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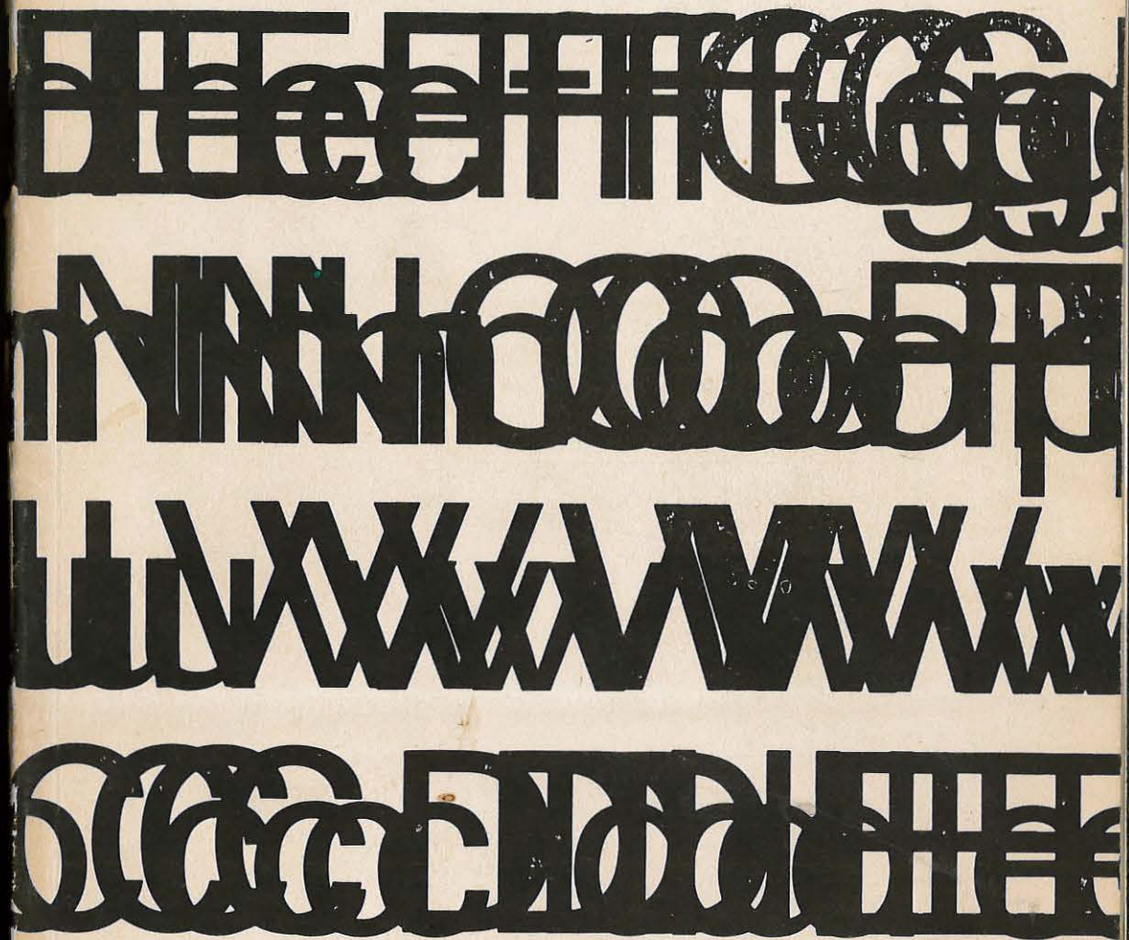

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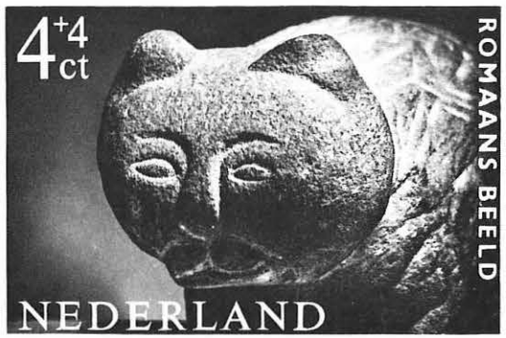
1968. Designer: Wim Crouwel.



1962. Designer: Cor van Weele.

Designer: Rein Draaier.

Designer: O. Oxenaar.

Search: An Approach to Cartographic Type Legibility Measurement

Barbara S. Bartz

It is proposed that a new task be selected for measuring the effect of type variation in cartographic context, and that since every name on a map must be found before it can be processed further, "search" would be such a meaningful task. From this, a definition of cartographic legibility would be held to include the notion, "the speed with which the map can be searched." Some literature is cited to show the utility of the search task in general, and various considerations which would restrict its use in map research context are also outlined.

Although the type used on any map is often the graphic element which attracts the most attention and tends to be the most criticized, there has been no substantive research conducted on the topic of cartographic type legibility. In the standard body of experimental type legibility research,[1] the word "map" never appears. We have seen in a previous article[2] how different are the ways in which type functions on a map, compared to standard text usage. The letter-forms encode meaningful sounds on the map, as they do in text, but they are also used to encode a variety of other quantitative and qualitative information about places. Any consideration of "legibility" in the cartographic context must be based upon quite a different array of assumptions, tasks, and questions.

Lacking experimental data from the map context, cartographers have resorted to the application of research findings from other type-use situations. Analysis points up the questionable nature of such application. For one thing, the type on a map is expected to function in a variety of ways. To put it another way (with the emphasis shifting from the map itself to the user of the map), the map user can carry out a wide variety of activities which involve type use.

