The effect of orthographic structure on letter search*

ELEANOR J. GIBSON, YVETTE J. TENNEY
RODERICK W. BARRON†, and MARTHA ZASLOW
Cornell University, Ithaca, New York 14850

Ss were asked to search for a single-letter target embedded in a context of (1) letter strings that were orthographically well structured though not English words, or (2) letter strings that were poorly structured and unpronounceable. Neither college students nor fifth graders differed in scanning rate as a function of the context structure. Reports from Ss revealed that orthographic structure was frequently noted but was used inconsistently, if at all, and without benefit to the search. It was concluded that optimal strategies for processing verbal features change with the task and that pickup of larger structural units is incompatible with fast letter search.

Earlier experiments have shown that orthographic structure, even in nonwords, is an important determinant of the ability to read a briefly displayed string of letters (Gibson & Guinet, 1971; Gibson, Osner, & Pick, 1963; Gibson, Pick, Osner, & Hammond, 1962; Gibson, Shurcliff, & Yonas, 1970). The explanation proposed was that as reading skill progresses, the reader learns to process units larger than a single letter by taking advantage of letter dependencies, especially clusters constrained by rules of English orthography to a given position in the word. Does this kind of processing occur only when the S is set to read the string and report on it, or is the rule structure, once learned, picked up automatically, without special intention? Is proficient reading an automatic process in which the graphological and phonological rules operate in decoding without any particular attention or notice on the reader's part?

We proposed to investigate the question by examining the effect of orthographic structure in the background display of a visual search task. The scanning task used by Neisser (1964) was chosen, since it has been shown (Neisser & Beller, 1965; Schapiro, 1970) that nontarget items are poorly remembered at the conclusion of the search and thus appear to be relatively unattended. However, Schapiro (1970) showed that contextual structural information which is useful for locating a target can be picked up without instructions. Ss in his experiment searched for a single target letter embedded in rows of six-letter strings. These strings were

made up of six different background letters, randomly permuted in every row and randomized for every list. When S reached asymptote, a new context letter was introduced without his knowledge. This letter was positioned randomly either above, below, to the right of, or to the left of the target letter in each list so that it could serve as a kind of "marker" or pointer for the target if noticed. Despite having reached an apparent asymptote, all the Ss proceeded to reduce their search time still farther after the introduction of the new letter that provided redundant information about the target location.

We wondered if good orthographic structure, as opposed to the random arrangement of context letters, would be noticed and if the structure would facilitate the search for a target letter by allowing the background to be processed in larger units. We also asked if there would be an age difference in automatic uninstructed pickup of orthography. A target letter was therefore searched for in two types of background. In one, letter strings were constructed according to rules of English orthography and were thus "pronounceable" pseudowords. In the second, letter strings were constructed which were anagrams of these pseudowords but were unEnglish in orthography and unpronounceable. Children in the fifth grade and adults were compared on the task. Since the orthographically possible strings were also phonologically possible, it was of further interest to discover whether or not the Ss would pronounce them subvocally in scanning for the target letter.

METHOD

The Ss were assigned to one of two experimental conditions. In Condition OS (orthographic structure), the horizontal strings of letters in the background were

orthographically well structured and pronounceable. In Condition NS (no structure), the horizontal strings of letters were orthographically unstructured and unpronounceable. It was originally planned to run Ss in both conditions, counterbalancing the order. Preliminary experimenting, however, suggested that the structure or nonstructure of the condition to which S was first exposed led to expectations which influenced his behavior on the second condition and contaminated the results. A recently reported experiment (Adelman & Smith, 1971) confirms the potential effect of expectation on pickup or nonpickup of structure. Therefore, we decided to run Ss in only one condition in order to give them a better chance to perceive the background structure when it was present.

Construction of Lists

A single target letter (N) was assigned for all lists. The lists were prepared in horizontal strings five letters wide and 30 rows from top to bottom. The five letters in each horizontal string (item) in Condition OS were arranged to conform to English orthographic structure (e.g., GLURK). The corresponding item of the corresponding NS list was composed of these same letters permuted so as to be unEnglish (e.g., RKUGL). All the OS words were monosyllabic. The items containing the target letter were similarly constructed (e.g., SLAND vs DSANL).

