ANATOMY OF AN ANOMALY:

THE CATEGORY-EFFECT IN VISUAL SEARCH

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ABSTRACT

ANATOMY OF AN ANOMALY: THE CATEGORY-EFFECT IN VISUAL SEARCH

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Previous research has demonstrated a category-effect in visual search when the array items are alphanumeric characters. It is easier, for example, to detect a letter embedded among digits (a between-category condition) than among other letters (a within-category condition). Several experiments have demonstrated that this effect is not simply due to visual featural differences between letters and digits. Furthermore, it has been demonstrated that there is a cost to categorization in visual search: Less information is registered about the identities of the array items when the targets and field items are drawn from different categories than when they are drawn from the same category.

The present paper elaborates a partial processing hypothesis to account for this category-effect. The claim is made that partially processing the array items in a between-category condition allows the subject to discover the target's location in the display (and hence its presence) without first identifying the array items. This hypothesis leads to three predictions which are tested in the present experiments.

Subjects should be able to tell where a target is in a between-category condition before being able to tell what it is. A weak form of this prediction was confirmed in a visual search experiment in which location and identification responses were required of subjects in

between- and within-category conditions.

To further investigate the location notion, a second experiment was conducted to test another prediction. If subjects in between- and within-category conditions are given pre-instruction concerning the target's location, the category-effect should disappear. An experiment was conducted in which subjects in the two category conditions were either left uninformed about the target's location, or were informed by use of a visual cue that was presented immediately before each stimulus display. The prediction was strongly confirmed, and evidence was presented to dispute the interpretation that eye movements triggered by the cue caused the reduction in reaction time in the cue conditions.

Finally, an experiment was conducted to test the prediction that there should be no category-effect in a visual search task with a display size of one. This prediction follows from the notion that partial processing singles out the target from among other array items; if no other array items are present, the between-category searcher should have no processing advantage over his within-category counterpart. This prediction was confirmed.

The three experiments, taken together with the results of previous research, support and elaborate the partial processing hypothesis of the category-effect in visual search.

CHAPTER I: INTRODUCTION

Perceptual recognition involves an act of categorization. We see a four-legged, long-haired, tail-wagging creature, and we call it a dog. This mental event - the contact that is made between a physical stimulus and a mental category - is the heart of the recognition process. Without this ability to categorize stimuli into equivalence classes, the infinite array of sensory patterns which we encouter would simply overwhelm our cognitive processing capacity. Probably because of this simple fact, examination of the processes underlying perceptual recognition has traditionally assumed a place of prominence throughout the history of experimental psychology (see, e.g., Woodworth and Schlosberg, 1954).

In spite of a long tradition of research, however, we still know precious little about the recognition process. The essential question remains: How does a perceiver determine to which of a number of categories a stimulus belongs? That is, what processes underlie our ability to assign a stimulus to a category? This question pertains, of course, to what we ordinarily call "identification" as well as to categorization in more inclusive classes. Identifying a particular dog as "Lassie" is no less an act of categorization than classifying her as a collie or as a dog.

As Nickerson (1973) has noted, there are in principle two methods one might use to determine whether a stimulus is a member of a category; we shall call these the featural and the hierarchical methods. The featural method involves a determination of whether the stimulus in question shares a perceptual attribute or set of attributes which define class membership.[1] One could, for instance, classify someone into one of the two categories "man" or "woman" by noting whether this person's features are more characteristic of males or of females. It is clear that the use of this method requires the existence of perceptual features or attributes that distinguish the alternative categories. That is, while we can assign a particular individual to the class male rather than female on the basis of visual featural information, it would surely be quite difficult to classify someone as a theoretical rather than an experimental physicist on a similar featural basis. (Such a featurally based classification might be achieved if one were to enlarge the set of features, and include appropriate disjunctions. But in that case, the critical set of required visual attributes would probably approach the set required to distinguish one physicist from another, thereby resulting in no cognitive economy.)

The hierarchical method of classification is better suited to these cases in which the distinguishing features are not immediately obvious. On this method, a stimulus is assigned to a particular class by determining

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1 For our present concerns, very little will be gained by discussing the distinction between featural theories and more analog theories of pattern recognition. It may certainly be that the processing mechanisms involved actually make overall form computations without attention to local "features." If so, then the notion of a feature may turn out to be wrong (or at best a metaphor). For the present, however, we have little concern about the particularities of the underlying processing mechanism. We instead use the term "featural" rather generically to refer to the class of theories which rely most importantly on the physical properties of the stimulus.

whether it is a member of a proper subclass of that class. If so, it must be a member of the class. To return to the physicists, one might first categorize the person in question as a member of the class Albert Einstein (what we ordinarily call identifying him), which in turn is a member of the class theoretical physicist. Needless to say, this second method of classification leaves open (or more properly, leaves begged) the question of how one manages to identify the person in the first place.

Suppose for the moment that these two methods of classification exhaust the possibilities; or, more modestly, suppose that they are at least the two principal methods one might use to classify stimuli.[2] There are reasons to believe that adult perceivers do in fact employ both methods under appropriate circumstances. When the potential categories into which a stimulus might be classified are distinguishable on the basis of a small set of features, the featural method will prevail. When the categories are not so easily discriminable featurally, the hierarchical method will be used. By now there is a fair amount of experimental evidence in support of these claims. We turn to a brief review of some of this

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2 These two alternative methods of classification may not exhaust all possibilities. Wittgenstein (1953) argues, for example, that many events are recognized because of their "family resemblance" to some known event. Whether this notion can be adequately concretized is, however, by no means clear as yet. Once further specified, it may reduce to one or the other of the two cited alternatives. For the present, it is sufficient to note that the two methods of classification described, the featural and the hierarchical, at least form the basis of many theories of the pattern recognition process.

evidence.

A. The Featural Method

There is considerable support for the hypothesis that subjects classify stimuli on the basis of featural information when such information is available to them. One line of evidence comes from the literature on discrimination learning and concept formation in humans and in animals. Many investigators in this area have been explicitly concerned with their subjects' attention to various featural properties of stimuli when making classifications (see, *e.g.*, Bourne, 1966; Bruner, Goodnow, and Austin, 1956; Trabasso and Bower, 1968). In general this work certainly supports the notion of a featural strategy in these experimental tasks. Whether one can generalize from these somewhat artificial situations to the broader (and perhaps more primitive) task of perceptual recognition, however, is debatable.

