuccessful, and on occasion, the rechecking may have been skipped, because more false-distorted than false-normal responses were made.

Alternatively, line segments may not be separable in either Experiment 1 or Experiment 2. Instead, it may be that features (line segments) are perturbed away (or otherwise lost) from but never added to the focal item. If line segments, but not blank spaces, were perturbed away from the focal item during processing, in Experiment 1 some perturbations would make distorted items appear to be normal, whereas in Experiment 2 perturbations would typically make normal items appear to be distorted. Thus, more false-normal responses might be made in Experiment 1, and
more false-distorted responses might be made in Experiment 2. To prevent an excess of errors, subjects might recheck most decisions in Experiment 1 before responding normal and most decisions in Experiment 2 before responding distorted. Thus, faster distorted responses might occur in Experiment 1, and faster normal responses might occur in Experiment 2.

One must also, however, consider the fact that familiar items are processed more rapidly than unfamiliar items. In the case of a distortion detection task, more false-distorted responses than false-normal responses would be expected, because there are many ways in which noise can make a normal item appear to be distorted, but there are few ways in which noise can make a distorted item look normal.

In Experiment 1, perturbations may increase normal RT and false-normal responses while familiarity effects may decrease them. Thus, these effects might cancel one another leaving equal RT and errors for normal and distorted items which is exactly what was found (see Table 3). In Experiment 2, on the other hand, perturbations might increase distorted RT and false-distorted responses while familiarity effects decrease normal RT and increase false-distorted responses. Thus, these effects add together leading to fast normal RT and many false-distorted responses. This is exactly what was found in Experiment 2.

More normal items appear to be distorted when processing of the focal item is relatively noisy rather than relatively noise free. Thus, one would expect that virtually all normal items would need to be rechecked with noisy processing. With a noise-free processing, virtually all normal items could be processed without rechecking. In either case, however, virtually all distorted displays would need to be rechecked.
Normal focal items are processed more rapidly than distorted focal items at the longest SOA, indicating that relatively few normal, but many or most distorted items apparently need to be rechecked (see Figure 5). This is not surprising, because subjects are more prepared for the focal item at the longest SOA. Thus, processing ought to be less noisy, and few normal focal items ought to be misperceived and require rechecking. As the SOA decreases, the amount of noise in processing increases. Thus, more normal focal items need to be rechecked. By the 0 SOA processing is so noisy that virtually all normal as well as all distorted focal items need to be rechecked. Thus, RTs are equal for normal and distorted items. In addition to the change in RT on normal focal items caused by rechecking, RT on both normal and distorted trials decreased with increasing SOA because the onset of the surround served as a general warning signal that the focal item was about to appear.

**Surround effects.** A normal focal letter is processed more rapidly if it is surrounded by an identical item, rather than by a non-identical same-family or a different-family item (see Figure 2). Additionally, with a normal focal letter, a same-family surround slows focal item processing more than does a different-family surround. When the focal letter is distorted, and thus needs rechecking anyway, neither the family nor the normality of the surround have any significant effects upon performance.

One might argue that in the mutilation detection task a familiar surround might facilitate RT even when the focal item is not familiar (cf. Mewhort, 1967). However, the normal surround might compete with the distorted focal item for use of the response system. Thus, response
competition would inhibit performance. If these two factors were of almost equal strength, they would cancel each other and there would be no significant RT differences with distorted focal items.

The normal focal item findings can be explained by a combination of the feature-specific inhibition model (Bjork & Murray, 1977) and the priming model (Krueger & Shapiro, 1981; Posner, 1978). The feature specific inhibition model predicts that the detection of a particular feature in the surround inhibits the detection of an identical feature in the focal item (d' is reduced). Performance in Experiments 1 and 2 was worse when the focal item was similar to the surround rather than very different from it. Thus, the data tend to support this model. This model would also lead one to predict that performance would be slowest of all when the focal item and the surround are identical. However, performance is actually best when the focal item and surround are identical.

This single aberrant point can be explained by priming. According to Posner (1978), repeating a display item causes faster performance on the exact repeated item. How might this priming operate? Priming could make it easier to see certain features in the display. However, the feature-specific inhibition model demands that identical features inhibit, rather than facilitate, one another. Thus, an improvement in feature extraction is not that likely, and Krueger and Shapiro (1981) cited further evidence against this position. Priming might also serve to facilitate the naming of the letter by activating the appropriate cognitive codes. In this case, one would expect priming to do the most good when the focal item and surround were identical but unfamiliar items, because unfamiliar codes can use more help than
the relatively automatic familiar ones. In reality, priming only seems to work when the focal item and surround are very familiar, and additional cognitive facilitation for repeated normal letters can explain the priming. This explanation, however, seems rather unlikely, since identification of familiar letters is so highly overlearned as to be relatively automatic, and thus it offers little opportunity for further improvement (Krueger & Shapiro, 1981). Finally, priming may cause a subject to relax his response criterion (beta), so that he is willing to name a repeated normal item with less evidence that he would normally require. This would lead to faster performance on identical, and more errors on non-identical focal-surround pairs.

Since feature-specific inhibition rarely makes distorted items look normal, the response criterion for repeated items may be relaxed if the focal item appears to be a normal letter without significantly increasing the number of false-normal responses. This seems to happen when the surround is identical to the focal item. Since feature-specific inhibition frequently seems to make normal items appear to be distorted, the response criteria for responding "distorted" cannot be relaxed without increasing the number of false-distorted responses. Thus, the distorted response criterion is not relaxed for repeated items. This amalgamation of feature-specific inhibition and priming accounts for the Experiment 1 and 2 data.

Wolford's (1975) perturbation model explains that focal items which share many features with the surround ought to be processed much more efficiently than focal items which share relatively few features with the surround. In Experiments 1 and 2 when the focal item and surround had many similar features, processing was slower and less
accurate than when they shared few features. Thus, the perturbation model cannot account for much of the Experiment 1 and 2 data.

Krumhansl's (1977) combination model predicts that performance ought to be as the feature-specific inhibition model predicts at the 0 SOA, and as the perturbation model predicts at the longer (forward) SOAs. However, in Experiments 1 and 2 the surround basically affects the focal item in the same way at each SOA. Thus, Krumhansl's theory does not explain these data.

Response competition. Response competition (Eriksen & Eriksen, 1979) significantly affected both accuracy and RT. Subjects were, on the average, 13 msec faster and .61% more accurate when the focal item and surround pointed towards the same response than when they did not (see Table 3). As Figure 4 shows, response competition was greater when most of the trials in the block pointed towards the same response (80/20 condition) than in the 50/50 or the 20/80 condition. Response competition decreased with increasing SOA (see Figure 6). This suggests that each and every item in a display momentarily preactivates or potentiates a response. If the momentary impulses from the focal item and surround occur at the same time, response competition occurs. If, however, the surround's impulse occurs before the focal item's, it will be ignored (cf. Dyer, 1973). Thus, the continued presence of the surround will not cause response competition after the initial impulse.

In Experiments 1 and 2 responses were much more rapid in the block of trials in which the response tendency to the focal item was suggested by the items in the surround (80/20 condition), on those trials in which the response to the focal item matched the response tendency from the surround. However, this rapid processing was accompanied by many
errors on those trials in which the responses did not match. This suggests that the high probability condition did not make it easier to see the focal item when the surround had the same response tendencies as the focal item. Instead, the predictable surround biased subjects to respond to the surround by inferring the response to the focal item.

According to Posner (1978) a person has a limited attentional capacity, so that when he or she attends to one process he or she has less capacity to devote to other non-automatic processes which also demand attention. If performing one task inhibits the performing of a second task, one may conclude that both tasks demand attention. Since there were costs but no benefits to be gained by having the response to the focal item being predictable from the surround in Experiments 1 and 2, Posner would argue that the process of classifying focal items as being normal or distorted would not be automatic. The response process in a normality classification task must, therefore, according to Posner require conscious attention. Response competition alone, however, cannot account for the effects of focal-surround family matches and mismatches, because responses were not based upon the focal-surround family relationship.

