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The cost of categorization in visual search: Incomplete processing of targets and field items

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A partial processing hypothesis is proposed to account for performance under a visual search condition where target and field items belong to the different conceptual categories, letter and digit (between-category search), as compared to a condition in which they belong to the same category (within-category search). This hypothesized mechanism implies that less information is registered and/or retained in between- than in within-category search. This prediction was tested and confirmed in three experiments. The results indicate that both targets and field items are processed less deeply in between- than in within-category search.

By now, many studies of visual search performance have demonstrated that ease of search (whether measured as accuracy or speed) is largely determined by the physical discriminability of target and field items (e.g., Donderi & Zelnicker, 1969; Estes, 1972; Gardner, 1973; Chase & Posner, Note 1). Recently, several experiments have provided evidence that the categorial membership of the array items can also serve as a basis for selection of the target. This has been demonstrated in several kinds of tasks, most involving visual search.

One variety of search task requires a subject to detect the presence of a target embedded among a number of field items in a small array which is too briefly presented to permit an eye movement. When the target and field items belong to the same conceptual category (a within-category condition, e.g., a "B" among several other letters), reaction time has generally proved to be a linearly increasing function of n, the number of items in the array (e.g., Atkinson, Holmgren, & Juola, 1969; Burrows & Murdock, 1969; Sternberg, Note 2). A different result is found when the target and field items belong to different categories (a between-category condition, e.g., a "3" among letters). Under these circumstances, the function relating RT to n has a much lower slope and may be altogether flat (Egeth, Atkinson, Gilmore, & Marcus, 1973; Egeth, Jonides, & Wall, 1972; Jonides & Gleitman, 1972).

A similar category effect has been obtained in [illegible] tasks. Subjects are asked to scan a long list of items for the presence of a target. Between-category conditions result in faster search rates than do within-category conditions [illegible] Ingling, Budiansky, Spain, and Johnston (1973) have demonstrated much the same phenomenon when the subject is required to search several small arrays which succeed each other at a fast rate. Finally, Posner (1970) has also provided support for a category effect in a same-different discrimination task.

One might argue that the greater ease of processing in a between-category search task is a banal consequence of trivial stimulus differences. After all, we would hardly be surprised to find RT independent of n if the subject were asked to find a *red* B among a number of *green* letters. A recent study rules out this and similar trivializing interpretations of the category effect; when the field items were letters, the target "0" produced a flat RT search function if the subject was asked to look for the digit "zero" but generated a sizable slope if he was told to look for the letter "oh" (Jonides & Gleitman, 1972). Ingling (1972) came to the same conclusion on the basis of different experimental manipulations.

The category effect in all these experiments is

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indicated by a faster rate of stimulus examination (time per display item) for between-category than for within-category search.[1] We might interpret this effect by suggesting that categorization (e.g., deciding whether any array item is a "digit") requires less complete processing than identification (e.g., deciding whether any array item is a "4"), thus resulting in less examination time for each item presented.

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. It is in principle quite possible that some alternative mechanism is at work. For instance, one might propose that between-category search is (for some unknown reason) a speeded up version of within-category search, differing in no way except by being faster. In order to put the partial processing hypothesis on a firmer footing, we have to develop some further deductions from it which are independently testable and which will then allow us to rule out such possible competitors as the "speeded processing" hypothesis. One such deduction is that partial processing results in impaired item identification in between- as compared to within-category search. On this account, partial processing has a benefit: the array items are processed just enough to allow fast extraction of class attributes. On the other hand, this shallow processing is assumed to have a cost: less information will be registered and/or retained during between- than during within-category search. In the present paper, we present evidence that there is indeed such a cost of categorization for both targets and field items.

EXPERIMENT I

Our first question concerns the field items. According to our hypothesis, a subject will process each item in the array less fully if he is searching for a digit among letters (between-category search) than if he is searching for a letter among other letters (within-category search). In the first case, by hypothesis, he has to determine whether each item is a "digit" or a "letter." In the second case, however, he must identify each individual item to determine whether one of them is the particular letter target. If this is so, we would expect that the subject will perceive and/or retain less information about the identity of the field items he encountered in a between-category as compared to a within-category search. The present experiment tries to demonstrate this effect using an incidental learning technique.