Another line of research has focused on recognition rather than concept discovery. One of the originators of this approach is Neisser (1963), who tried to test a featural hypothesis by using reaction time as the chief index of "processing difficulty." An important predecessor to this research was Neisser's own work with Selfridge on the Pandemonium model of pattern recognition, in which visual patterns are classified at one stage on the basis of featural properties (Selfridge and Neisser, 1960). To test some of the predictions of this model, Neisser and his colleagues (*e.g.*, Neisser, 1963; Neisser, Novick and Lazar, 1963) used a visual search paradigm in which subjects are required to detect the presence of a prespecified target which is embedded among a number of distractor or field items. Thus, for example, the subject might be told to search for the presence of the letter "Z" which is presented among other letters. Reaction time (RT) is typically recorded from the onset of each stimulus display until the subject stops a clock by responding. One can view such a visual search paradigm as a pattern classification task in which each of several items must be classified as either "target" or "field".

The visual search paradigm can be used to study pattern classification processes by systematically varying the nature of the target and field items. Thus Neisser (1963) found that when the target item was physically similar to the field items, search times were slower than when the two were dissimilar. For example, it took six times longer to find a Q when it was embedded among curvilinear letters rather than among angular letters. This suggests that a featural examination of the array items might be a sufficient basis for their classification. Similar findings have been repeatedly obtained in subsequent studies (e.g., Egeth, Jonides, and Wall, 1972; Gardner, 1973).

Some further support for such a featural mechanism comes from a study by Neisser, Novick, and Lazar (1963) who found that after extensive practice, subjects took no longer to search for a set of ten arbitrarily chosen target letters than for one. Neisser's (1967) interpretation was that target-field discriminations are made on a featural level, and that with practice, the relevant features are learned even for the ten-target case. (He added the further assumption that different feature tests are carried out simultaneously. This particular assumption, however, is not directly germane to our present concerns.) The notion that discriminative features are learned with practice allows the extension of a featural hypothesis to cases in which the features are too subtle to be an immediately available basis for discrimination.

Rabbitt (1967) has provided a further (and perhaps a more convincing) test of the hypothesis that subjects learn to use critical features with practice. He reasoned that performance should suffer if the set of field items were changed after training on a particular target-field discrimination. But very little if any impairment should result if the new task were given after a small amount of practice on the original search task. Rabbitt confirmed this prediction with a card sorting task. He also found that the negative transfer effect becomes larger when the subject is searching for more targets. When transferred to a new set of field items after extended practice on a prior set, subjects who searched for eight targets showed a much greater decrement in performance than subjects who searched for only two targets. It thus appears that with practice, subjects learn to use the relevant discriminative features. The more targets there are, the more features must be used so as to successfully complete the task of detecting the target.

An experiment by Yonas (1969) provides yet further support for a featural mechanism of classification. Each of three groups of subjects was given a pre- and post-test which consisted of a speeded classification of letters according to whether they were members of either the set C, Q, R or the set F, N, V (distinguishable on the curvilinear-angular dimension). The three groups differed in the type of classification trials that intervened between pre- and post-test. One group was given a G, O, S vs. A, E, Z discrimination where curvature was useful. The second group was given a J, O, S vs. D, G, U discrimination in which curvature was not useful. The third group was given an A, X, Z vs. H, L, T discrimination in which curvature was irrelevant but diagonality was useful. The RT improvement between pre- and post-test was three times greater for the first group than for either of the other two. Once again, this suggests the use of a featural strategy which is sensitive to continued experience.

The results of the visual search and transfer studies taken together, then, support the assertion that subjects classify patterns using featural information when it is available. Furthermore, given sufficient practice, they will even classify on the basis of quite subtle featural distinctions between items. But what happens when there is no featural distinction? How do subjects classify patterns when the information inherent in the stimulus is not sufficient by itself?

B. The Hierarchical Method

It is easy enough to imagine a case in which a featural strategy could not possibly work. Consider again the distinction between theoretical and experimental physicists cited above. There is obviously no reliable facial or bodily characteristic that would allow us to assign any given physicist to one or the other category. In such cases enumeration of the category members is probably the only way to distinguish the classes perceptually. To classify a particular physicist we will have to first identify him, and only then note to which group he belongs, presumably by comparing the name to a stored list. Such a two-stage process implies a prediction: to name a physicist should be faster than to categorize him (as either theoretical or experimental). This general prediction has been tested and confirmed for several categories of items (though not to this date for physicists).

Neisser and Beller (1965) performed a search experiment in which targets were specified as particular words (e.g., "Monday") or as members of a class of words (e.g., "a person's name"). The second condition is surely a case in which there is no obvious set of visual features which unites all the members (e.g., what is similar about "John" and "Gerald"?) The hierarchical notion would predict that this condition (searching for a person's name) should lead to longer search times than the other condition (searching for a particular word). This prediction was confirmed.

Further support for hierarchically organized levels of classification in recognition comes from the work of Posner and Mitchell (1967). They had subjects give "same" and "different" judgments to simultaneously presented pairs of letters. There were three separate criteria for judgment: a) phsyical identity, as in the pair AA, b) name identity as in the pair Aa, or c) rule identity, as in the pair AE in which both letters are vowels. Reaction times for the response, "same" were shortest when the stimuli were physically identical, intermediate when they were identical in name only, and longest when the identity was only by rule. These results are clearly in accord with a hierarchical model of the recognition process.

In summary, the evidence cited in the previous two sections supports the claim that there are at least two mechanisms underlying the categorization process: One mechanism classifies stimuli on the basis of physical featural information; the other makes use of the hierarchical nesting relationship existing among categories. Theories such as Selfridge's Pandemonium (Selfridge, 1959) in fact treat the former mechanism as the first of a series of hierarchical processing stages each of which operates on ever more complex categorizations. Here, both types of categorization strategies are incorporated into a single model. Such refinements aside, however, it remains true that a featural categorization is limited to those cases in which a set of features reliably discriminates the relevant categories. A hierarchical method is assumed to operate otherwise.

C. The Category-effect in Visual Search

1. The Phenomenon

As argued above, identification (that is, classification by name) must precede conceptual classification unless the conceptual categories can be distinguished on a simple physical basis. Recently, however, several investigators have discovered a "conceptual" category-effect in visual search that seems to contradict this statement. Using a variant of Neisser's scanning paradigm, Brand (1971) found that subjects could detect a digit more rapidly when it was presented among letters (a between-category condition) rather than among other digits (a within-category condition). She found a similar effect for letter targets embedded among digits rather than among other letters, Using a similar paradigm, Ingling (1972) has replicated this basic effect.