**Surround similarity.** Although the presence of a distorted surround significantly slowed focal item processing as Table 3 and Figure 2 show, this effect occurred primarily when the focal item was normal, not when it was distorted. When the focal item was distorted a familiar (normal) surround item may have facilitated the encoding process (Mewhort, 1967), but if it did response competition between the focal and surrounding items canceled out the gain. Thus, any familiarity effect for items in the surround was concealed.
Summary. Experiments 1 and 2 have shown that performance is better when a normal focal item matches its surround exactly rather than when the focal item and surround are quite different (different family) but have the same response tendency. Performance is worse when the focal item and surround are similar but not identical (same family) rather than quite different, even though the focal item and surround have different response tendencies in both cases. This finding occurred in both Experiment 1 (supplemental alteration) and Experiment 2 (deletion alteration). Various post-hoc tests showed this effect to be reliable. An amalgamation of the feature-specific inhibition model (d') (Bjork & Murray, 1977) with the priming model (beta) (Krueger & Shapiro, 1981) can account for the observed data as follows: the detection of a particular feature in the surround might inhibit the detection of an identical feature in the focal item. Thus, a focal item is more difficult to see if it is very similar to the surround rather than quite different from it. Priming may counter the effects of feature-specific inhibition by causing the subject to relax his criterion for identifying a focal item when the focal item is identical to the surround and a familiar letter. Thus, normal focal items which are identical to the letters in the surround are processed more rapidly than other focal items.

Response competition also plays a role in this task. The facilitative effects which occur when the response to the focal item is predictable from the surround regardless of whether the focal item and surround are members of the same family may be mostly a response bias (Taylor, 1977), due to conscious processes (Posner, 1978).
The noisy-operator theory explains why the more familiar normal focal items are processed more rapidly than distorted ones. Noise is asymmetrical in nature. Thus, it makes more normal focal items appear to be distorted than vice versa. This effect is especially noticeable at the longest SOA where processing of many normal items is noise-free (see Figure 5).

Experiments 3 and 4

Experiment 3, like Experiments 1 and 2, used a distortion detection task, whereas Experiment 4 used an identification task, in which subjects pressed one button if the focal item was an A, and another button if it was an E. The displays were identical in both experiments (see Figure 1). The main purpose of Experiment 3 was to replicate the general findings of Experiments 1 and 2. The main purpose of Experiment 4 was to determine whether the findings would change if the task changed.

If the pattern of performance does not change between seemingly very different tasks, the effects of a surround can more readily be attributed to early (pre-response) processing, involving either feature extraction or identification of the stimuli. If the pattern of performance does change, the effects of the surrounding items may be attributed either to a change in the interpretation process or to response competition. In the identification task (Experiment 4) subjects could disregard or ignore the few noisy features in distorted items, since both a normal and a distorted letter led to the same response. Thus, they ought to be able to respond to both normal and distorted items on a single examination. In this case, a same name non-identical surround ought to be processed as rapidly as an identical surround. This would indicate that task caused a change in criterion
affecting the interpretation stage. On the other hand, the only change in performance could be due to a switch in response competition between experiments. In Experiment 3, processing of a normal focal item would be impeded by response competition if the surround was distorted and the processing of a distorted focal item would be impeded if the surround was normal. Thus, response competition could occur if the focal item and surround were in the same family or in different families. In Experiment 4 processing of an A family focal item would be impeded if the surround was a member of the E family, and processing of an E focal item would be impeded if the surround was a member of the A family. Response competition could not occur if both the focal item and surround were intact or distorted A, or both were intact or distorted E.

In Experiments 3 and 4, unlike Experiments 1 and 2, two rather than one distorted forms of each letter were used. This was to insure that subjects encoded the entire focal item rather than merely searched for a specific added or deleted feature.

In addition to having normal and distorted "square" A and E surround letters, the letters H, C, and X were also used. However, as in Experiments 1 and 2, the focal items were restricted to normal and distorted A and E. No added feature letters were used in Experiments 3 or 4; distortions were made by deletion only.

In Experiments 1 and 2, distorted surround letters disrupted processing more than both identical and non-identical normal surround letters. This disruption could have been due to the fact that less familiar forms are processed more slowly than familiar forms (Mewhort, 1967). On the other hand, the distorted letters may simply have
caused more feature-specific inhibition because they looked more like the focal item than do other normal surround letters. Thus, similarity as well as familiarity could have affected performance in Experiments 1 and 2. To determine whether both similarity and familiarity caused the interference, subjects in Experiments 3 and 4 were shown an H or C surrounding item in addition to the normal and distorted A and E forms. As may be seen in Figure 1, the H surround was a member of the A family, and the C surround was a member of the E family.

If familiarity of the surround plays an important role in processing, then the H and C ought to be processed more readily than the distorted A and E. If not, H and C ought to be processed no more readily than the distorted items. If similarity plays an important role, then the H and C ought to cause as much interference as the distorted A and E when the focal item and surround come from the same family, since all family members in Experiments 3 and 4 either were the normal A or E or differed from the normal A or E by only one line segment.

The letter X is very different from the letters A and E. There are many features in the X which are not present in the A and E. Thus, the feature-specific inhibition model (Bjork & Murray, 1977) would predict best performance with an X in the surround. The perturbation model (Wolford, 1975) would predict neutral performance with an X in the surround, since the X would not be readily confused with the A or E families.

Response competition would predict worse performance with a normality mismatch (than a normality match) in Experiment 3, and worse performance with a name mismatch (than with a name match) in Experiment 4.
Method

Apparatus and stimulus materials. The same apparatus and stimulus materials were used as in Experiments 1 and 2, except that the surround letter set was expanded to include two distorted A letters (one with the top left vertical segment missing and one with the top right vertical segment missing), two distorted E letters (one with the top left vertical segment missing, and one with the bottom left vertical segment missing), an H, a C and an X (see Figure 1). The new letters were the same size as the letters employed in Experiment 1. The SOAs in Experiments 3 and 4 were 0, 200, and 800 msec.

The 480 trials in the experimental session included 240 trials with an A focal item and 240 trials with an E focal item. Half of these focal items were distorted and half were not. Each focal item appeared 12 times each with a) the normal A surround, b) each of the two distorted A surrounds, c) the normal E surround, d) each of the two distorted E surrounds, e) the H surround, f) the C surround; and 24 times with the X surround, for a total of 120 replications (2 names [A vs. E] X 2 levels of normality [distorted vs. normal] X 120 replications = 480).

Procedure. The 30 subjects in Experiment 3 performed a distortion detection task identical to that in Experiments 1 and 2. The 30 subjects in Experiment 4 judged whether the focal item was an A (normal or distorted) or an E (normal or distorted), rather than whether it was normal or distorted. Half of these subjects pressed the left button if the focal item was an A, and the right button if it was an E. The remaining subjects had the reverse hand assignment.
Results

Combined Analysis

Data from Experiment 3 (distortion detection) and Experiment 4 (identification) were examined in a combined analysis to determine whether the change in task affected performance. The between-subjects factor was task (Experiment 3: distortion detection vs. Experiment 4: identification). The within-subjects factors were: SOA (0, 200, or 800 msec), focal normality (normal vs. distorted focal item), focal name (A vs. E), family match (focal item and surround similar or dissimilar), and surround type which had three levels: 1) at the first (AE) level the surround was either a normal A or a normal E, the prototype letters; 2) at the second (distorted AE) level the surround was a distorted form of either the A or E prototype letter; 3) at the third (HC) level the surround was either an H or a C, i.e., letters which look (and sound) like the prototype letters. The combined analysis will be reported first, followed by separate analyses of the RT and error data for each experiment. Summary data for Experiments 3 and 4 are shown in Tables 4 and 5, respectively. Performance was no different when the surround item was an X than when it was a member of the opposite family, and the X surround will not be considered further. The particular style of the distorted letter (e.g., A vs. A) did not affect performance in any meaningful way. Having identical distorted letters, as opposed to same family distorted in the surround did not affect performance either, and individual distortions will not be discussed further.