The use of an incidental learning paradigm to investigate processes underlying visual search performance is not novel. For instance, Neisser (1964) reports poor incidental learning to support his claim that subjects typically do not process distractor items as deeply as they do targets. More recently, Caramazza and Gilmore (Note 3) have used differences in incidental memory between trials on which there is and those on which there is not a target to examine the issue of whether visual search is an exhaustive or self-terminating process. In the present experiment, we use the technique to assess the relative depth of processing of identity information in between- and within-category conditions.

Method

Subjects. Ten male and 14 female undergraduates served as subjects. Each was paid for participation in a 30-min session.

General design. The subjects were assigned to two groups (B and W) of 12 subjects each, both of which performed a visual search task. For Group B, the search was between-category, for Group W, it was within-category. Immediately following the search trials, all subjects were tested for their recognition of the stimulus cards they had just been shown. These cards had to be picked out from among distractor cards on which only the field items (and not the targets) were altered.

A secondary object of the experiment was to determine whether the category effect is affected by stimulus familiarity. To this end, the presentation frequency of the stimulus cards was varied within each group.

Stimulus materials. The stimulus cards were presented in a mirror tachistoscope (Iconix, Model 6137-4). Prior to each trial, the subject saw a fixation point on an otherwise blank screen (15.5 mL) and initiated the trial himself by depressing a foot pedal. Half a second thereafter, the stimulus card appeared and remained in view for 150 msec, to be finally replaced by the fixation point which continued in view for the entire intertrial interval (approximately 5 sec).

Each stimulus card contained four items that formed the vertices of an imaginary square whose diagonal was 2.3° and whose center coincided with the preexposure fixation point. The items consisted of numerals and uppercase letters (black Letraset, Alternate Gothic No. 2, 24-point .39° in height). For Group B, the targets were the four numerals 0, 2, 4, and 5; for Group W, they were the letters A, O, S, and Z. The field items for both groups were randomly chosen from among the letters B, E, F, G, J, K, L, M, N, P, R, T, U, X, Y. Within each group, each target was placed equally often at all four locations; furthermore, each target was used equally often during the session.

There were 16 unique stimulus cards for each group. Eight contained a target and three field items; eight contained no target and four field items. Each card used for Group B was matched to a card used for Group W. In each such pair, the identity and location of the field items was the same; all that differed was the identity (though not the location) of the target if there was one. Note that this entire procedure permits a quasi-replication of the oh-zero effect obtained in a previous study (Jonides & Gleitman, 1972), because the cards that contained the target "0" were physically identical for Groups B and W.

To check on the role of familiarity, half of the stimulus cards were presented four times, half eight times (approximately balanced for target vs. no-target cards, particular target used, etc.). There were thus 96 trials in all, which were presented in two identical 48-trial blocks.

Procedure. Before starting on the search task, the subjects were shown both the target set appropriate to their group and the total population of field items. They were also informed that a target appeared on a randomly ordered half of the trials. The subjects were instructed to depress a telegraph key if one of the targets was present and not to respond otherwise.[2] That is, on

each trial subjects were to search for the presence of any one of the four targets that was orally specified at the outset of the experimental session. They were exhorted to respond as quickly as possible while still maintaining a high level of accuracy.

The first block of 48 trials was treated as a practice block, and subjects were informed of this; the data analyses reported below are based on the second block of 48 trials only. Any subjects who exceeded an error rate of 6.5% on the second block of trials were excluded from analysis and replaced. In all, seven subjects had to be replaced for this reason (one in Group B, with an error rate of 8.3% and six in Group W with a mean error rate of 9.4%). The error rates for the remaining subjects were 2.6% for Group B and 3.3% for Group W ($t = 0.72$, $df = 22$, $p > .20$).

Subsequent to the search task, the subjects were given a four-alternative forced-choice recognition test for the 16 unique stimulus cards they had encountered in the search task. Each correct card was simultaneously presented with three false alternatives. The position of the correct and the three false alternatives was randomly determined. For each nontarget card, the false alternatives were constructed by randomly choosing items from the field population and placing them on the four card locations. For each target card, false alternatives contained the correct target in the correct card location, but the choice and placement of the field items was determined at random. Upon completion of the experiment, all subjects were asked whether they had expected a memory test; happily, all answered in the negative.

