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Keith E. Stanovich
Oakland University

Richard F. West
James Madison University

STANOVICH, KEITH E., and WEST, RICHARD F. *A Developmental Study of the Category Effect in Visual Search.* CHILD DEVELOPMENT, 1978, **49**, 1223–1226. Several studies have demonstrated that adults display a category effect in visual search paradigms. That is, when searching an array for the presence of a target letter, subjects detect the letter faster when the array is composed of numbers rather than letters, and vice versa. Groups of 8-year-olds, 10-year-olds, and adults searched for the presence of a target in fields of items that were either of the same or a different category (letter or number) than the target. Highly significant category effects were evident in the search times of all 3 age groups. While search times were found to decrease with development, there was no evidence of an increasing effect of category with age. It was concluded that the feature extraction process that mediates the category effect is fully automated by age 8.

The present study makes use of a visual search task in order to investigate the developmental course of the category effect in visual information processing. The category effect in visual search was first observed by Brand (1971) and replicated by Ingling (1972). These investigators found that, when searching for a letter, subjects were faster when the field items were numbers rather than letters. Similarly, subjects searched for numbers faster when they were embedded in letters. Whereas Brand (1971) observed a category effect in a variant of the Neisser search paradigm, Egeth, Jonides, and Wall (1972) observed category effects with visual displays that were presented tachistoscopically.

Since the category effect can be obtained under stimulus conditions that preclude eye fixations, the effect is not due to conscious scanning strategies. Thus, it is possible that the category effect in visual search is mediated by an automatic process of the type discussed by LaBerge and Samuels (1974). A process that is automatized can take place without attention being directed to it, thus allowing central processing capacity to be allocated elsewhere. LaBerge and Samuels (1974) developed a hierarchical model of reading that incorporated the concept of automaticity. In their model, a reader develops fluency by automatizing certain low-level processes such as letter and word identification so that attention can be directed at higher-level functions such as comprehension. Processes become automatized with practice, and the primary measure of automaticity is the speed, rather than the accuracy, with which a process is executed.

Under the automaticity hypothesis, one would expect the category effect to increase with age or to be relatively invariant if the differential knowledge of the features distinguishing letters and numbers becomes automatized upon first experience with these categories. Contrary to this prediction, Lefton and Fisher (1976) presented evidence that appears to suggest a decreasing effect of category with age (third graders, fifth graders, and adults in their experiment). However, the crucial statistical analyses were not reported. In addition, a possible artifact was introduced by their procedure of allowing a second pass through the column of letters that constituted the field when the target was not located on the first pass. Given certain not implausible assumptions about the relations between time, errors, and development in a task of this sort, such a procedure could well have differentially affected the observed category effects of the age groups tested.

Requests for reprints should be sent to Keith E. Stanovich, Department of Psychology, Oakland University, Rochester, Michigan 48063.

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The experiment reported here bypasses the procedural difficulties described above by using a letter-cancellation search task that has been successfully employed in previous developmental studies of visual search performance (Henderson 1974). The task is more data efficient and, after a brief practice period, results in stabler performance on the part of children than does the Neisser search task. With this more appropriate task it is possible to gain more precise knowledge of how processing operations that are involved in reading become automated with development. The importance of the concept of automatized processes has been evident in recent research on the development of the component abilities of reading (e.g., Doehring 1976). Also, since the category effect in visual search is a reflection of the overlearning of the feature sets that differentiate letters and numbers, it is of interest to researchers investigating the development of component processes in reading per se.

One hundred twenty-one primary school children (75 males and 46 females) of two age groups took part in the experiment. The younger group had 53 children with a mean age of 8-2 (range 6-3 to 8-9). The older group had 68 children with a mean age of 9-9 (range 8-10 to 12-2).

Sixteen undergraduate college students (four males and 12 females) also participated in the study. The students were enrolled in an introductory psychology course and received credit toward course requirements for participating in the study.

Materials consisted of lists of alphanumeric characters. Each list was typed on a separate stimulus card (21 cm × 28 cm) with a Smith-Corona electric typewriter that had a large, primary school type font. All letters used were uppercase. Each stimulus card contained four 20-line columns. Each line contained five letters. Of the 400 characters that formed a list, 20 characters were occurrences of a single target character and the remaining characters constituted the field. Target characters were randomly placed in the lists with the constraint that a target occurred only once in every four lines of a column. Target items were the numerals 2 and 3 and the letters H and N. The numerals 1–9 and the letters A–Z, excluding those characters used as target items, constituted the numeral and letter field populations. Three types of fields were used: (1) a numeral field, which was composed of items selected randomly from the numeral field populations; (2) a letter field, composed of items selected randomly from the letter field population; and (3) a numeral-letter field, composed of items selected randomly from both the numeral and the letter field populations. A hand-held stopwatch was used to measure the search duration. Latencies were measured to the nearest 0.1 sec.