Performance was significantly faster, $F(2, 116) = 272.46, p < .001$, and more accurate, $F(2, 116) = 7.24, p < .01$, as the SOA increased (see Figure 7). The main effect of letter name (i.e., whether the focal item...
TABLE 4

Experiment 3: Mean Response Time and Percentage of Error Rate by Focal Type, Surround Type, Family Match, SOA, and Focal Letter Name

<table>
<thead>
<tr>
<th>Focal Name</th>
<th>Normal Normal Item</th>
<th>Distorted Normal Item</th>
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<td>668 0.83</td>
<td>642 0.00</td>
<td>716 1.67</td>
</tr>
<tr>
<td></td>
<td>E 656 5.00</td>
<td>689 3.33</td>
<td>645 0.83</td>
<td>700 3.33</td>
</tr>
<tr>
<td>800</td>
<td>A 621 0.00</td>
<td>658 0.42</td>
<td>679 1.67</td>
<td>701 0.83</td>
</tr>
<tr>
<td></td>
<td>E 657 1.67</td>
<td>658 1.25</td>
<td>657 2.78</td>
<td>709 3.33</td>
</tr>
</tbody>
</table>
Table 5

Experiment 4: Mean Response Time and Percentage of Error Rate by Focal Type, Surround Type, Family Match, SOA, and Focal Letter Name

<table>
<thead>
<tr>
<th>Family Match, SOA, and Focal</th>
<th>Intact Focal Item</th>
<th>Distorted Focal Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Normal</td>
<td>Distorted</td>
</tr>
<tr>
<td>Name</td>
<td>MRT</td>
<td>PE</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>652</td>
<td>3.33</td>
</tr>
<tr>
<td>E</td>
<td>651</td>
<td>0.83</td>
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<tr>
<td>200</td>
<td></td>
<td></td>
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<tr>
<td>A</td>
<td>562</td>
<td>0.00</td>
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<tr>
<td>E</td>
<td>611</td>
<td>2.50</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>575</td>
<td>0.83</td>
</tr>
<tr>
<td>E</td>
<td>582</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Family Mismatch

| 0    |      |      |      |      |      |      |      |      |      |      |
| A    |  775 | 1.66 |  678 | 2.50 |  660 | 0.83 |  809 | 3.33 |  777 | 2.50 |
| E    |  685 | 1.67 |  683 | 2.92 |  691 | 5.83 |  832 | 4.17 |  783 | 2.92 |
| 200  |      |      |      |      |      |      |      |      |      |      |
| A    |  616 | 3.33 |  599 | 1.67 |  568 | 2.50 |  683 | 1.67 |  669 | 2.50 |
| E    |  623 | 2.50 |  601 | 1.67 |  617 | 3.33 |  689 | 2.50 |  705 | 2.08 |
| 800  |      |      |      |      |      |      |      |      |      |      |
| A    |  568 | 0.83 |  575 | 1.67 |  582 | 1.67 |  646 | 4.16 |  649 | 0.83 |
| E    |  575 | 1.67 |  562 | 1.67 |  555 | 0.83 |  628 | 1.67 |  645 | 2.08 |
Figure 7. Experiments 3 and 4: Mean response time and percentage of error rate at each surround-focal onset delay (abscissa) in Experiment 3 (detection task) and Experiment 4 (identification task) by focal normality (parameter).
was an A or an E) was not significant on RT, but more errors were made on E than A trials, $F(1, 58) = 4.64, p < .01$ (see Table 6). The Focal Normality X Letter Name interaction was significant, on both RT, $F(1, 58) = 5.15, p < .05$, and on errors, $F(1, 58) = 4.24, p < .05$ (see Table 6). Normal A focal items were processed more rapidly and accurately than other focal items (distorted A, normal E, distorted E). Perhaps an A, because of its closure, looks more complete and letter like than an E. There was no overall effect on either errors or RT of whether the subjects were engaged in distortion detection (Experiment 3) or letter identification (Experiment 4).

**Focal item.** Normal focal items were processed significantly more rapidly than distorted focal items, 664 vs. 737 msec, $F(1, 58) = 95.78, p < .001$ (see Figure 7). Focal normality interacted significantly with task on RT, $F(1, 58) = 14.27, p < .001$, reflecting the fact that the advantage for having a normal focal item was greater with name identification in Experiment 4 (101 msec) than with distortion detection in Experiment 3 (45 msec). The Focal Normality X Task interaction was also significant on errors, $F(1, 58) = 14.49, p < .001$. A normal focal item was more frequently misperceived as distorted than vice versa in Experiment 3, 2.72% vs. 1.85%. In Experiment 4 the opposite pattern was shown: a distorted focal item was misidentified more often that a normal focal item, 3.02% vs. 1.89%. A Tukey test showed that the RT advantage for a normal focal item was significant in both experiments ($p < .01$ in each case). The error effect was significant in Experiment 4 ($p < .05$), but not quite so in Experiment 3 ($p < .10$)(see Figure 7).
### TABLE 6

Experiments 3 and 4: Mean Response Time and Percentage of Error Rate by Focal Type, Task (Experiment 3 vs. Experiment 4), and Focal Letter Name

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Focal Type</th>
<th>Normal</th>
<th>Distorted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MRT</td>
<td>PE</td>
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<tr>
<td></td>
<td>Normal</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>695</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>Distorted</td>
<td>713</td>
<td>3.65</td>
</tr>
<tr>
<td>Experiment 3:</td>
<td>Distortion Detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Normal</td>
<td>615</td>
<td>1.83</td>
</tr>
<tr>
<td>E</td>
<td>Distorted</td>
<td>633</td>
<td>1.94</td>
</tr>
<tr>
<td>Experiment 4:</td>
<td>Identification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


The Task X SOA X Focal Normality interaction was significant on RT, $F(2, 116) = 7.37, p < .001$, but not on errors, $F(2, 116) = 1.59$, see Figure 7. The usual RT advantage for a normal focal item almost vanished at the 0 SOA in Experiment 3 (detection task).

**Surround effects.** There were no significant error results involving the surround. On RT, the main effect of surround type (AE, distorted AE, HC) was significant, $F(2, 116) = 5.72, p < .01$ (see Table 7). A Tukey test showed that distorted AE surround letters slowed RT significantly more than normal AE letters ($p < .01$). The HC letters were intermediate; they slowed RT more than the AE letters, but less than the distorted AE letters. However, the latter two differences were not significant.

The Surround Type X Task interaction was significant on RT, $F(2, 116) = 5.96, p < .01$ (see Table 7). Overall RT was not affected by surround type in Experiment 4, the identification task. In Experiment 3, the distortion detection task, overall performance was significantly faster when the surrounding items were normal AE letters (713 msec) rather than distorted AE letters (742 msec) (Tukey test, $p < .01$). The RT with HC surround letters fell in between (725 msec) and was significantly faster than RT to a distorted surround ($p < .05$).