Results and Discussion

Reaction times. The same category-effect noted in previous studies was found again. The mean RTs for Groups B and W were 421 and 564 msec, respectively (with standard deviations of 33 and 28 msec; $F = 61.6$, $df = 1,22$; $p < .001$). The corresponding figures for the ambiguous targets (i.e., the digit zero and the letter "oh") are less impressive but still in the right direction and statistically significant: 465 msec for Group B and 524 msec for Group W (with standard deviations of 50 and 79 msec; $F = 4.9$, $df = 1,22$, $p < .05$). To this extent, our prior finding of an oh-zero difference that depends upon the categorical specification of the target is upheld (Jonides & Gleitman, 1972).

The mean RTs for the six subjects originally assigned to Group W but replaced because of overly high error rates was 542 msec (SD = 86 msec), a value not substantially different from the mean value of the 12 Group W subjects who did meet the error rate criterion ($t = 0.83$, $df = 16$, $p > .20$).

Not surprisingly, frequency of presentation speeds up RT. Cards that were seen twice during the last block of 48 trials led to a mean RT of 515 msec; those that were seen four times, to a mean RT of 484 msec ($F = 5.79$, $df = 1,22$, $p < .05$). This effect does not interact with the category phenomenon, for it is virtually identical in Groups B and W ($F < 1$).

An objection may be raised about the present experiment. Since the field items for both groups were letters, we clearly confounded category membership (that is, letters vs. digits) with categorical condition (that is, between- vs. within-category). One might argue that digits are easier targets than are letters regardless of the category of the field items among which they appear. One obvious way of controlling for this possibility would have been to perform the appropriate counterbalancing. This counterbalancing was, in fact, performed in a previous study of the category-effect using a similar procedure (Jonides & Gleitman, 1972): the results showed that the between-category condition was easier than the within-category condition whether the targets were letters or digits. Moreover, the present experiment demonstrates the category-effect even with the ambiguous target "0," which of course is physically identical whether specified as a letter or as a digit. Finally on this point, Experiment III of the present paper demonstrates a category-effect for letter and digit targets and digit field items.

Recognition test. The results of the recognition test lend credence to the hypothesis that categorization has a cost. Group B, which searched for digits among letters, attained a mean recognition score that was essentially at chance: 4.1 correct out of 16 choices with an SD of 1.8. The corresponding figure for Group W, which searched for letters among letters, was 6.6, with an SD of 2.2. The performance of this group may not be impressively high—not too surprising given the fact that whatever learning took place was incidental. What matters is that it was clearly superior to the performance of Group B ($F = 9.3$, $df = 1,22$, $p < .01$).

The recognition score for the one subject in Group B discarded because of a high error rate was 3; the mean recognition score for the six subjects discarded from Group W was 6.7 with an SD of 3.4. Frequency of presentation had no effect on recognition scores, nor was there any interaction with groups ($F < 1$).

One possible interpretation of these recognition results is that they are an artifact of the difference in reaction times (as predicted by the speeded processing hypothesis presented above). We already know that Group B completed the search more quickly than Group W; does this mean that it had less time to attend to the individual items? Various lines of evidence suggest that this was not the reason for the difference in recognition scores. If it were, one might expect a positive correlation within Group W between each subject's mean RT and his recognition performance. The actual correlation was +.04. (Since the recognition performance of Group B was at chance, a similar analysis would have been trivial since this correlation must be—and is—0.) In another analysis, we considered the relation between the subject's mean RT on each stimulus card and his ability to pick *that* card from among the false alternatives on the later recognition test. For each subject in Group W, the target cards were classified according to their mean RT during the last 48-trial block. Two point biserial correlation co-

efficients between mean RT and recognition performance were calculated for each subject: one for the cards presented with low frequency and one for those presented with high frequency. The mean point biserial correlations for the 12 Group W subjects were .23 for the low-frequency and −.05 for the high-frequency cards. There is evidently no superiority of the "slow" cards over the "fast" cards on the later recognition test. The inferior recognition performance of Group B is apparently not an artifact of its shorter RTs. This evidence further undermines the speeded processing explanation of the category-effect. It appears that in between-category search, the field items are not as fully perceived, or perhaps not as well coded in memory, as they are in within-category search. The result is that they are more poorly recognized.

EXPERIMENT II

The preceding experiment has demonstrated one cost of between-category search: the field items are not well processed. Does the same hold true for the targets? Suppose a subject looks for a "4" among letter field items. In principle, he does not have to look for a "4" at all; all he has to do is to look for a *digit*. This strategy presumably accounts for the category-effect, given the assumption that less processing is required to determine that an item is a digit than to determine what particular digit it actually is.