Egeth, Jonides, and Wall (1972), Jonides and Gleitman (1972), Gleitman Jonides, and Friedman (1975), and Jonides, Gleitman, and Foland (1975) have demonstrated the same phonemenon by means of a somewhat different visual search technique which permits a more precise evaluation of the processing time per item. Their subjects were required to detect a target within an array of items presented too briefly to permit a functional eye movement. The number of array items was varied systematically, and the processing time per item was indexed by the slope of the function relating RT to n, the number of items in the array. The results showed that these slopes are much shallower for between-category than for within-category search; in fact, between-category search sometimes yields RT functions that are completely independent of n (Egeth, Atkinson, Gilmore, and Marcus, 1973; Egeth, Jonides, and Wall, 1972; Jonides and Gleitman, 1972).

Finally, an analogous category-effect has been obtained in still other experimental paradigms: in search through successive arrays that follow one another very quickly (Sperling, Budiansky, Spivak, and Johnson, 1971), and in a same-different simultaneous discrimination task (Posner, 1970).

On the face of it, the category-effect appears inconsistent with either of the categorization strategies previously described. On the one hand, there doesn't seem to be any reason to believe that a particular letter is on the average more discriminable from the set of digits than it is from the other letters. At least _a priori_ one would probably guess that the two classes letter and digit are not readily distinguishable except by listing their members. If so, the fact that between-category search (_e.g._, a letter among digits) is easier than within-category search (_e.g._, a letter among other letters) is hard to explain by the featural hypothesis.

On the other hand one would assume that a hierarchical model of the search process is more readily applicable to alphanumeric situations of the kind here described. But unfortunately, this model does not predict the facts. If a category judgment is made only <u>after</u> each item is identified, then a between-category search ought to be at least as slow as a within-category search. In fact, it ought to be slower because it requires categorization as an extra step. The category-effect is thus an anomaly.

2. <u>A Feature Hypothesis</u>

The notion that the category-effect is anomalous rests, of course, on one basic assumption: There is no simple set of features which discriminates letters from digits. If this assumption proves to be false, one might easily argue that the effect is mediated by the same kind of featural strategy that allows us to classify a person as a man or woman faster than as a particular man. The results of two studies in fact contradict such a simple featural explanation of the category-effect (Ingling, 1972; Jonides and Gleitman, 1972).

Ingling (1972) had subjects perform a list scanning task similar to Brand's (1971); however, the letters and digits included in the experiment were carefully chosen so as to minimize differences in physical features. She nevertheless demonstrated a sizable category-effect.

A more direct test of the feature issue was conducted by Jonides and Gleitman (1972) utilizing the visual search paradigm of Egeth, Jonides, and Wall (1972). On some of the trials of the experiment, the ambiguous character O served as target, cometimes being specified as the digit "zero" and sometimes as the letter "oh." Here, the physical featural differences between the target and field items for the two conditions are perfectly equated. That is, exactly the same stimulus cards were used for the within- and between-category conditions when the target was "O." The results showed no less a difference in processing time per item between the within- and between-category conditions when the target was the ambiguous O than when it was an unambiguous letter or digit (e.g., A or 4). Evidently, then, the category-effect is not simply due to featural differences between members of the two categories letter and digit.

3. A Direct Access Hypothesis

The zero-oh effect clearly demands either that a feature hypothesis be abandoned, or that it be modified. Consider first the possibility of abandoning a featural notion altogether. Is there an alternative explanation of the category-effect?

In fact, Posner (1970) and Brand (1971) have suggested an alternative interpretation that hinges on the possibility that letters and digits can be classified independently of being identified because they have been so highly overlearned. On this view, the visual character "4" can be classified as a digit without first having to be identified as a member of the class "four." But even if this were so, how does this explain the category-effect? One interpretation hinges on a difference in the number of internal response classes among which the subject must choose. In a between-category condition there are only two classes (letter and digit) while in a within-category condition there are either 10 or 26 (depending upon whether the items are digits or letters). If reaction time is an increasing function of the number of internal response classes, then - given all of the prior assumptions - the category-effect follows. The last assumption is plausible enough, and seems to be supported by the literature on choice reaction time (Broadbent, 1971). The relationship between reaction time and number of response classes is presumably caused by an increase in associative interference among the classes as their number increases. It is this difference in the degree of response interference that presumably results in faster between- than within-category responses.

At first blush, this alternative seems quite attractive, but closer examination reveals a fatal flaw. Consider the key assumption: Classification and identification can proceed independently of one another. This assumption really begs the question at hand. The category-effect is an anomaly precisely because there doesn't seem to be any basis on which one can classify an alphanumeric item short of identifying it. To claim that one *can* classify without identifying because of the highly overlearned nature of the material just evades the question of *how* practice or familiarity aids the perceiver. It is no explanation at all.

Under the circumstances, we must reject this hypothesis as a viable explanation of the category-effect.

4. *A Modified Feature Hypothesis: Partial Processing*

Almost by elimination, then, we return to a featural explanation. On this account, categorization requires less complete processing (*i.e.*, less extensive feature analysis of the array items) and hence a shorter examination time than does identification; thus, the decision about whether a given item is a "digit" will be faster than the decision about whether it is a "4." But this explanation requires an amendment so that it can account for the zero-oh effect: There must be an appropriate set to search for the features of a target category when it is embedded among field items of the other category. Specifically, we claim that in a search for a digit among letters, the array items are processed only partially for the features of digits and no more. In contrast, a search for a letter among letters will lead to more complete processing of each array item, for only in this way can each item's identity be determined. In principle, such an explanation can be applied to the target O as well as to the unambiguous letters and digits. In effect, we assume that the item "O" acts like a figure that has the attributes of two classes. By appropriate instructions, one or the other of these class-determining feature sets can be made to be salient.

a. The Cost of Categorization

The partial processing hypothesis here suggested is essentially ad hoc: We are postulating a mechanism on the basis of a phenomenon which this very mechanism is proposed to explain. In order to put the partial processing hypothesis on firmer footing, Gleitman, Jonides, and Friedman (1975) developed some further deductions from it which were independently testable. Partial processing implies that categorization has a cost: between-category search (in which the processing is partial) should result in impaired item identification as compared to within-category search. This hypothesis was confirmed for both field items and targets. When tested subsequent to a series of visual search trials, within-category searchers showed some incidental learning of the field items to which they had just been exposed. In contrast, between-category searchers showed no incidental learning at all. An analogous cost of categorization was also demonstrated for target items by means of a catch-trial procedure. Between-category searchers who were searching for, say, a "4 or a 7" among letters, were given a catch trial on which the stimulus card actually contained a "3" among letters. Virtually all subjects responded that the specified target was present. The subjects in this case evidently noted that a digit was present, without noting what particular digit it was.

b. The Benefit of Categorization

Such evidence demonstrates that partial processing has a cost. But how does it confer its benefit, the faster discovery of a target in between- than within-category search? The hypothesis, again, is that fewer features have to be extracted to determine that, say, a digit is present. But if partial processing is this and nothing more, than between-category search would yield only the discovery that there is a digit present somewhere in an array of letters. The between-category searcher would not know where, and hence would have no further advantage over the within-category searcher should he be asked to process the target further. A more plausible guess is that partial processing is a preliminary stage to more complete processing of the selected item. If so, partial processing would not only enable the searcher to discover that one of the items is different from the others, but also to determine which of the items is different. As a result the different item can then be singled out and subjected to further analysis. This additional assumption is a way of combining both the featural and hierarchical hypotheses into one (admittedly very sketchy) model.