The target letter occurred an equal number of times (four) in each of the five horizontal positions in an item. Four different word structures were utilized to allow the N to appear in all five positions while maintaining the pronounceability of the item. The consonant-vowel arrangements were: (1) CVVCC (e.g., NEARL); (2) CCVCC (e.g., SNORK, SLAND); (3) CVCCC (e.g., BENTH); (4) CCVVC (e.g., THAIN). The corresponding NS item was of the same CV structure, with the target letter in the identical position.

Context items conformed to the same CV structures and were distributed over the four CV types in the same proportion as the target items. This rather elaborate control of CV structure was necessary because we had reason to think that Ss would notice very subtle changes in CV structure if they could be used to differentiate an item containing a target from other items.

A pool of context items was prepared containing 60 OS items paired with 60 corresponding NS items. Every letter of the alphabet was

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used except N. A pool of *target items* was prepared containing 20 OS items, with the target letter N appearing in each one, paired with 20 corresponding NS items.

Twenty OS lists and 20 corresponding NS lists were constructed by drawing one item from the target pool (without replacement) and 29 items from the context pool (with replacement) for each list. No context item was permitted to appear on two successive lists or twice on the same list, so each context item appeared at most 10 times during the 20 trials. The positions of the context items were determined randomly for each list. The target item appeared in a different row, randomly determined, on each list so that a rate measure of scanning could be obtained (Neisser, 1964). The target letter's position was thus randomized both horizontally and vertically over the lists, but with equal distribution horizontally, and with representation in all segments vertically.

The lists were printed on white unlined paper with the standard business type of an IBM 1403 printer and were pasted on heavy cardboard for insertion in the scanning box.

Procedure

The S was taught how to operate the scanning box (described in detail in Gibson & Yonas, 1966a) and given three practice trials. A trial was initiated when the S pressed a button that turned on the light in the scanning box and also started a Hunter Klockounter. When S found the target, he pressed the switch again, turning off the light and the clock. The target letter on the practice trials was the same as on the experimental trials, but the context items and target items were different. An S's practice lists conformed to the construction rules for the condition to which he was assigned (OS or NS). The S then scanned through the 20 experimental lists, while E recorded his latencies. E asked him afterwards if he had noticed anything about the list construction and if he had pronounced any of the horizontal strings to himself.

Instructions

The fifth-grade Ss were instructed as follows: "The name of this game is *Find the letter 'N'* as fast as you can [E holds up a card displaying the letter N.] Let me show you how it works. Hold this block in your lap and push the button with your thumb. Push it again and see what happens. You may practice pushing the button. Turn on the light and look into the window. What do you see? [A practice list appears in the display window. E records whether S reports letters or

Table 1
Mean Rate of Scan Per Line (in Seconds)
to Locate a Target Letter

	Condition	
	OS	NS
Fifth-Grade Ss	.81	.88
Adult Ss	.38	.37

tries to pronounce words.] Look at the top line. Do you see the letter N anywhere in that line? Look at the second line. Is the N there? How about the third? Fourth? [If S did not see it there, E said, 'Are you sure?'] Good. You have found the letter N. Push the button and turn off the light. [E inserts a new practice card.] Do you see the light? [E points out lighted fixation point.] Watch it closely. When you are ready, push the button and start looking down the list. This time the N will be in a different place. As soon as you find the N push the button again. Ready? Go ahead. Where was it? Always be sure to start at the top and look *down* the list. [E illustrates with finger moving straight down lighted window.] If you get all the way to the bottom of the list [E illustrates with finger] and you still have not found the N, don't back up and look for it, but push the button and say 'I didn't see the N' [E changes to Practice Card 3.] OK? Let's try it again. Watch the dot. When you are ready, push the button and start looking for the N."