This general line of reasoning suggests an experimental prediction. A subject searching between categories should respond "present" on a "catch trial" on which the stimulus card contains an item that is not the target but belongs to the target's category. For example, if searching for a "4" among letters, he should respond "present" when given the item "7."

The remaining two experiments report several variations on this catch-trial theme.

Method

Subjects. The subjects included in the data analysis were 16 male and 16 female undergraduates who were paid for their participation in a 40-min session.

General design. The subjects were assigned to two groups, B and W. Group B was given a between-category and Group W a within-category search task. On each trial, both groups had to look for two targets drawn from a set of eight potential targets. For Group B, the target set comprised all digits except 0 and 1. For Group W, the target set was made up of 8 letters (A, B, G, L, P, R, S, and Z). The field items for both groups were drawn from a set of 13 letters that were never used as targets (C, D, E, F, H, J, K, M, N, 0, U, V, and Y). On a randomly ordered half of the trials, one of the two specified targets was present; on half, there was no target. Three display sizes (2, 4, and 6) were used. The experimental session consisted of 192 test trials.

After the 192nd trial, each subject was given a catch trial. Two particular targets were specified; the stimulus card contained neither of these targets but instead contained another item from the appropriate target set.

Stimulus materials. The stimulus items were black Letraset numerals and uppercase letters (Folio Medium, 24-point, .34° in height). The general method of stimulus construction was adapted from a procedure developed by Eriksen and his colleagues (e.g., Eriksen & Rohrbaugh, 1970). Both target and field items were located around the circumference of an imaginary circle of 3.4° in diameter, whose center coincided with the fixation point. The potential item locations were chosen from among the 12 clock positions. The first step was the construction of the target cards. Each target was used equally often. Across all display sizes, each target was used once at each location. The choice and placement of the field items were governed by two constraints. First, each field item was used equally often overall. Second, one field item on each card was always placed diametrically opposite to the target. As a consequence, the maximum visual angle subtended by the array items was kept constant. Within those constraints, the field-item locations were chosen randomly from among the 11 loci remaining after placement of the target. Overall, each locus contained an item an equal number of times. This procedure yielded 96 target cards (8 targets × 12 loci). A matched set of 96 nontarget cards was constructed by substituting a randomly selected field item for the target on each of the target cards. This procedure is similar to that utilized by Egeth et al. (1972).

Procedure. The subjects were first familiarized with all the field items and with the targets appropriate to their condition. They were informed about the randomly varying display size and the fact that a target was present on exactly half of the trials. They were instructed to depress a telegraph key if one of the two specified targets was present and not to do so otherwise. They were also instructed to perform as quickly as possible while maintaining a high level of accuracy. They were run for one session of 192 test trials. At the start of the session, they received 32 practice trials that used cards constructed according to the general principles described above. Seven subjects were excluded because they did not meet an error criterion of 7.5%. All of these were in Group W and were replaced. Their mean error rate was 10.6%.

The stimulus cards were presented in the mirror tachistoscope. The sequence of events was identical to that described in Experiment I, with the following exceptions: Each stimulus card was exposed for 200 msec and was followed by a masking field constructed of pieces of letters and digits that remained exposed for 1 sec, after which the fixation field returned and remained for the entire intertrial interval of about 5 sec.

Two targets were specified on each trial (e.g., "press the button if you see an L or a G"). This specification was accomplished for target cards by pairing the target on the card with another one of the potential targets, randomly chosen from the appropriate target set. For nontarget cards, both specified targets were chosen randomly from the appropriate set. The order in which the two targets were specified was counterbalanced. Each target was presented and specified equally often.

The 193rd test trial was a catch trial with a display size of 6 for both groups. On that trial, the subjects in Group B were told to look for a "2" or a "4," and were presented with a card that contained the item "3." The subjects in Group W were told to look for an "S" or a "Z" but were actually presented with a card containing "R" (which previously had served as a target). Except for the "false targets" (that is, "3" or "R"), the catch trials were identical for both groups and contained five letter field items.