This line of reasoning leads to an immediate prediction: between-category searchers should take less time than their within-category counterparts even on a task in which the target must be identified prior to responding. Jonides, Gleitman, and Foland (1975) have confirmed this prediction by means of a modified between-category condition which included a large number of the kind of catch trials just described. The field items were always letters; the targets were digits. On half of the trials the specified target was present. On one-quarter of the trials there was no digit present. The crucial trials were the remaining quarter, on which a digit was present but it was not the one specified as the target. To perform accurately in this condition (that is, to respond only on the trials on which the specified target was present, and not on the catch trials), the subjects had to identify the target before they responded. Yet their mean search time per item was almost identical to that of subjects in a standard between-category condition (9.2 versus 9.9 msec. per item), and substantially faster than the mean search time per item of subjects in a standard within-category condition (29.9 msec. per item). We can thus conclude that the relative advantage of between- over within-category search continues past the processing required to simply detect the target's presence. Thus partial processing of category membership is shown to be an early stage in a hierarchy of processing stages.

D. Some Further Predictions of the Partial Processing Hypothesis

The present study is an attempt to develop the combined feature and hierarchy model of the category-effect still further. The results of the modified between-category search condition have shown that partial processing "tags" the categorially different item in some way so that attention can be devoted to it to the exclusion of other items. What is the nature of this tag? A provocative bit of evidence in this regard is that between-category searchers often report that the target "jumps out" at them. That is, they report a kind of spatial isolation effect similar to that reported by Neisser's (1963) subjects when faced with a visual search task involving a fairly simple discrimination. Perhaps the phenomenal experience of "jumping out" (mediated by the partial processing of a categorial difference) is the subjective equivalent of a focusing of attention upon a particular array location. This suggests that the between-category searcher first registers the target item's location in the array, after which he can concentrate his "attentional energy" on this location to process the item further.

Is this an unreasonable hypothesis considering the fact that the category-effect has been obtained under conditions that do not permit the subject to make a functional eye movement before offset of the stimulus display? After all, the most effective way by which humans (and certainly many animals) focus their visual attention is by moving their eyes. Nonetheless, there have been many experimental demonstrations of attention shifting in which eye movements could not have played a role (e.g., Sperling, 1960; Averbach and Coriell, 1961; Eriksen and Collins, 1969; Eriksen and Rohrbaugh, 1970; Colegate, Hoffman and Ericksen, 1973). It is thus not unreasonable to suppose that a similar central selective attention mechanism operates in categorial search tasks and allows subjects to isolate the target item spatially.

Thus, the assumption is that partial processing confers its benefit on the between-category searcher by permitting him to isolate the target item spatially. He does so by use of a smaller amount of featural information than is required for item identification. This hypothesis makes several interesting claims: The first is that a between-category searcher should register the target's location before he registers its identity. The second is that when subjects in both within- and between-category conditions are preinformed (in a way not permitting eye movements) of the location of their respective targets, the category-effect should disappear. Finally, there should be no category-effect if only <u>one</u> item is presented on each trial; partial processing singles out one item among many, but if there is only one item present, there are no further benefits that between-category search can confer. These predictions are more fully outlined and tested in the three experiments described below.

CHAPTER II: EXPERIMENT I

Jonides, Gleitman, and Foland (1975) have shown that the partial processing which underlies the category-effect not only determines the existence of a categorially different item, but also tags that item so that it can be processed further should the task require this. As outlined above, it is not unreasonable to suppose that the spatial location of the target item in the array serves as this tag. The present experiment is an attempt to provide a test of this "location corollary" of the partial processing hypothesis.

The location notion makes certain predictions. Consider a subject who is presented with one of several targets which may be at one of several locations. Suppose he is sometimes asked <u>what</u> the target is, and sometimes <u>where</u> the target is. If he is a between-category searcher he should locate the target before he identifies it. This follows from the hypothesis that partial processing first singles out an item in a particular location and this item is then further processed if need be. We would therefore predict that $L_B < I_B$, where L_B and I_B are mean RTs for locating and identifying a target respectively in a between-category condition. But the opposite should be the case for a within-category searcher. For him, locating an item can't possibly be the first step in the search process. His sole way of knowing that a given item is a target is to identify it; he therefore has to answer <u>what</u> the target is before he can answer <u>where</u> it is. Under the circumstances, we predict that $L_W > I_W$, where L_W and I_W are mean RTs for locating and identifying a target respectively in a within-category condition.

The situation is somewhat more complicated, however. The predictions $L_B < I_B$ and $L_W > I_W$ only follow from the location notion if this is coupled with a further assumption. The actual response of telling where the target is must be as easy to perform as the response of telling what it is. But this assumption is undoubtedly false. Suppose the target is a "B". If asked to identify, the subject says "B"; if asked to locate, he says, _e.g._, "left." The second response is certain to be more difficult than the first. The processing sequence by which the subject comes to the "mental" decision that the target is a "B" may take _longer_ than that by which he decides that it is to the left. But these two _decisions_ have to be mapped onto two indexing _responses_. If these responses are not equally difficult, the predicted inequalities may well be masked. That is, there are undoubtedly different stimulus - response compatabilities in the two response conditions that make for longer locational responses than identificational responses (Broadbent, 1971). This would tend to obscure the predicted inequalities, $L_B < I_B$ and $L_W > I_W$.

Under the circumstances, the location hypothesis can make predictions only about _relative_ differences. That is, as described above, the difficulty of giving a location response is presumably greater than that of responding with the name of the item. The prediction of the location hypothesis must therefore be altered to take the comparative difficulty of the locational response into account. This would modify the original predictions. Instead of predicting $L_B < I_B$ and $L_W > I_W$, we predict $(L_B - I_B) < (L_W - I_W)$. In words, the location response will be more difficult than the identification response for both within- and between-category conditions, but this difference should be comparatively larger in the within-category condition.