The main effect of family match was significant on RT, $F(1, 58) = 22.08, p < .001$. Overall performance was 18 msec slower if the focal item and surround came from the same family rather than from different families (see Table 7). The Surround Type X Family Match interaction was significant on RT, $F(2, 116) = 9.56, p < .001$ (see Table 7). Same-family interference occurred only when the surround was a distorted AE or an HC (confirmed at .05 level with Tukey tests). Mean RT was
TABLE 7

Experiments 3 and 4: Mean Response Time and Percentage of Error Rate by Surround Type (Normal AE, Distorted AE, Normal HC), Task (Experiment 3 vs. Experiment 4) and Family Match

<table>
<thead>
<tr>
<th>Experiment and Family Match</th>
<th>Surround Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal AE</td>
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<td>MRT</td>
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<tr>
<td>Experiment 3:</td>
<td></td>
</tr>
<tr>
<td>Distortion Detection</td>
<td></td>
</tr>
<tr>
<td>Match</td>
<td>712</td>
</tr>
<tr>
<td>Mismatch</td>
<td>713</td>
</tr>
<tr>
<td>Experiment 4:</td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td></td>
</tr>
<tr>
<td>Match</td>
<td>674</td>
</tr>
<tr>
<td>Mismatch</td>
<td>678</td>
</tr>
</tbody>
</table>
actually 2 msec faster with a normal AE surround when the family matched.

The Focal Normality X Family Match Interaction was significant on RT, _F(1, 58) = 16.36, p < .001 (see Table 8). When the focal item and surround were members of the same family, the RT to respond to a distorted focal item was especially long, indicating that a same-family surround seemed to disrupt distorted more than normal focal item processing. This result did not appear in Experiments 1 and 2 (see Figure 2). It seems that focal normal trials appear to be distorted more frequently in Experiment 3 and 4 than in Experiments 1 and 2. This may, in fact, be caused by having more types of distortions in the later two experiments. Thus, there are more ways for a normal item to appear distorted, and more processing of distorted focal items from the same family must occur to prevent excessive errors. The Task X Focal Normality X Family Match interaction was also significant on RT, _F(1, 58) = 4.74, p < .05, and on errors, _F(1, 58) = 9.00, p < .001 (see Table 8). The RT indicates that the same-family surround was more disruptive of distorted focal item processing in Experiment 4 than Experiment 3. The error interaction shows that many errors were made on family match trials with a normal focal item in Experiment 3, but few errors were made on the same condition in Experiment 4.

The Focal Normality X Surround Type (AE, distorted AE, HC) X Family Match interaction was significant on RT, _F(2, 116) = 3.68, p < .05 (see Figures 8 and 9). Thus, a separate analysis of normal and distorted focal items was mandated. The surround type did not influence processing of distorted focal items. On normal focal item trials, by contrast, the Surround Type X Family Match interaction was significant
### TABLE 8

Experiments 3 and 4: Mean Response Time and Percentage of Error Rate by Focal Item Type (Normal vs. Distorted), Task (Experiment 3 vs. 4), and Family Match

<table>
<thead>
<tr>
<th>Family Match</th>
<th>Focal Item</th>
<th>Normal</th>
<th>Distorted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MRT</td>
<td>PE</td>
</tr>
<tr>
<td>Match</td>
<td>Normal</td>
<td>708</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td>Distorted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mismatch</td>
<td>Normal</td>
<td>700</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>Distorted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Experiment 3:**

**Distortion Detection**
- Match: 708 (MRT), 3.20 (PE)
- Mismatch: 700 (MRT), 2.24 (PE)

**Experiment 4:**

**Identification**
- Match: 625 (MRT), 1.62 (PE)
- Mismatch: 623 (MRT), 2.15 (PE)
Figure 8. Experiment 3: Mean response time and percentage of error rate for family match and surround type (abscissa) by focal normality (parameter).
Figure 9. Experiment 4: Mean response time and percentage of error rate for family match and surround type (abscissa) by focal normality (parameter).
on RT, $F(2, 116) = 14.80$, $p < .001$. Scheffé tests revealed that performance with distorted AE and normal HC surround letters combined was significantly ($p < .01$) faster when the families mismatched than when they matched. Performance with normal AE focal items was faster when the focal item and surround came from the same family ($p < .01$). Thus, when the focal item was normal, family matches slowed RT if and only if the surround was not a normal A or E.

The Family Match X SOA interaction was significant, $F(2, 116) = 5.40$, $p < .01$ (see Figure 10). The cost of having a family match was greater with successive presentation than with simultaneous presentation.

**Separate Analyses**

Separate analyses were performed on Experiments 3 and 4, thus eliminating the sole between-subjects factor. The within-subjects factors were the same as in the combined analysis. The results were, in general, consistent with the combined analysis.

**Experiment 3: Distortion Detection.** On RT, the main effects which were significant in the combined analysis were also significant in the Experiment 3 analysis ($p < .01$ or better). RT decreased with increasing SOA (see Figure 7). Normal focal items were processed more rapidly than distorted focal items (see Figure 7). Family match slowed performance (see Table 7).

On errors, the main effects of SOA, letter name, and family match were significant ($p < .05$ or better). Errors decreased as SOA increased (see Figure 7). More errors were made on E than on A focal items (2.75% vs. 1.82%, see Table 6). More errors were made if the focal item was from the same family as the surround (see Table 7).
Figure 10. Experiments 3 and 4: Mean response time and percentage of error rate for each surround type (abscissa) by family match at each delay (parameter).
The Surround Type X Family Match interaction was significant on RT in this analysis, \( F(2, 58) = 3.45, p < .05 \), as well as in the combined analysis (see Table 7). Scheffé tests revealed that performance was faster when the focal item was identical to the surround rather than slightly different from it \( (p < .05) \). Performance was faster when the family mismatched than when the surround was a non-identical member of the focal item's family. Thus, family matches slowed RT if the surround was not a normal AE. On errors, the Surround Type X Family Match interaction was significant, \( F(2, 58) = 3.21, p < .05 \). More errors were made with a normal surround if the family mismatched, whereas more errors were made with a distorted surround if the family matched.

Focal letter completeness interacted with focal letter name in this analysis, but not in the combined analysis, on RT, \( F(1, 29) = 5.86, p < .025 \), and on errors, \( F(1, 29) = 9.68, p < .01 \). Subjects tended to say normal to an A and distorted to an E. Perhaps this is due to the fact that an A is more of a closed form than is an E.

Experiment 4: Identification. On RT, the main effects of SOA, family match, and focal normality were significant, just as they were in the combined analysis \( (p < .001) \). The surround type main effect was not significant, but it was in the main analysis (see Table 7). The focal item letter name effect was significant also \( (p < .001) \). The letter E was named more slowly than the letter A (see Table 6). RT decreased as the SOA increased (see Figure 7). It took longer to name a distorted focal item than a normal one (see Table 8). Family matches slowed performance (see Table 4). More errors were made when the focal item was distorted, \( F(1, 29) = 14.97, p < .001 \), suggesting that it is difficult to categorize a distorted focal item (see Figure 7).
The Focal Normality X Family Match interaction was significant, $F(1, 29) = 23.61$, $p < .001$, reflecting the fact that normal focal items were processed equally fast regardless of which family they were from relative to the surround (see Table 8). Only the distorted focal items were processed more slowly if they were from the same family as the surround. The Focal Normality X Family Match interaction was also significant on errors, $F(1, 29) = 9.25$, $p < .01$. When the family matched many more errors were made on distorted focal items, but when it mismatched nearly an equal number of errors were made on normal and distorted focal items (see Table 8).

The Surround Type X Family Match interaction also was significant, $F(2, 58) = 6.71$, $p < .01$, reflecting the fact that family matches slowed RT if and only if the surround was not a normal AE (see Table 7 and Figure 9). These findings were confirmed with a Tukey test.

The SOA X Family Match interaction was also significant, $F(2, 58) = 5.10$, $p < .01$. Different family helped performance at the 200 and 800 msec SOAs, but performance was equally slow on both family matches and mismatches at the zero SOA. Similar items apparently had more of an opportunity to interfere with perceiving a focal item at the long SOA.