Instructions for the college Ss were essentially the same, but the wording was adapted for adults.

If S missed a target, the list was presented again when all the other lists had been scanned through. E watched Ss' eyes for the first few trials to check whether he actually scanned from the top downward.

Subjects

There were 76 SS from the fifth grade, 38 in each condition, and the same number from the introductory psychology course at Cornell University.

RESULTS

The validity of the measure of scanning (mean rate of scan per line) was tested by correlating the mean time of a group of Ss to locate the target in each of the 20 vertically distributed list positions with the target position. The time should, of course, increase as the target's position is more remote from the initial position at the top of the scanning box. The correlations were .85 (Condition OS, fifth grade), .86 (Condition NS, fifth grade), .91 (Condition OS, adult), and .90 (Condition NS, adult). These

correlations seem very satisfactory. They reveal, in addition, that fifth-grade children are able to scan as instructed just about as systematically as adults.

The mean rate of scan per line to find the target letter is presented in Table 1 for both conditions and both age samples. It appears that scanning rate was not affected in either age group by the orthographic structure of the context items. The only obvious difference is between the scanning rates of the children and the adults. An analysis of variance confirmed the trends mentioned, showing that age is the only significant variable ($F = 123.89$; $df = 1, 148$; $p < .001$). The fifth graders, although they were able to scan systematically down the list, did so much more slowly than college students.

Did the Ss in Condition OS notice that the horizontal strings of letters conformed to English orthographic structure and were pronounceable as syllables? Did they, in addition, articulate them subvocally? An experiment by Baddeley (1971) on immediate memory for redundant and nonredundant sequences of letter names showed that acoustic confusions between letter names disappeared as redundancy within the strings increased. Baddeley suggested that Ss were coding the letters into larger units of speech sounds, such as syllables.

When our Ss were first shown a practice list, they were asked, "What do you see?" In Condition OS, 91% of the fifth-grade Ss responded "words," whereas in Condition NS, 88% responded "letters." During the experiment, some fifth-graders in the pronounceable condition spontaneously reported the whole word in which the target letter was embedded, but the extent to which the whole word was subvocally pronounced without report is unclear. A few fifth-graders who scanned exceptionally slowly in the pronounceable condition reported that they were saying the letters to themselves, one by one. A few pilot Ss who were given both kinds of list spontaneously remarked at the end that the pronounceable lists were "much easier because I can say the words to myself." Thus it seems plausible that some of the fifth graders treated the pronounceable strings as words and even pronounced them subvocally.

Of the adult Ss in Condition OS, 74% said they saw "words," 10% said "nonsense syllables," and there were a few idiosyncratic responses such as "list" and "names." In Condition NS, 89% said "letters" and again a few said "nonsense syllables." The distinction

was not as clear-cut as with the children, due to the greater variety of answers available to the university students. Reports about treatment of the pronounceable items revealed inconsistencies. About half the Ss thought they pronounced the items as words occasionally, but not all the time. It appeared from their remarks that some of these Ss vacillated from a "word" strategy to a "letter" strategy within a list or changed their strategy part way through the experiment.

If some of the Ss were processing the pronounceable words as units, whereas others were proceeding literally letter by letter, the contrasting strategies might be reflected in the mean latencies of individual Ss. Although we were not able to classify each S on this basis with any confidence, it seemed possible that such a difference would show up in a frequency distribution of mean latencies for the individual Ss in each condition. If the distribution in Condition OS were bimodal, as compared to a unimodal distribution for Condition NS, it would suggest the use of two difference processing strategies on Condition OS. For each age group, the range of latencies in each condition was divided into 10 equal intervals and the number of scores falling into each interval was plotted. Distributions for both OS and NS conditions had only one mode in both age groups, and the OS and NS distributions were similar in shape. Thus, the comparison affords no convincing evidence for a division of Ss in Condition OS into two types.