To test this prediction, subjects were presented with one of four possible targets in one of four possible locations in either a within-category or a between-category condition. On some trials, they were asked to indicate the target's identity; on others, to indicate its location.

Method

Subjects. Twelve female undergraduates were paid for participation in a 30-min. experimental session.

General Design. All subjects were run in a within-subject 2x2 factorial design with categorial condition (within vs. between) and type of response (location vs. identity) as the two factors. The four conditions of the experiment were run in blocked fashion with order counterbalanced according to a Latin square design. Three subjects were run in each of the four orders of the Latin square.

Stimulus Materials. On each trial, the stimulus card contained one target and three field items. The four items were always displayed at the four vertices of an imaginary diamond whose center coincided with the fixation mark and whose diagonals were 3.1° of visual angle in length. The items were black Letraset numerals and uppercase letters (Futura Demi bold, 24-point, $.35^{\circ}$ in height). Four letters -- D, N, R, and X -- served as targets for all conditions. For the within-category conditions, the targets were chosen from among the letters A, B, C, H, L, P, S and Z;

for the between-category conditions, the field items were chosen from the set of digits 2 to 9.

Within each of the four experimental conditions, each target was used equally often overall and was placed equally often at each of the four loci. The choice and placement of the field items was randomly determined except that each field item was used equally often for each of the two response types. In all, there were 128 test trials, during the experimental session, 32 for each of the four experimental conditions. In addition, there were 32 practice trials (8 each per condition), constructed according to the same principles as those used for the test cards.

Apparatus. The stimuli were presented in an Iconix mirror tachistoscope, Model 6137-4. Prior to each trial each subject was asked to look at a fixation dot on a blank screen (15.5 mL). He could initiate a trial himself by depressing a footpedal; this caused a stimulus card to appear (after a 500 msec. delay) for a duration of 200 msec. After offset of the stimulus display, the fixation dot reappeared and remained in view for the entire intertrial interval of approximately 5 sec.

Procedure. The subjects were first familiarized with the four targets and with all of the field items used in the experiment. They were told that each trial would contain one target and three field items, that the items were placed at the four vertices of an imaginary diamond, that the location of the target was randomly determined, and that for this reason the most efficient strategy was to maintain fixation at the center of the field. There were further told that on each trial they had to search for the presence of any one of the four targets, D, N, R, or X, each of which was equally likely to occur. In the two conditions that required an identity response, the subjects had to give the name of the target by speaking into a microphone placed about 2 cm. from their lips. In the two conditions that required a location response, the subjects had to utter one of the four words, "up", "down", "left", or "right". RT's were measured from the onset of the display until the subject's response, which triggered a voice-operated relay that stopped a clock. All subjects were told to respond clearly and crisply, and to respond as quickly as possible while maintaining a high level of accuracy. If a subject slurred a response (which only happened on .8% of the trials overall) this was counted as an error. Three subjects failed to meet an error criterion of 9.5%; they were replaced.

All subjects were given 32 practice trials before starting the experimental session. Before each block of 8 practice trials, they were fully informed about the response required (location or identity) and about the kind of stimulus materials that would follow (within- or between-category). This information was also supplied before each of the four blocks of the experimental session.

Results and Discussion

The mean RTs were 972 msec. and 794 msec. for location and identity responses respectively in the within-category condition. The corresponding mean RTs for the between-category condition were 719 msec. and 607 msec. (see Appendix A for the means for each subject). An analysis of variance showed that both main effects and the interaction between them were highly significant. There was the usual category-effect, with longer RTs for within- than for between-category search: $F(1,8) = 79.3$, $p < .001$.

There was also a strong effect of response type, with longer RTs when subjects had to locate rather than identify: $F(1,8) = 69.6$, $p < .001$. Of primary concern to the present discussion is the interaction, which reveals that the difference between L and I depended upon the categorial condition. As predicted, this difference was significantly greater for within-category search (178 msec) than for between-category search (112 msec): $F(1,8) = 17.1$, $p < .005$.

The error rates roughly mirror the RTs. The mean error rates were 8.3% and 4.7% for location and identity responses respectively in the within-category condition. The corresponding figures for the between-category condition were 2.6% and .8%. Analysis of variance showed that while both main-effects were significant at the .05 level or better, the interaction was not.

CHAPTER III: EXPERIMENT II

Experiment I showed that $(L_B - I_B) < (L_W - I_W)$, a result which is consistent with the location hypothesis described above. Partial processing apparently singles out the categorially distinct item by tagging its spatial position.

The obtained inequality of reaction times, however, is evidence for the location hypothesis only if one assumes that the differential response compatabilities of locating and identifying result in some constant increment of time that is added to the location responses of both the within- and between-category conditions. But there is an alternative interpretation of this inequality. We already know that between-category search is faster and presumably easier than is within-category search. Suppose the effect of coupling a difficult indexing response onto each of these search tasks does not simply add the <u>same</u> increment of time to each. This might be the case if, for example, there is a limited total amount of processing capacity which must be shared by all the processes involved in a particular task (see Rumelhart, 1971, for such a model). On this hypothesis, the addition of a difficult location response onto an easy between-category search process might add less to the total RT for this task than for the more difficult within-category task. The result would be an interaction of just the sort that was actually obtained.

Under the circumstances, some further test of the location hypothesis is clearly desirable. One approach is to find some independent way of manipulating the difficulty of the two indexing responses - for example, by making the location response easier and the identity response more difficult. In actual practice, this turns out to be quite cumbersome. An alternative approach was therefore adopted. For both the within- and between-category conditions, subjects were informed of the target's location before it was actually presented. According to the location hypothesis, the only benefit of categorial partial processing is to isolate the distinct item in space. If so, pre-informing both within- and between-category searchers about the target's location should nullify the difference between these two conditions.

How can the subject be pre-informed about the target's location? One can't just tell him that the target will be at, say, 9 o'clock, for he will then simply move his eyes to that spot before the trial starts. This, of course, would drastically change the paradigm in which the category-effect has been demonstrated. To overcome this problem subjects were run according to a procedure adapted from one developed by Eriksen and his colleagues (e.g., Eriksen and Collins, 1969, Eriksen and Hoffman, 1972, 1973; Colegate, Hoffman and Eriksen, 1973). The subject was first presented with the fixation mark. Immediately afterwards he was given a very brief pre-stimulus cue, a small arrow that pointed to one of four possible target locations. Following this, the array items were flashed; letter targets were sometimes embedded among other letters and sometimes among digits, but they were always located in the position pre-cued by the arrow. Since there is some disagreement about the latency of saccades and about individual differences in these latencies (Komoda, Festinger, Phillips, Duckman, and Young, 1973; Saslow, 1967; White, Eason, and Bartlett, 1962), the duration of the array displays was varied parametrically.