**Discussion**

**Focal item.** In Experiments 3 and 4, as well as Experiments 1 and 2, normal focal items were processed more rapidly than distorted ones. Normal focal items were processed 101 msec faster than distorted focal items in Experiment 4 (identification) and 45 msec faster in Experiment 3 (distortion detection) (see Figures 8 and 9). In Experiment 3, a normal focal item was misperceived as distorted slightly more often than a distorted focal item was misperceived as being normal. In
Experiment 4, on the other hand, a distorted focal item was misidentified slightly more often than a normal one. The change in both RT and error performance is no doubt due to the task the subject was performing. Now let us look at focal item performance in Experiments 3 and 4 separately.

In Experiment 3 (distortion detection), the subject determined whether the focal item was missing any line segments. Since the normal and distorted focal items were very similar, encoding needed to be very accurate. A noisy encoding would have made a normal item appear to be distorted, whereas a noisy encoding of a distorted focal item would rarely have made it look normal (cf. Krueger, 1978). Thus, most normal items were processed rapidly and accurately. A small number of normal items were, however, left looking distorted, but virtually no distorted items appeared to be normal. To prevent noisy normal letters from generating many false-distorted responses, additional rechecking was performed on those few normal as well as most distorted focal items. Thus, slower processing occurred on distorted items. There were more errors on normal than distorted items but not significantly so, indicating that this rechecking process was largely successful.

Figure 7 shows the SOA data in Experiment 3. These data are very similar to the SOA data in Experiments 1 and 2. At the long SOA normal focal items needed to be rechecked less frequently than distorted focal items, because of the asymmetric properties of noise. Noise ought more frequently to make a normal focal item appear to be distorted than a distorted focal item appear to be normal. Thus, few normal focal items, but many or most distorted ones had to be rechecked at the relatively
noise-free long SOA. At the relatively noisy short SOA virtually all displays appeared to be distorted, and demanded rechecking.

In Experiment 4 (identification), on the other hand, the subject did not need to encode each line segment of the focal item perfectly. He or she only needed to extract enough features to be able to identify the focal item as being an A (normal or distorted) or an E (normal or distorted). Very few normal items needed to be rechecked at any SOA because there were many differing features between an A and an E (see Figure 7). Many of the distorted items, however, looked similar enough to the opposite family that they had to be rechecked. Thus, the more familiar normal letter was processed more rapidly and accurately than the unfamiliar distorted letter, as one would expect (Krueger, 1975).

**Surround effects.** The results of Experiments 3 and 4 generally confirm the results observed in Experiments 1 and 2 (see Figures 2, 8, and 9). On normal focal items, RT was fastest when the focal item was identical to the surround, somewhat slower when the surround was from a different family, and slowest of all when the surround was from the same family as the focal item.

In Experiment 3, as well as in the combined analysis, Scheffé tests confirmed that these differences were significant. In Experiment 4, non-identical same family items were processed more slowly than either different family items or identical items. However, identical items were not processed faster than different family items. The very long RT on trials with both distorted focal items and distorted different family surrounds observed in Experiments 1 and 2 (see Figure 2) was not observed in these studies. Thus, the very long RT in this single condition must have been due to chance factors.
The basis for possible response competition changed from Experiment 3 to Experiment 4. In Experiment 3, the subjects decided whether a focal item was distorted or not. Thus, response competition occurred with normality mismatches regardless of whether family matched. In Experiment 4, the subjects identified a focal item. Thus, response competition occurred only with family mismatches (see Figure 9). The RT advantage for having an identical focal item and surround was greater in Experiment 3 than in Experiment 4, because in Experiment 3 the RT advantage included a response factor. In Experiment 4, it did not. The RT disadvantage for having an AE surround with a family mismatch in Experiment 4 was probably due to response competition, because it is difficult to decide whether to respond A or E while looking at both A and E.

The increase in errors on distorted focal items in the same family condition of Experiment 4 is no doubt due to the difficulty involved in assigning the name A or E to a distorted item. The decrease in errors on normal focal items in Experiment 4 is no doubt due to the fact that small amounts of noise which would make a normal focal item appear to be distorted in Experiment 3 did not affect performance in Experiment 4, because those subjects did not need to decide whether the focal item was normal or distorted.

The results of these experiments are, in general, consistent with Bjork and Murray's (1977) feature-specific inhibition model, according to which it is very difficult to perceive features in an item which has a very similar item next to it. In Experiments 3 and 4, when the focal item and the surround came from the same family, processing was much slower than when they came from different families (even with distorted
focal items). This suggests that similarity does, indeed, disrupt focal item processing, with normal as well as distorted focal items. It is important to note that feature-specific inhibition occurred even in Experiment 4 where similar and identical items were responded to in the same way. There is, however, one datum in each experiment which contradicts the feature-specific inhibition model. The model predicts that the more similar the focal item is to the surround, the worse performance ought to be. Thus, one would expect that performance would be worst when the focal item and surround were identical. Instead, performance was actually fastest, and very few errors were made when the focal item was a normal letter which was identical to the surround. Feature-specific inhibition, most likely, occurs even with identical focal items and surrounds. The inhibition is, however, concealed by another factor: priming. Priming would facilitate the encoding of a repeated letter, but it should not inhibit the encoding of a nonrepeated letter (Krueger & Shapiro, 1981; Posner, 1978). How might this priming work?

Priming could, as we have seen in the introduction, either increase the rate at which information is built up (d'), or it could reduce the amount of evidence required to name the second letter (beta). There are two ways in which priming could affect d'. The percept could be cohered more readily for a repeated item, or the cognitive coding could be facilitated. Since lateral inhibition seems to play a major role in this study, it is impossible to see how the percept for identical items could be cohered more readily. Since the priming only seems to work on whole focal items, which are already very efficiently coded in a relatively automatic manner (Krueger & Shapiro, 1981; Proctor, 1981),
the notion of coding facilitation does not seem able to explain the priming notion, either.

It could be that when the focal item and surround are similar and feature-specific inhibition occurs, subjects do not normally adjust their criterion to allow for the increase in imperfections in the focal item. Thus, with similar surrounds subjects make many false-distorted responses.

When the surround is identical to the focal item, nature may compensate for feature-specific inhibition by priming. The subject merely relaxes his criterion (beta) somewhat to identify the same item twice in a row. Thus, normal focal items are perceived more readily if they are surrounded by identical letters.

One might expect that with a criterion shift fewer false-distorted and more false-normal responses would be made. Although fewer false-distorted responses are made, the number of false-normal responses remains very low. This suggests that the priming (criterion adjustment) which is called for by repeating the display items is an appropriate compensation for feature-specific inhibition. It would seem as if this compensation ought to occur when the surround is similar but not identical to the focal item. However it does not. If it did overgeneralization would occur, and it would be difficult to discriminate one letter from another, because all letters are somewhat similar to one another (Krueger & Shapiro, 1981).

Wolford's perturbation model predicted that processing would be best when the focal item and surround were the most similar, and worst when they were quite different. Since very similar items are processed less efficiently than quite different items, perturbations
do not explain these data.

In addition to specific interference caused by similarity between the focal item and the surround and response competition, surround type seems to have had a general effect upon RT. Overall and in Experiment 3 separately, the HC surround interfered more than the normal AE but less than the distorted AE surround (see Table 7). This suggests that having a familiar item in the surround did indeed facilitate processing of a focal item (Mewhort, 1967). When the focal item was normal and both the focal item and surround were from the same family in Experiment 3 (see Figure 8), the HC and distorted AE surrounds interfered almost equally. This shows that when the focal item and surround were similar, the feature-specific inhibition caused by similarity combined with the added response competition for HC over AE concealed the facilitative effects of familiarity on RT. In Experiment 4 (identification) having a similar surround did not facilitate RT (see Table 7). Response competition caused by the prototype of the opposite family in the surround (e.g. E surround with A focal item) may have been much stronger than response competition caused by H or C from the opposite family. Thus, response competition may have overridden familiarity effects (see Figure 9).