Results and Discussion

Reaction time and error rates. Figure 1 shows means RTs as a function of display size for both groups. RTs that were above or below 2.5 SD (for each subject and each display size) were excluded

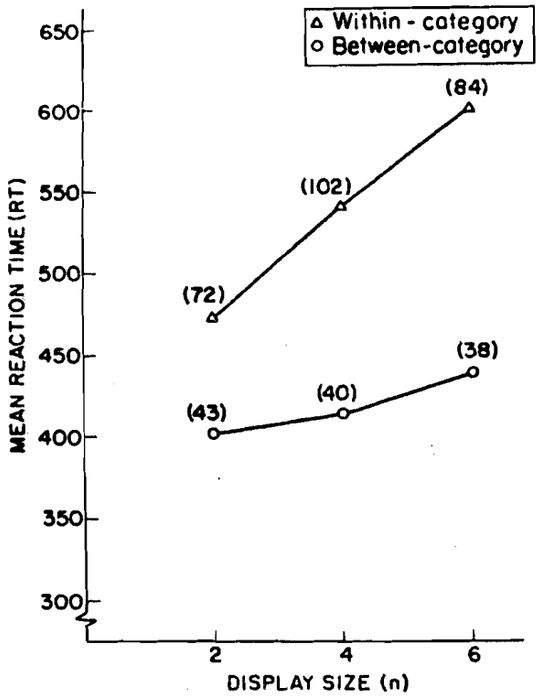


Figure 1. Mean reaction time (± estimate of σ) as a function of display size for within- and between-category conditions of Experiment II.

from all calculations. Best linear trends were determined for each subject in each condition using a least squares criterion. The slopes of these functions were 31.8 and 9.2 msec/item for Groups W and B, respectively ($F = 85.23$, $df = 1,30$, $p < .001$). The strong category effect indicated by the difference in slopes is supported by a difference in group error rates. Within-category search again resulted in more errors, 6.0%, than did between-category search, 2.3% ($t = 5.81$, $df = 30$, $p < .005$). The intercept difference is not reliable ($F = 1.64$, $df = 1,30$, $p > .20$).

Since we were forced to discard (and replace) seven subjects from Group W because of high error rates, we checked to see whether the slopes of their RT functions were out of line with those obtained for Group W. They were not: their mean slope was 38.7 msec/item ($t = 1.27$, $df = 21$, $p > .10$).

Catch trial effects. As expected, none of the 16 subjects in Group W gave a "present" response on the catch trial (nor did any of the seven subjects in that group who were discarded for high error rates). In contrast, 14 out of 16 subjects in Group B gave a "present" response on the catch trial. The reaction times on these catch trials were comparable to those obtained on six-item target cards during the regular trial block just preceding. For Group B, the mean RT for catch trials was 459 msec, compared with 440 msec on six-item target cards in the immediately preceding trial block ($t = .82$, $df = 26$, $p > .20$). This suggests that the subjects performed essentially the same operations on catch trials as on regular trials preceding.

These results accord with our prediction. The between-category searchers evidently gave their response when they had categorized the item but had not yet identified it.

In further support of the catch-trial results here reported, we ran an additional group of eight subjects in a between-category condition. This was identical in all respects to the one of the present experiment except that *four* targets were specified before each trial instead of two. The results were as before. The mean slope (11.2 msec/item) was typical of a between-category condition, and all eight subjects responded on the catch trial.

It is interesting to note that the between-category subjects seem to identify the item eventually, *after* they make the response. In many cases, they spontaneously mentioned that they had made an error after they responded "present" on the catch trial. In all, 14 subjects in Group B gave a catch-trial response; of these, 12 spontaneously said that they had erred. Some memorial representation of the item is evidently still present after the response despite the visual mask.

Serial position effects. Some further confirmation of a strategy difference between within- and between-category search comes from an inspection of the effect of serial position, the order in which the targets were specified during the regular trials. In Group W, reaction times were shorter when the stimulus card contained the target that was mentioned first rather than second. The mean RTs were 522 and 556 msec, respectively ($F = 13.80$, $df = 1,15$, $p < .005$). This difference makes sense considering that the within-category searcher must identify each item and must compare it with each of the targets in his memory. The comparison is presumably performed in turn. No similar effect was obtained in between-category search: the mean RTs for Serial Positions 1 and 2 were 415 and 418 msec, respectively ($F < 1$). The absence of a serial position effect is to be expected if the subject's response does not depend on specific identification at all. If he looks for any digit, it should not matter *which* particular digit target was mentioned first.