Method

Subjects. Twelve female undergraduates were paid for participating in a 30-min. experimental session.

General Design. Four subjects each were assigned to three groups which differed according to the exposure duration of the stimulus displays (25, 50, or 75 msec.). Each group received four blocks of experimental trials whose order was determined by a Latin square principle. The blocks corresponded to the four conditions of a 2x2 factorial design with categorial condition (within- vs. between-category) and locational information (cue vs. no cue) as the factors. On all trials, the subjects had to indicate which of four targets had appeared. A constant display size of 4 was used throughout.

Stimulus Materials. The 176 stimulus cards were constructed according to the same principles as those used in Experiment I, with the same four targets, the same population of field items, and the same diamond-shaped display arrangement. For the pre-cued conditions, 88 cue cards were constructed. Each of these contained an arrow head whose point was at the precise spot where the target would appear immediately thereafter.

Prior to the experimental trials, all subjects were given 32 specially constructed practice trials to familiarize them with the use of a locational pre-cue. All 32 cards contained one of the four targets D, N, R, or X and three dots at the remaining 3 item loci. The pre-cue was omitted for the first 16 of these trials, and included for the last 16.

Apparatus. All stimulus materials were presented in the mirror tachistoscope previously described. For the two conditions without pre-cue, the order of events was identical to that of Experiment I except that the stimulus display was presented 625 msec. after depression of the foot pedal. For the two pre-cue conditions, the pre-cue appropriate to that trial appeared 500 msec. after depression of the foot pedal and remained on for 125 msec. As already mentioned, the duration of the stimulus display varied between the three groups, lasting for either 25 msec., 50 msec., or 75 msec..

Procedure. The experimental instructions were identical to those used in Experiment I with the following exceptions. First, subjects were told that they always had to identify the target regardless of its location. They were further told that on two of the trial blocks they would receive a pre-cue pointing to the location of the target. They were also informed that there would be 32 special practice trials, and further, that the first 12 trials of each experimental trial-block would be considered as additional practice and "wouldn't count."

Only two subjects failed to meet the error criterion of 9.5%; one was in the 75 msec. exposure group, the other in the 25 msec. exposure group. Both were replaced.

Results and Discussion

Table 1 presents mean RTs as a function of categorial condition and locational pre-cue (see Appendix A for means by subject). These means are based on the last 32 trials of each trial block since the first 12 were considered as practice trials. The means are pooled for all subjects regardless of the display duration at which they were run since the results were virtually identical in all three groups ($F < 1$).

As the Table shows, the locational pre-cue led to a considerable reduction of RT in within-category search. But there was no such reduction for the between-category condition. An overall analysis of variance (df = 1,9 for all F values) yielded highly significant main effects for categorial condition ($F = 76.5$, $p < .001$) and for locational pre-cue ($F = 66.7$, $p < .001$) as well as a highly significant interaction ($F = 89.6$, $p < .001$). In effect, all differences are due to one condition: uncued within-category search. Individual comparison showed that the mean RTs produced by this condition were significantly higher than those in each of the other three ($p < .001$ in all cases). Comparisons among the means of the other three conditions

Table 1

MEAN REACTION TIMES FOR WITHIN- AND BETWEEN-CATEGORY CONDITIONS WITH AND WITHOUT LOCATIONAL PRE-CUE

	Locational Information	
Category Condition	No Cue	Cue
Within-category	788	552
Between-category	589	564

showed no significant effect ($p > .05$ in all cases).[3]

The general pattern of these results is mirrored in the error rates. Uncued, within-category search led to far more errors than any of the other three conditions; these other three were virtually identical in their error rates. The mean error rates were 9.4% and 1.0% for uncued and cued within-category search respectively. The comparable figures for between-category search were 1.6% and 1.00%. Analysis of variance ($df = 1,9$ for all F values) showed significant main effects of categorial condition ($F = 8.7$, $p < .02$), and of locational pre-cue ($F = 8.7$, $p < .02$) as well as a significant interaction ($F = 9.1$, $p < .02$).

Since exposure duration proved an insignificant factor, one can safely conclude that the facilitating effect of pre-cuing was not mediated by eye movements. That is, if the cuing effect were caused by eye

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[3] The lack of a significant difference between the means for the cued and uncued cells of the between-category condition is worthy of comment. In the cued block each subject had 125 msec. (the duration of the cue) to shift his attention to the target's location before it appeared, while his attention could not be shifted in the uncued block until the stimulus itself appeared. Under the circumstances, one might have expected the cued RT's to be shorter than the uncued RT's. In fact the means (564 vs. 589) do substantiate this expectation, but not significantly so. The fact that this difference is small may be attributed to three possible causes: a) 125 msec. may not be a long enough interval for attention to be shifted (see Colegate, Hoffman, and Eriksen, 1973, and Eriksen and Hoffman, 1973) so that the subject is still in the process of directing his attention when the stimulus appears; b) the arrow cue may have a forward masking effect on the target, which slows its processing and c) the shift in attention caused by a categorial difference between target and field may be more efficient (and hence faster) than that caused by an arrow precue. At present we have no evidence in support of any of these alternatives. The absence of a strong cue versus no-cue difference in the between-category condition, however, does not bear on the main result of the experiment, the interaction of the category condition with the cue factor.

movements triggered by the onset of the cuing arrow, this effect should have diminished in magnitude with decreasing total exposure duration (cue plus display). No such diminution occurred. Thus, as Eriksen and his colleagues have shown in similar paradigms (Eriksen and Collins, 1969; Eriksen and Rohrbaugh, 1970; Colgate, Hoffman and Eriksen, 1973), the effect of the pre-cue is on the "inner eye", not on the external eye muscles.

The important result for the present purpose is that pre-cuing abolishes the difference between within- and between-category search. The within-category searcher is enormously aided by the pre-cue; the between-category searcher is not helped at all. This result follows directly from the location hypothesis which asserts that categorial partial processing tags the spatial location of the distinct item which can then be processed further. If this is so, the category searcher already has everything the pre-cue can give him: information about where to attend, that is, where to "look with the inner eye." Under the circumstances, the pre-cue should have no effect. Not so for the within-category searcher. He has no means of partially processing the array to single out the target item, but once he is pre-informed about its location, he is on a par with his between-category counterpart.