Experiment 5

Experiments 3 and 4 showed that non-identical, but similar looking items, which were members of the same family, interfered with one another in both the identification and distortion detection tasks. Performance was slowed when an A focal item was surrounded by either a distorted A or an H, and when an E focal item was surrounded by either a distorted E or a C. In those experiments, similar looking surround
items from the same family as the focal item also had very similar surrounding names. Thus, the interference could have been caused by acoustic similarity rather than by visual similarity (Egeth & Santee, 1981; Krueger, 1970). Experiment 5 used an identification task in which acoustic similarity and visual similarity were unconfounded. One purpose of Experiment 5 was to determine whether feature-specific inhibition is caused by acoustic or sound similarity (Egeth & Santee) or by visual or shape similarity (Bjork & Murray).

In Experiment 4, distorted items were present in many displays. Their presence may have changed the way in which the subjects processed normal display letters. In order to test this possibility, no distorted items were presented in Experiment 5.

In Experiment 5, subjects were presented with an A or an E focal item embedded in a surround of either A, E, H, C, R, K, F, T, or X. The A, H, R, and K surrounds were considered members of the A family, and the E, C, F, and T were considered members of the E family. The surrounding letters were chosen such that they were 1) identical to the focal item (e.g., a surround-focal combination of AA or EE), 2) looked and sounded like the focal item (e.g., a surround-focal combination of HA or CE), 3) looked like the focal item, but did not sound like it (e.g., a surround-focal combination of RA or FE), or 4) sounded like the focal item, but did not look like it (e.g., surround-focal combination of KA or TE). Each surrounding item was unrelated to the other focal item (e.g., a surround-focal combination of RE, TA, KE, FA, EA, CA, AE, or HE). An X surround also appeared with A and E focal items. Performance with the X surround was very similar to performance on the family mismatch trials, and data from the X trials will not be presented.
If same family interference were due just to visual appearance, performance ought to be equal when the focal item and surround look-alike and when they look-and-sound-alike and ought to be worse than performance when they are unrelated. Performance when the focal item sounds like the surround ought to resemble performance when they are unrelated. If, on the other hand, the interference is due to sound as well as shape, performance ought to be worse when the focal item and surround sound-alike than when they are unrelated.

**Method**

The apparatus and procedure were similar to that in Experiment 4. Subjects judged whether the focal item was an A (square form) or an E. The focal item was surrounded by either an A, E, H, C, R, K, F, T, or X (see Figure 1). The 9 surrounds appeared 30 times each with the A focal item and 30 times each with the E focal item. Thus, there were 270 trials with an A focal item and 270 trials with an E focal item, or 540 trials in all. Each SOA (0, 200, or 800 msec) appeared equally often (10 times) for each focal-surround pair. Thus, the design was 2 (focal item of A or E) X 9 (surround letters of A, E, H, C, R, K, F, T, or X) X 3 (SOA of 0, 200, or 800 msec) X 10 replications = 540. Thirty subjects participated in this experiment.

**Results**

The analyses examined the following factors: SOA (0, 200, or 800 msec), family match (focal item and surround came from the same family or from different families), and surround type which had four levels: 1) at the first (AE) level the surround was either a normal A or a normal E, the prototype letters; 2) at the second (HC) level the surround was either an H or a C, i.e., letters which look and
sound like one of the prototype letters; 3) at the third (RF) level the surround was either an R or an F, i.e., letters which look but do not sound like one of the prototype letters; 4) at the fourth (KT) level the surround was either a K or a T, i.e., letters which sound but do not look like one of the prototype letters.

Performance became faster as the delay increased from 0 to 800 msec, $F(2, 56) = 177.31, p < .001$ (see Table 9), but errors did not vary. The main effect of surround was significant, $F(3, 84) = 17.49, p < .001$, as was the interaction between surround type and family match, $F(3, 84) = 20.06, p < .001$, which reflected how performance differed between each focal-surround pair (see Figure 11). Performance was slower when the surround was identical to the prototype from the other family than with any other focal-surround combination (Tukey test, $p < .01$). This most likely was due to having the most response competition when the focal item and surround pointed towards opposite responses. Otherwise, performance on other family mismatch pairs did not differ from one another.

Special analyses were performed on family match pairs. RT was significantly slower when the focal item and surround looked and sounded alike, $F(1, 58) = 10.24, p < .01$, than when the focal item and surround were identical. Similarity, RT was marginally slower when the focal item and surround looked alike but did not sound alike in name rather than when they were identical, $F(1, 58) = 3.51, p < .10$. RT was much faster when the focal item was similar to the surround in name or sound alone (Tukey, $p < .05$), rather than in shape alone or in both name or sound and shape. Indeed, performance on similar sound trials resembled performance on opposite family trials. This suggests
### Table 9

**Experiment 5: Mean Response Time and Percentage of Error Rate by Surround Type, Family Match, and SOA**

<table>
<thead>
<tr>
<th>Family Match and SOA</th>
<th>Surround</th>
<th>AE</th>
<th>HC</th>
<th>RF</th>
<th>KT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MRT</td>
<td>PE</td>
<td>MRT</td>
<td>PE</td>
<td>MRT</td>
</tr>
<tr>
<td><strong>Family Match</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>648</td>
<td>0.50</td>
<td>674</td>
<td>2.00</td>
<td>663</td>
</tr>
<tr>
<td>200</td>
<td>576</td>
<td>1.67</td>
<td>587</td>
<td>2.17</td>
<td>586</td>
</tr>
<tr>
<td>800</td>
<td>544</td>
<td>1.35</td>
<td>554</td>
<td>1.85</td>
<td>554</td>
</tr>
<tr>
<td><strong>Family Mismatch</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>736</td>
<td>1.67</td>
<td>640</td>
<td>2.00</td>
<td>652</td>
</tr>
<tr>
<td>200</td>
<td>615</td>
<td>2.52</td>
<td>574</td>
<td>1.33</td>
<td>584</td>
</tr>
<tr>
<td>800</td>
<td>563</td>
<td>2.33</td>
<td>534</td>
<td>1.00</td>
<td>528</td>
</tr>
</tbody>
</table>
Figure 11. Experiment 5: Mean response time and percentage of error rate for each surround type (abscissa) by focal-surround family match (parameter).
that the interference which is caused by having similar focal and surrounding items is due to physical appearance rather than to name sound. These results follow the same trends as the results in Experiments 1 to 4. The RT to respond to identical focal-surround pairs was much slower, relative to other RTs, in this experiment than in Experiments 1 to 4. It may be that subjects were afraid that if they responded too rapidly in an identical display they would be responding to the surround alone.

Individual analyses of variance were done for each surround type (i.e., AE, HC, RF, KT). The RT advantage for having truly identical focal-surround pairs (as opposed to, for example, an A focal item and an E surround) was significant, $F(1, 28) = 51.36, p < .001$. The RT advantage for having different family letters rather than look and sound alike letters (HC surround type) also was significant, $F(1, 28) = 10.76, p < .01$. The RT advantage for having dissimilar surrounding letters, rather than look-alike letters (RF surround type) was marginally significant, $F(1, 28) = 2.88, p < .10$. These results are rather remarkable considering that they were achieved in the face of response competition, which is working to slow down different-family responses.

The SOA X Surround Type interaction on RT was significant, $F(6, 168) = 4.07, p < .001$. Showing that overall performance on AE trials was especially slow at the zero SOA, the SOA X Surround Type X Family Match interaction was also significant on RT, $F(3, 84) = 20.06, p < .001$, reflecting the fact that the slow performance on AE trials at the zero SOA only occurred when the focal and surround items were from different families, so that the focal item and surround had competing names (e.g., focal item was A and surround was E, or vice
versa). On errors, the only significant effect was the Family Match X Surround Type interaction, $F(3, 84) = 3.27, p < .05$. Most errors were made when the focal item and surround had competing names (A, E).