DISCUSSION

It has been known for nearly a hundred years (Cattell, 1885) that the number of letters that can be read in a brief visual exposure is significantly greater when the letters form a word than when they do not. Recently, several experiments have shown that a target letter is more easily identified when it appears in a word than when it appears in a string of unrelated letters or is displayed alone (Lott & Smith, 1970; Reicher, 1969; Wheeler, 1970). James & Smith (1970), however, obtained apparently contradictory results. They measured latency of report on presence or absence of a probe letter in a five-letter string and found no advantage for a word compared to an unpronounceable anagram of that word.

All these experiments differ from the present one in that the type of redundancy studied was the kind found in real, familiar words as opposed to nonwords. It is possible that the meaning and familiarity of the real words, rather than their orthographic structure, could account

for the positive results. Yet English orthography is rule-like and does provide strong intraword redundancy (Garner, 1962, p. 240 ff.). Since we were interested specifically in orthographic structure, two sets of pseudowords were contrasted that differed only in this type of redundancy and were not confounded with other types.

Why did the orthographically structured context in our experiment not facilitate discovery of the target letter, even for the adult Ss? To understand the results of the present experiment, it is essential to consider the nature of the task. The task calls for discrimination, not recognition of meaning or even identification. The S was asked to scan a list of letter strings searching for a specified single target letter. It is possible, in Condition OS, to code the pronounceable letter strings as words. But is this coding, however economical for picking up the string, compatible with deciding if a given letter is a part of it? The answer seems to be no. The analysis of an orthographic unit into its constituent parts evidently requires additional processing time. The advantage of a structured background which can be dealt with in larger units is cancelled by the necessity of further processing for a specific letter. A search for the graphic features which distinguish the target letter N from the set of background letters is probably more economical in this task.

At first glance, our results appear to be contradicted by experimental findings published by Krueger (1970) midway during our investigation. He reports that his Ss searched more rapidly for a target letter through real words and through pseudowords with a high degree of approximation to English than through scrambled letter strings. There is an important difference concerning the target letter between his experiment and ours. He used a different target for each list, while we kept the target the same throughout. His Ss, unlike ours, did not have the opportunity to learn to search for the distinctive graphic features of a single target letter. However, the James and Smith experiment also presented different letter targets for each display and found no advantage in the time required to locate the target in words rather than in their unpronounceable anagrams. Both our experiment and the James and Smith experiment used different Ss for the pronounceable items than for the unpronounceable items. Krueger's Ss were shown both types of items, randomly presented, which may have led to a different strategy.

Krueger concludes (p. 398): "The

fact that Ss exploited sequential letter and word dependencies to search faster indicates that they were not restricting their attention to the letter shape being sought, employing a selective filter to exclude all other, unwanted information, but rather were engaging in broader encoding operations, similar perhaps to those in reading." Our Ss were clearly *not* engaged in coding operations similar to reading in the usual sense.

While no direct test for subvocal articulation of the pronounceable strings during scanning was provided, it was expected that articulation, if it occurred, would increase latency. Since the two conditions did not differ in search rate, it seems unlikely that the typical S coded the pronounceable strings into subvocal speech. We know that articulation of letter names does not occur in the scanning task in such a way as to interfere with scanning rate (Gibson & Yonas, 1966b; Kaplan, Yonas, & Shurcliff, 1966). Phonological encoding of letter names and, when possible, of larger pronounceable linguistic units does occur in short-term memory tasks (Baddeley, 1971), but typically not in a search task.

To return to the original question posed, does a proficient reader automatically process orthographic structures, whatever the specific goal his task has set him? The answer is not simple. Nearly all the Ss in this experiment did notice the higher-order structure present in the OS condition, and many of the adults thought that they used it some of the time. But the results indicate that the structure certainly did not reduce search time. In accordance with the theory (Gibson, in press) that the perceptual process is highly adaptive and tends to utilize only that information most economical for satisfying task demands, we conclude that the pickup of orthographic structure in this task was incompatible with the most economical search for a single target letter and hence was not used. The results of this experiment lend further support to the notion that the sequence in which the various features of words are processed depends on the task.

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