CHAPTER IV: EXPERIMENT III

The results of Experiments I and II strongly invite the conclusion that the benefit that partial processing confers on the between-category searcher is that he can spatially isolate the target item in the array without first identifying all the array items. When this same benefit is granted to the within-category searcher (by a pre-cue), he also speeds up considerably - in fact, to the same level of RT performance shown in between-category search. Thus, just as subjects introspectively report, processing in a between-category search results in a kind of perceptual isolation effect. The target does "jumps out" at them in the sense that it becomes the figure on which attention can be concentrated, and the other array items become the ground.

There is a very straightforward implication of this interpretation: If only one item is presented on each array, there should be no category-effect. That is, the between-category searcher can only perceptually isolate the target if there are distractor items to isolate it from. If this isolation effect is the only benefit of partial processing (as seems likely judging from the results of Experiment II), the between-category searcher should have no further processing advantage over the within-category searcher if the potential target is already isolated by dint of being the only item present.

To test this prediction, subjects were presented with between- and within-category search tasks with a display size of one.

Method

Subjects. Five male and five female undergraduates served as paid volunteers for participation in a 30-minute experimental session.

General Design. Each subject was given four blocks of experimental trials, two of which were within-category search (W), and two between-category (B). There were two orders of presentation of the blocks: Half the subjects received them in the order WBBW, and half in the order BWWB. A display size of one was used on all trials. On half of the trials this one item was a target (a letter for condition W, a digit for condition B). On the other half of the trials, the one display item was a field item (a letter for both conditions).

Stimulus Materials. There were a total of 192 test trials in the experimental session. Of these 96 were within-category trials with the targets chosen from the population of letters, A, B, G, L, P, R, S, Z, and the field items chosen from the population C, D, E, F, H, J, K, M, N, O, U, V, Y. The other 96 trials were between-category trials which were constructed using the same field items, but using as targets digits chosen from the set 2-9 inclusive.

Each stimulus card contained one item, which (for each condition) was 50% of the time a target, and 50% of the time a field item. The placement of the array item was accomplished by using twelve clockface positions on an imaginary circle whose diameter was 3.4° of visual angle. For the between-category trials on which a target appeared, each of the eight targets was placed at six loci, which were randomly chosen from among the twelve potential loci so that each locus was used equally often overall. The 48 between-category non-target cards were constructed similarly: Each locus and each potential field item were used about equally often. The same system was followed in constructing the 96 within-category cards. Each within-category card was matched to a between-category card. Within any one of the four trial blocks, of course, the target and non-target cards were randomly ordered.

In addition to the cards for the test trials, stimulus cards for 16 practice trials were constructed for each condition, eight containing a target (each target was used once), and eight containing a field item. Each of the twelve loci was again used about equally often.

Apparatus. The stimulus cards were presented in the mirror tachistoscope previously described. Before each trial, the target item (whose identity differed randomly from trial to trial) was specified, and the subject was given a verbal ready signal. He then initiated a trial himself by pressing a foot pedal. Five hundred msec. after the depression of the footswitch, the centered fixation dot was replaced by a stimulus which was presented for 200 msec.. This was followed by a visual mask made up of pieces of letters and digits. The mask remained in view for one sec., and was succeeded by the fixation dot which remained in view until the next trial began (approximately five sec. later). Subjects indicated their responses by pressing a telegraph key with their preferred hand when the target was present. No response was required when only a field item was present.

Procedure. The subjects were familiarized with the set of field items and with the two sets of targets. They were also informed about other relevant aspects of stimulus construction, such as the potential item loci, the display size of one for all trials, the proportion and random distribution of target and non-target trials, and the blocking of within- and between-category trials. In addition, they were, as usual, told that they had to respond as accurately as possible, but within that limitation, as fast as possible. Preceding each of the first two blocks, each subject was given the 16 practice trials appropriate to the condition of that block. The last two blocks were preceded by no practice trials.

All of the subjects met the error criterion of 6.0% so none had to be replaced. In fact the mean error was quite low (1.9%).

Results and Discussion

The key result is quite unequivocal: There was no hint of a significant difference between the mean RT's of the within- and between-category conditions (see Appendix A for individual subject means). The respective means were 335 msec. and 340 msec. ($F < 1$). Likewise, there was no significant difference ($F < 1$) between the mean error rates for the conditions (1.8% for within-category, and 2.0% for between-category). As predicted, there is no category-effect with a display size of one.

This finding is not completely novel. Dick (1971) and Nickerson (1973) both report that they find no advantage (in fact they find a disadvantage) of "categorization" over "identification" in tasks which require subjects to classify singly presented alphanumeric characters.

Nickerson (1973) used these results to argue that subjects cannot distinguish between letters and digits unless they first identify the characters, a conclusion which is clearly at odds with the present argument. There are however, several sources of difference between the work of Dick (1971) and Nickerson (1973) on the one hand, and the present work on the other - some empirical, some theoretical - to which one might point to reconcile the different interpretations.

Dick (1971) required subjects either to name or to categorize individually presented letters or digits. He found that the time taken to name an alphanumeric character varied as a function of the size of the stimulus set (number of potential stimuli), and that categorization time could be predicted from naming time plus a constant. From these results he concluded that naming must precede categorization. However, there is a serious flaw in his experiment which calls his conclusion into question. As Dick himself recognizes, there is clearly a differential stimulus-response compatability between the critical experimental conditions. A subject who is presented with the figure "A" and asked to respond with the name "A," has to perform what is surely a quite "natural" and over-learned response. But if he is given an "A" and asked to respond with the word "letter," he is required to perform a less compatable and much less practiced response. This categorizing response may well take longer than the identifying response for reasons that have nothing to do with the order in which the underlying classification operations are performed (Broadbent, 1971), a point we have previously raised in relation to our own results in Experiment I.

Nickerson's findings (1973) are also not really comparable to our own, for there are some important differences in method between his study and the present work. In brief, he used computer displayed dot matrix stimuli which are quite different in type style from the black on white stimuli used in the present work; he degraded these stimuli by randomly adding additional dots; and he did not require his subjects to give a speeded response. Under these conditions, subjects may well have adopted a strategy different from the partial processing strategy we assume to operate during visual search. For example, they may have set themselves to look for a quite different set of features to discriminate the characters.