**Discussion**

Experiment 5 replicated the main findings of Experiments 1 to 4. Performance was faster when the surround was very different (a member of a different family) from the focal item rather than very similar to it (a look-alike member of the same family). There was no difference in performance between the look-alike and the look-and-sound-alike condition on family matches. Sound-alike surrounding items did not seem to inhibit performance at all. Indeed, the sound-alike condition behaved as if it were really a member of the other family. Responses were extremely slow and relatively inaccurate with a family mismatch when the surround item was an E and the focal item was an A, or vice versa. This most likely was due to response competition (Eriksen & Eriksen, 1979).

Bjork and Murray's (1977) feature-specific inhibition model explains most of the same-family look-alike and look-and-sound-alike letter data quite well. When focal items are very similar to the surround, feature-specific inhibition causes the subjects to either miss seeing certain features in the focal item, or to add features to the focal item. Thus, similar items (i.e., same family look-alike and look-and-sound-alike letters) are processed more slowly and less accurately ($d'$ change) than different family items and same family sound-alike items. Thus, the "family" concept ought, in future work, to refer only to visually similar items.
There was no evidence to support Egeth and Santee's (1981) finding that inhibition is caused by name (auditory) similarity rather than by physical (visual) similarity. There was no inhibition present on trials in which the focal item and surround had similar sounding names, but did not look alike. Performance was an insignificant 4 msec slower in the look-and-sound-alike condition than in the look-alike condition. Such a difference could, among other things, have been due to the fact that an R may be slightly more different from an A than is an H, and an F may be slightly more different from an E than is a C.

The RT on an identical focal-surround pair was not faster than RT on different family matches. However, processing was more rapid than on non-identical family match pairs. This suggests that focal items which are identical to their surrounds may be primed. This priming may override feature specific inhibition the same way here that it did in the other experiments. Priming may operate by causing subjects to relax their criterion (beta), so that identical items are processed rapidly and accurately (Krueger & Shapiro, 1981).
CHAPTER 3

GENERAL DISCUSSION

Experiments 1 to 5 have shown that performance is slower and less accurate when the surround is very similar (but not identical) in appearance to the focal item rather than very different from it (see Figures 2, 8, 9, and 11). In Experiments 1 to 4 performance was faster and more accurate when the surround items were identical to the focal item rather than very different from it. In all five experiments, performance was faster when the surround was identical to the focal item rather than similar to it, and overall performance tended to be faster and more accurate when the focal item and surround pointed towards the same response. In Experiments 1 to 4 responses were more rapid when the focal item was a normal English letter, rather than a distorted form. This effect was especially noticeable at the long SOAs.

There is, as of yet, no single model which can account for all of the results in these experiments. However, the amalgamation of the feature specific inhibition model (Bjork & Murray, 1977), priming (Krueger & Shapiro, 1981; Posner, 1978; Proctor, 1981), response competition (Eriksen & Eriksen, 1979), and the noisy operator theory (Krueger, 1978) can account for most of these results quite nicely. Let us now see how each component fits into the picture.

Sensitivity (d') changes. The feature-specific inhibition model explains that seeing the features in a focal item is inhibited when the
focal item is surrounded by a similar item rather than by a different item or, for that matter, no item at all. According to the feature-specific inhibition model, there are a limited number of feature detectors for each type of feature. These detectors will become engaged and thus pre-empted as soon as a single occurrence of a particular feature in the display is detected. If it happens that a given feature is first detected in the surround, the processing of that feature in the focal item would be preempted. Thus, focal item processing would worsen as the focal item and surround become more similar in shape. This explains most of the surround effect observed in the five experiments.

There is, however, one very noticeable datum in each experiment which does not fit with the feature-specific inhibition model. The model predicts that when the focal item and surround are most similar (i.e., identical) performance ought to be worse than when the focal item and surround are only somewhat similar. However, in Experiments 1 to 4 performance actually was best when the focal item and surround were identical, and in Experiment 5 performance was better with focal item and surround identity than with similarity. Priming may account for the unusual datum.

Posner (1978), Proctor (1981), and Krueger and Shapiro (1981) predicted that repeating a display letter will facilitate the encoding of a repeated letter. But priming of an automatically activated pathway will not affect other pathways operating in parallel with it (Posner, 1978). In the current study, repeating a normal focal item resulted in faster performance on the repeated item. However, repeating a distorted focal item did not affect performance at all. This indicates that
priming only operates when a display item is rather familiar, and there
is an established pathway which can be primed. Perhaps, letters are
identified automatically, but distorted forms demand attention.
Thus, an individual can process many normal letters but few distorted
forms at the time.

What causes priming? Priming could be caused by an increased
sensitivity to see repeated display elements (d'). This increased
sensitivity could operate in two ways. First, a person could simply see
a repeated item more clearly than a nonrepeated item, due to some type
of sensory tuning. This is not consistent with the notion of feature-
specific inhibition, which would occur on all similar displays, and thus
make it more difficult to see repeated than non-repeated features.
Secondly, priming could be caused by facilitation of the retrieval
and assignment of an appropriate letter name or classification to the
focal item. However, priming seems to occur only on normal letters.
Letter naming on normal letters is so highly overlearned that it is
relatively automatic and offers little opportunity for real improvement.
If priming facilitated the cognitive coding, one would instead have
expected to see it be most predominant on the repeated distorted focal
items which are much less familiar to subjects. Thus, it seems
that priming does not make a repeated item any clearer than a non-
repeated one. Now, let us see if a change in criterion can explain
priming.

Criterion (beta) changes. Krueger and Shapiro (1981) proposed that
priming does not make it easier to see a repeated item. Instead,
priming causes a person to relax his or her criterion (beta) and to
require less evidence to identify the second of two items as the same
as the first. Thus, the person would be more willing to say that a
given item is, for example, an A if its predecessor was an A rather
than an E.

The subject knows that feature-specific inhibition is constantly
occurring on input. Thus, a normal focal item may appear to be dis-
torted. To compensate for the effect of feature-specific inhibition,
the subject may relax his criterion for responding normal to a
repeated display item. This results in faster processing of normal
display items, and fewer errors on normal display items. One also
might expect that this would lead to an increase in false-normal
responses in a distortion detection task when the surround was a normal
letter with the same name as the focal item. In Experiments 1 and 2
false-normal responses increased slightly and in Experiment 3 they
decreased slightly with a same-name normal surround (see Table 3 and
Figure 8). The small changes in the false-normal responses, combined
with the large decreases in false-distorted responses in Experiments
1 to 3, and the decreases in RT on all five experiments when both the
focal and surround items were identical suggest that this criterion
adjustment was appropriate. Indeed, it may be that priming is nature's
way of compensating for feature-specific inhibition.

Subjects do not, however, relax their response criterion for
responding "distorted." Perhaps identifying distorted items is not an
automatic process, whereas identifying normal letters is an automatic
process. It could be that people only relax their criteria for respond-
ing when the encoding process is automatic. Alternatively, due to the
fact that feature-specific inhibition will rarely make a distorted
focal item look normal, as the noisy-operator theory contends (Krueger,
1978), the subject may be more than willing to relax his criterion to say an item is normal, because there is little risk of making an error. The person is, however, never willing to relax his criterion concerning whether to say that an item is distorted, because feature-specific inhibition makes so many normal items look distorted. Let us turn next to consider whether the surround also completes with the focal item for use of the response system.