Subjects were individually tested in a session that lasted approximately 15 min. Six separate lists were shown to the subjects, who were told to search through the lists and cancel (i.e., "put a small line through the target") every occurrence of a designated target character. Subjects were instructed to work as rapidly as they could without missing any of the targets. A small card (8 cm × 10 cm) with the appropriate target item typed on it was shown to the subjects before each trial. Beginning with the left-hand column, search progressed downward from the top of each column. Timing began when the experimenter uncovered a stimulus card and said "Go." Timing ended when the subject finished searching through the bottom line of the right-hand column and said "Done."

Subjects received two practice lists at the beginning of the experimental session. On the first practice list they scanned a numeral-letter field for occurrences of "the number 3"; on the second practice list they scanned a numeral-letter field for occurrences of "the letter H." Subjects were prompted during the practice lists when they failed to follow directions. Following the practice lists, subjects received one block of two experimental lists that required scanning through letter fields and another block of two trials that required scanning through numeral fields. The order of presentation of these blocks was counterbalanced across subjects. For both blocks, the first target was "the letter N" and the second target was "the number 2." Thus, each subject participated in four experimental conditions (N between category, N within category, 2 between category, 2 within category).

Since there were no sex differences on any of the performance measures, data from boys and girls will be pooled in the analyses that follow. The mean search times and mean number of errors (which are indicated in parentheses and were almost always omissions)

for the target letter N were as follows: younger children within category, 110.2 (3.3); young children between category, 84.3 (.8); older children within category, 92.8 (3.1); older children between category, 70.5 (.9); adults within category, 44.8 (.5); adults between category, 29.8 (.1). The category effect is indicated by the drop in search time from the within-category condition to the between category condition. An analysis of variance on the search times from the target N conditions indicated that there was a significant effect of age, $F(2,134) = 43.7$, $p < .001$, and category condition, $F(1,134) = 232.9$, $p < .001$. However, the age × category condition interaction was not significant, $F(2,134) = 2.48$.

A similar pattern of results obtained when the search times for the target 2 were considered. The mean search times and mean number of errors were 93.3 (2.2) for younger children within category, 87.6 (.9) for younger children between category, 79.4 (2.4) for older children within category, 72.6 (1.1) for older children between category, 37.6 (.9) for adults within category, and 32.4 (0) for adults between category. It is clear that the category effect for the target 2 was much less than that for target N. An analysis of variance on the search times from the target 2 conditions indicated that there was a significant effect of age, $F(2,134) = 44.8$, $p < .001$, and category condition, $F(1,134) = 22.2$, $p < .001$. However, the age × category condition interaction was not significant, $F(2,134) = .12$.

For both targets an analysis of covariance on the search times was carried out, with number of errors as a covariate. This analysis gave results virtually identical to those obtained from the analysis of variance. In addition, age was found to account for no more than 4% of the variation in the category effect when 95% confidence intervals were constructed for the correlations between the size of the category effect and the children's ages in months (target N, −.18 to .18; target 2, −.17 to .19).

The present investigation was an attempt to look at the development of an automatic process. The category effect in visual search seemed a good candidate for a developmental investigation since the mechanism that mediates the effect operates at a low level of the processing hierarchy. Indeed, even the youngest age group displayed a category effect with both targets, and no developmental trend toward increasing automaticity was evident in the data. The highly significant category effects exhibited by all age groups demonstrate that the present experiment was sensitive enough to detect the effect. The lack of significant differences between the groups does not appear to be due to a lack of sensitivity in the experiment or the analysis.

While it might at first seem surprising that the category effect does not increase from age 8 through adulthood, there are some indications that certain low-level processes can become fully automatized at a young age. Schiller (1966) conducted a developmental study of performance on the Stroop Color-Word Test. If the delay in naming the color of a word is indeed due to automatic processing of the word form (Posner & Snyder 1975), then the fact that Schiller (1966) found no increase in interference from grade 2 through adults indicates that recognition of the simple words used in the study was fully automatized by grade 2. Rosinski (1977) obtained similar results using a slightly different paradigm.

Although one must be cautious in drawing educational implications from a single study, it would appear that at least one tentative conclusion is warranted. Since 8-year-olds have automatized the process that extracts the features that distinguish letters and numbers, it would seem that further practice at tasks tapping this level of processing is unnecessary. Children of this age are probably in the process of automatizing operations at higher levels such as word recognition and sentence comprehension. Studies of the development of automaticity at these higher levels would be of theoretical and practical importance.

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