Methodological considerations of this sort indicate that Dick's and Nickerson's procedures are not, strictly speaking, comparable to our own. But even if they were, their results would not invalidate our general conception. Quite the contrary. They find that identification is no easier (and sometimes, even harder) than classification *if only one item is present in the array*. But that, of course, is just what we predict. In our view, the categorial partial processing strategy results in a kind of perceptual isolation, in which the target is singled out from the field items. If there *are* no field items from which the target must be isolated, there should *be* no category-effect. The present experiment and the experiments by Dick (1971) and Nickerson (1973) *all* confirm this prediction. But this lack of an effect with a display size of one is in no way a disproof of the category-effect in general. If anything, it should be taken as a further confirmation of the spatial isolation produced by partial processing for categorially distinctive features. Thus, on this theoretical level, the results of Dick and Nickerson confirm rather than disconfirm the predictions of our model.

CHAPTER V: GENERAL DISCUSSION

The three present experiments, taken together, provide support for a partial processing hypothesis of the category-effect in visual search. Jonides and Gleitman (1972), Gleitman, Jonides, and Friedman (1975), and Jonides, Gleitman, and Foland (1975) proposed such a hypothesis as an explanation of the category-effect in general, and of the zero-oh effect in particular. They suggested that categorization requires less complete processing than does identification, and thus requires less examination time for each item; the result is a faster reaction time for between- than for within-category search. Gleitman, Jonides and Friedman (1975) demonstrated that this partial processing has a cost: Less information is registered and/or retained about both targets and field items during between- than during within-category search. The present experiments provide evidence on the benefit of partial processing: It allows the target to be located without the necessity of a prior identification of all the distractor items.

Remaining Problems

Perhaps the major weakness of the partial processing hypothesis is that it assumes that there are some features which distinguish the two categories in question, but it does not specify what these are. By now there is considerable evidence in favor of the hypothesis, at least in general terms. Its implied claim that such a set of features does indeed exist gains plausibility from this fact. But so far, there has been no direct experimental proof of this claim.

This, of course, is not a problem which is unique to the present work. Much of recent pattern recognition theory includes feature analysis as an essential stage in the recognition process (see Reed, 1973). Yet even within the limited domain of alphabetic character recognition (by far the most intensively studied), there has been little progress in achieving a specification of the relevant features. In fact, even such an apparently simple first step as constructing a visual alphabetic confusion matrix has led to a singular lack of consensus (Fisher, Monty, and Glucksberg, 1969). It is quite obvious, then, that much further research is required to empirically substantiate what is now more of a feature mythology than a feature theory.

Conclusion

Advances in psychological theories are often made by investigation of anomalies; the perceptual illusions are an excellent case in point. The category-effect in visual search is one such anomaly; on the one hand it seems to contradict a featural notion of pattern recognition, while on the other hand it is hard to explain by a hierarchical notion. The present experiments and the work of Jonides and Gleitman (1972), Gleitman, Jonides, and Friedman (1975), and Jonides, Gleitman, and Foland (1975) suggest a resolution to this anomaly. We claim that there is a set of features (as yet unspecified) that distinguishes letters and digits, and that these features form the basis of the greater ease of between-category as compared to within-category search. This feature analysis (which we call partial processing) allows the subject to spatially localize the target which can then be further processed so as to determine its identity. In this regard, the process we suggest is in many respects similar to Selfridge and Neisser's Pandemonium (1960), in that feature analysis precedes identification. It is different in that the kind of feature analysis we propose may extract category membership of a more complex sort than identification. This additional assumption is quite obviously not limited to the classes letter and digit. It is a rather common sort of classification which, for example, allows us to classify a person as a male before being able to identify him. In summary, we claim that the category-effect is consistent with both featural and hierarchical methods of classification. But feature analysis is more than just a servant to processes which perform complex cognitive classification; it itself can directly result in a complex classification.

APPENDIX A

EXPERIMENT I: MEAN REACTION TIMES (WITH STANDARD DEVIATIONS IN PARENTHESES) FOR EACH SUBJECT

Category condition:		Within-category		Between-category	
Response:		Identity	Location	Identity	Location
Subject:	1	766 (212)	862 (166)	532 (72)	614 (77)
	2	815 (184)	903 (215)	668 (104)	688 (83)
	3	760 (125)	1006 (226)	700 (87)	777 (107)
	4	807 (192)	965 (298)	594 (74)	682 (97)
	5	879 (266)	1109 (308)	568 (39)	711 (138)
	6	780 (131)	910 (163)	589 (48)	787 (112)
	7	835 (182)	1219 (290)	544 (59)	732 (138)
	8	908 (225)	976 (135)	739 (67)	837 (82)
	9	724 (136)	947 (204)	590 (58)	686 (91)
	10	731 (168)	860 (198)	562 (61)	659 (103)
	11	851 (229)	1075 (251)	635 (70)	685 (96)
	12	666 (83)	827 (170)	563 (57)	768 (98)

EXPERIMENT II: MEAN REACTION TIMES (WITH STANDARD DEVIATIONS IN PARENTHESES) FOR EACH SUBJECT

Category condition:		Within-category		Between-category	
Location information:		No Cue	Cue	No Cue	Cue
Subject: 25 msec. display exposure	1	766 (231)	544 (67)	548 (49)	508 (43)
	2	822 (220)	479 (74)	586 (66)	458 (44)
	3	799 (190)	568 (48)	649 (86)	601 (53)
	4	796 (201)	628 (133)	553 (63)	611 (91)
50 msec. display exposure	5	801 (157)	551 (57)	638 (89)	543 (47)
	6	666 (189)	435 (24)	469 (39)	479 (45)
	7	917 (182)	610 (61)	582 (72)	646 (84)
	8	709 (158)	546 (42)	585 (100)	552 (42)
75 msec. display exposure	9	815 (134)	598 (67)	651 (79)	631 (47)
	10	827 (233)	525 (55)	590 (80)	503 (51)
	11	901 (143)	634 (60)	707 (50)	730 (79)
	12	631 (72)	506 (36)	514 (34)	501 (32)

EXPERIMENT III: MEAN REACTION TIMES (WITH STANDARD DEVIATIONS IN PARENTHESIS) FOR EACH SUBJECT

Category condition:		Within-category	Between-category
Subject:	1	325 (40)	302 (45)
	2	301 (26)	306 (23)
	3	330 (32)	327 (32)
	4	340 (37)	363 (48)
	5	318 (38)	316 (37)
	6	349 (41)	334 (30)
	7	311 (26)	325 (30)
	8	436 (69)	459 (110)
	9	319 (47)	310 (46)
	10	324 (47)	351 (48)

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