EXPERIMENT III

The same argument already discussed in connection with Experiment I can be raised against Experiment II. Since the field items for both groups were letters, category membership (that is, letters vs. digits) and categorial condition (that is, between-

vs. within-category) were confounded. To meet this objection head on, we ran a variant of Experiment II in which the targets were letters or digits but in which the field items were always digits. As in Experiment II, the primary concern was with the subject's response on a final catch trial.

Method

Subjects. The subjects included in the data analysis were 10 male and 10 female undergraduates, who were paid for their participation in a 30-minute experimental session.

General design. The subjects were assigned to two groups, B and W, which were given a between-category and a within-category search task, respectively. On each trial, both groups looked for two targets drawn from respective sets of three. For Group B, the target set was the letters L, S, and Z; for Group B, it was the digits 2, 5, and 7. The field items for both groups were selected from the set of digits 3, 4, 6, 8, and 9, none of which was ever used as a target. On a random half of the trials, one of the two specified targets was presented; on the other half, no target appeared. One display size of 4 was used throughout for each of 72 test trials. After 72nd test trial, each subject was given a catch trial.

Stimulus materials. The apparatus was identical to that used in the previous experiments. The cards for the 36 test trials on which a target appeared were constructed as follows. Each card contained four items placed at the four vertices of an imaginary diamond whose center was the fixation point and whose diagonal was 3°. Three of the four items were chosen randomly from among the population of field items, except that over all trials each field item was used equally often. The fourth item was chosen from among the three potential targets. Each of these was used equally often and was placed at each of the four loci with equal frequency. The 36 nontarget cards were constructed by replacing the target item on each target card with a field item drawn randomly from those remaining (once again, with the constraint that each item be used equally often). Twelve practice cards (6 with targets, 6 without targets) were constructed following the same design. In all other respects, the manner of stimulus construction was identical to that employed in Experiment II.

Procedure. The sequence of events (fixation field, stimulus card, masking field) was identical to that used in Experiment II. The method of target specification was also identical. Six subjects were excluded (and replaced) because they exceeded an error criterion of 8.5%. Of these, three were in Group B and had a mean error rate of 10.7%. The other three were in Group W and had a mean error rate of 10.7%.

The 73rd test trial was a catch trial. On that trial, for both groups, two of the three targets were specified but instead the third was actually presented. For different subjects, a different pair of targets was specified. The three field items were randomly chosen from the field item population.

Results and Discussion

Test trials. RTs that were above or below 2.5 SD for each subject were excluded from all calculations. The mean RTs for the two groups show that a category effect occurs under the present circumstances. For Group B, which searched for letters among digits, the mean RT was 436 msec (SD = 39 msec). For Group W, which searched for digits among digits, the mean RT was 490 msec (SD = 54 msec). This difference was reliable ($F = 6.46$, $df = 1,18$, $p < .02$). There was no corresponding difference in group error rates, which were 2.8% for Group B and 2.6% for Group W. This is not too surprising given that only one display size of four was used (as in Experiment I, in which there was also no group difference in error rates). The difference between the error rates of the two groups in Experiment II was largely attributable to errors made in response to a display size of six.

Catch trials. The results were virtually identical to those obtained in Experiment II. Of the 10 subjects in Group W, only 1 responded "present." Of the 10 subjects in Group B, 9 gave a "present" response. The mean RT of the catch trials for Group B was 431 msec, which was virtually identical to the mean RT of the immediately preceding block of 36 test trials (430 msec). As in Experiment II, it appears that the subjects followed essentially the same strategy on catch trials as on standard test trials.

The results of the present experiment indicate that the effects obtained in Experiment II are not an artifact of the confounding of target category and category condition. Whether the field items are digits or letters, the basic effect is the same.

A response set hypothesis. There is the possibility that the catch-trial results obtained in Experiments II and III are really an artifact of a response set. The "false" targets on the catch-trial stimulus cards had been actual targets previously, and the between-category subjects may have simply been accustomed to respond to these targets. This argument is rather farfetched since it does not explain why there was no comparable effect for the within-category subjects. Nevertheless, it seemed worthwhile to rule out this possibility by presenting a "false" target on the catch-trial that had never served as a target before. We did so with a group of eight subjects, who were run in a between-category search task according to a procedure much like that of Experiment II with digit targets and letter field items. The targets (all of which were specified on each trial) were always 2, 5, 7, and 9, and the catch-trial items were chosen from among the digits 3, 4, 6, and 8. The results on the catch-trial test rule out the possibility of a response set artifact: all but one of the eight subjects gave a "present" response.