**Response competition.** Response competition (Eriksen & Eriksen, 1979) accounts for some, but not all of the interference observed in these studies. In all of the experiments, except Experiment 4, performance was slightly faster (13 msec in Experiments 1 and 2 combined, 4 msec in Experiment 3, and 49 msec in Experiment 5) when the focal item and surround pointed to the same response rather than to different responses. In Experiment 4 there was a 12 msec cost when focal items and surrounds pointed towards the same response. This was caused primarily by the fact that it was extremely difficult to name an incomplete focal item which was embedded in a same-family surround (see Figure 9). If one looks at only the complete focal items in Experiment 4, performance was 9 msec faster when the focal item and surround pointed towards the same response. In Experiments 1 to 3 (distortion detection task), response competition might explain, in part, why identical focal-surround pairs are processed more rapidly than normal items with distorted surrounds. However, response competition cannot account for all of the effect. If it did, performance would be helped as much by having any two distorted items as any two normal items. Family match would be irrelevant. Clearly, family match influenced performance. Thus, response competition only tells part of the story.
In Experiments 4 and 5 (identification task), response competition explains some of the family match effect. Since subjects must name the focal item, response competition predicts that performance ought to be worse when the focal item is a member of the opposite family from the surround. However, response competition cannot explain any variations in performance within the same family, nor the fact that performance was worse with a surround from the same family as the focal item.

Response competition tends to be strongest at the 0 SOA, and weakest at the longest SOA. This implies that a response tendency is a momentary impulse. Once the response is called for, the display can remain on forever without generating another response (Dyer, 1971). Perhaps, this shows that we tend to respond only to change in the environment. Now, let us see how our combination model fits the data from various studies.

Converging data. The data from Bjork and Murray's (1977) studies converge very nicely with the data from the current studies. Bjork and Murray found that a focal item which is physically or ostensibly identical to the surround is processed more rapidly, but less accurately, than a focal item embedded in a surround of very different items. They did not, however, establish that a physically identical display always appeared to be identical. In their studies, displays were presented very briefly. To insure that the subjects did not dwell on the display after it was turned off, a backwards mask followed the offset of the display. Due to random noise (Krueger, 1978) some ostensibly identical displays may simply have been seen so unclearly that they did not seem to be identical. Other physically identical displays may have appeared
less noisy. Thus, they may have, in fact, appeared to be identical. When they did, feature-specific inhibition may have been overridden by priming. Thus, processing of displays which appeared to be identical was rapid and accurate. Some of the errors on different displays may have been caused by this priming. Physically identical displays which did not appear to be identical were processed inaccurately because feature-specific inhibition occurred, but priming did not.

In the current studies with clear displays, most physically identical items appeared to be identical. Similar (most same family) items were equivalent to Bjork and Murray's physically identical items which did not appear to be identical. The same results (most errors on similar items and fastest processing on identical items) were obtained in these studies as by Bjork and Murray.

Various experiments by Taylor (1977), Eriksen (e.g., Eriksen & Eriksen, 1979), and Krueger and Shapiro (1980) have shown that identical focal and surrounding items are processed more quickly than quite different ones. In these tasks, the focal items were all presented in clear displays, so that the physical stimulus to all intents and purposes was the functional stimulus. Thus, the effects of feature-specific inhibition were overridden and subjects were able to benefit from priming. Now, let us look at some other models in which feature-specific inhibition is amalgamated with perturbations or response competition.

Other hybrid models. The hybrid model, which combines the feature-specific inhibition at the short SOA with perturbations at the long SOA (Krumhansl, 1977), does not account for the data from these five studies. Indeed, the relative interference caused by surround type
which was observed in all five studies did not change very much across SOA, indicating that the same mechanisms were operating at the longest and shortest intervals.

Santee and Egeth (1980) proposed a combination of the feature-specific inhibition model and the response competition model. They suggested that when items are not seen clearly, feature-specific inhibition occurs. When the display items are seen clearly, they suggested that competing response tendencies reduce performance. This model is accurate, but incomplete. The RT is actually slower when the focal item is a non-identical, but visually similar member of the same family as the surround. Thus, the model may be extended to allow feature-specific inhibition whenever the focal item is very confusible with the surround due to either an unclear display or due to extreme focal-surround similarity (i.e., the focal item and surround differ from one another by the presence, absence, or displacement of a single line segment). With this modification, and the addition of the priming principle, Santee and Egeth's model becomes very similar to the current model.

**Focal items.** Normal focal items are misperceived as distorted more frequently than distorted focal items are misperceived as normal, especially at the longer SOAs in Experiments 2 and 3. This is consistent with Krueger's (1978) theory of perceptual matching. Internal noise, according to Krueger, is not symmetrical. There are more opportunities for internal noise to make a same pair look different (only one feature among many needs to be distorted to do this), than vice versa (several select features would need to be changed).
The same principles apply to encoding focal items. A single misperceived feature (among many in the display) makes a normal focal item look distorted, whereas a particular feature in the focal item (and no others) would have to be misperceived to make a distorted focal item look normal. This would happen very rarely. Thus, only distorted focal items and noisy normal focal items need to be rechecked.

When many display items appear at the same time, processing will be noisier than when one item appears at the time. At the shorter SOAs, virtually all normal items were noisy. Thus, much rechecking was mandated. At the longer SOAs, there were fewer noisy normal focal items. Thus, most normal focal item processing did not need to be rechecked. Shorter RTs on normal focal items resulted.

In Experiment 1, where segments were added to form distorted letters, distorted and normal focal items were processed equally rapidly. It seems that the added segment was separable from the letter. Thus, the subject was making a binary decision about a single feature. In this case, the noisy operator theory argues that a single feature is no more likely to appear than to disappear (Krueger, 1979). Thus, equal performance on normal and distorted items in Experiment 1 may not be inconsistent with the theory. Alternatively, noise may serve only to delete, but never to add features to a focal item. In this case, the noisy-operator theory would correctly predict equal performance on normal and distorted trials. In Experiment 4, although longer RTs were observed on distorted focal items, more errors were also made on distorted focal items. This is due, probably, to the fact that identification does not require as careful an encoding of normal items as does distortion detection. Furthermore, it is probably more difficult
to identify a distorted focal item than a normal one. Thus, subjects relax their criterion for perfect encoding of features in the identification task, but they are unable to do this in the distortion detection task.

Summary. Similar surrounding items seem to inhibit the perception (d') of features in a focal item, as Bjork and Murray (1977) proposed. However, on functionally identical stimuli, feature-specific inhibition is overridden by priming (Posner, 1978; Proctor, 1981; Krueger and Shapiro, 1981). Priming seems to be caused by subjects' demanding less evidence (beta) to name a repeated item, than to name a novel item. Priming, however, only occurs when the focal item is familiar. Response competition (Eriksen and Eriksen, 1979) also accounts for some of the data.

Normal focal items are processed more rapidly than distorted focal items, because noise is more likely to make a normal focal item appear to be distorted than vice versa. Thus, in many cases where the display is not very noisy, only a few noisy normal items, but virtually all of the distorted focal items must be rechecked. When the displays are very noisy, everything must be rechecked, causing normal processing to be as slow as distorted processing. Now, let us look at some implications of this work.

Implications. In assembly line inspections where a person is required to find defective products, a slightly defective (similar) item in the surround is more likely to mask features and make a perfect focal item appear to be defective than vice versa, because a slightly defective surround item prevents priming. Thus, feature-specific inhibition will have the opportunity to predominate.
Artificial-eye cameras do not need to capture every last feature in the display when the focal item and surround are similar to one another, because the normal perceiver constantly deals with missed features due to feature-specific inhibition at feature extraction. When various elements in the display are similar to one another, subjects will automatically recheck the display for missed features. Thus, occasional missing features in the TV camera ought not be very serious.

These studies also suggest that some reading problems might be caused by feature-specific inhibition between similar letters. Thus, the studies ought to be repeated with both good and poor readers to determine whether poor readers perform worse than good readers when the focal item and surround are similar. If so, remedial instruction in coping with inhibition could be offered. Perhaps, even mixing type-fonts between adjacent letters might reduce feature-specific inhibition, and improve reading ability in some youngsters!
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