GENERAL DISCUSSION

The preceding experiments have demonstrated the cost of categorization in visual search: both targets and field items are processed less deeply in between- than in within-category search. Our evidence comes from two main sources. First, we find that between-category subjects remember less about the nature of the field items to which they had been exposed than do subjects run on a comparable within-category task. On the partial processing hypothesis, they registered less information about the array items. A second finding shows a similar cost of categorization for the targets. When presented

with incorrect items that belong to the target's category, between-category subjects give false alarms while within-category subjects do not. This result also follows from the partial processing hypothesis, according to which less information is required to determine the *category* of an alphanumeric item than is necessary to establish its *identity*.

Can we give some further substance to the metaphor of partial processing? One strategy would be to try to specify *what* has been processed, whether in part or in full. Here the concern would be with the structure of the information which the subject must extract from the stimulus display. One possibility is to assume that the critical information about alphanumeric items is featural. A hypothesis consistent with this notion is that the features required to abstract a category such as "letter" are a proper subset of those that are necessary to identify, say, the letter "A." An alternative hypothesis might claim that the letter-defining features are not nested in the set of "A"-defining features but are nevertheless fewer in number or are "easier" to extract. Any of these hypotheses would be consistent with the metaphor of partial processing and could in principle account for the present findings. This general line of attack has been considered by various investigators (e.g., Jonides & Gleitman, 1972; Nickerson, 1973; Reed, 1973).

A possible argument against a featural interpretation of the category effect hinges on the oh-zero phenomenon reported here and previously (Jonides & Gleitman, 1972). Can a featural mechanism account for a category effect that occurs solely as a function of instruction? In principle, it might. A given item could contain some features of two different categories in the sense in which a baseball belongs both to the class of white objects and of spherical ones. Given such an overlapping feature membership, the item would be in this sense ambiguous. If the featural analysis is flexible and can be guided by the subject's strategy, then instructions might by themselves produce a category-effect. If the subject looks for a zero among letters, he extracts those fewer (or perhaps easier) features that define the category digit, processing partially and thus more quickly. Seen in this light, the "oh-zero" effect does not rule out a featural interpretation; it only proves that if there is a featural mechanism it must be flexible.

There is a more serious obstacle to pursuing the featural approach to the category-effect; we know very little about the features that distinguish among alphanumeric items, whether within or between categories. One might try to discover them, but, given our scant knowledge about the psychophysics of form, this may prove to be a very difficult undertaking. Under the circumstances, one may opt for an indirect assessment of the general class of hypotheses which we have subsumed under the term "partial processing." As applied to the category effect, these hypotheses share an assumption: less information is extracted in between- than in within-category search. We have here tested and confirmed several consequences of this assumption. To this extent, we have provided indirect evidence for the class of featural hypotheses we have discussed.[3]

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NOTES

1. The slope of the RT function has often been taken as a test of serial vs. parallel comparison models in visual search. This issue is not crucial to our present concerns: we regard the slope of the RT function in this task as merely an index of how difficult the search is. The lower slope of between-category search indicates the benefit of categorization: less processing is required, and so the search is easier. In principle, this view is probably compatible with several different models of the underlying search mechanism, whether based on serial processing (e.g., Nickerson, 1966; Sternberg, Note 2) or on the assumption of parallel search coupled with limited capacity in which "processing energy" is thought to be spread out ever more thinly with increasing n (e.g., Rumelhart, 1970). In fact, Townsend (1971) has pointed out that it may be very difficult to experimentally discriminate such hypothesized search processes altogether.

2. Pilot studies have indicated that RT distributions have lower variance if the subject is required to make only one response (in this case, "present") than if he is obliged to choose between two (e.g., "present" and "absent"). We therefore opted for the "go, no-go" procedure of the present experiment, despite the fact that this meant that we could collect RTs on only half of the trials.

3. The depth of processing notion here presented to account for the category effect in visual search obviously has a close relative—Craik and Lockhart's conceptualization of memory processes (Craik & Lockhart, 1972). The parallel is methodological as well as conceptual. For example, proponents of the Craik and Lockhart position assume, as we do, that incidental learning reflects processing depth (e.g., Gardiner, 1974).

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