He may look for names, he may read off the names in a particular area, he may try to remember all the names he has seen, he may make locative, qualitative, and quantitative comparisons of mapped features on the basis of the name type characteristics, and so on. In text usage, type can also be used in a variety of ways, but these are rather different from those just mentioned. In most experimentation it can be shown that the particular way in which type is used (the nature of the task performed) will affect the conclusions the researcher may reach about the effect of typographic variation on the speed, accuracy, or ease with which the task is performed. Thus the notion of achieving a general goal of legibility of type becomes less useful than it might at first be thought.

In themselves, the physical variations in type characteristics can be evaluated only in an aesthetic, subjective sense, for typography is no more than an arrangement of marks on paper. But type in use *is* more than itself; thus there is concern with the effect of typographic variation on the activity in which type is used to achieve some goal. Type can be evaluated, then, not for itself but on the basis of how it affects the performance of that activity. Generally, an increase in legibility is equated with an increase in the speed, accuracy, or ease with which the activity involving type can be performed. That typographic arrangement is considered best which maximizes one or more of these three activity characteristics.

In text legibility research, the word "reading" is either left undefined, or is defined in a particularly limited way for a particular experimental situation. There is, for example, the pronouncing aloud of running text, or the recognition of isolated words, or the reading of text for meaning which is tested for some kind of comprehension. Clearly, the "reading" of names on a map is an entirely different and rather novel use of the word. The combination of letters is vocalized, but may or may not have further meaning, depending upon the

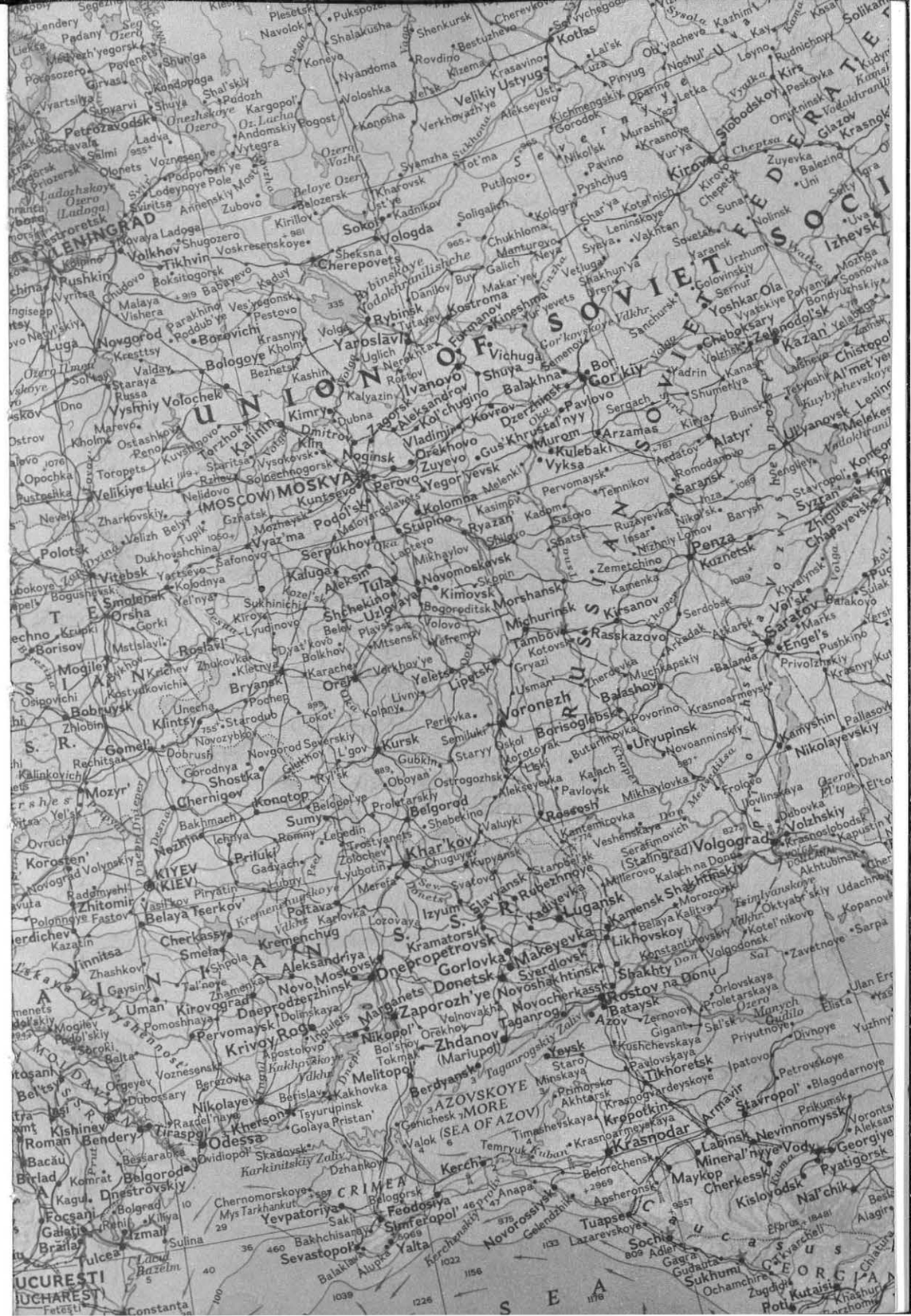


Figure 1. A densely-lettered, place-name reference map (illustration is the same size as the original map). It makes clear the difference between "reading" continuous text for meaning, and "reading" the names on an unfamiliar map. It also illustrates the complexity of cartographic typography. Source: National Geographic Society *World Atlas* (Washington: 1959), The National Geographic Society, Plate 30.

experiences of the map user. Speed-of-reading and comprehension do not seem particularly useful concepts in the cartographic context. In order to evaluate cartographic typography, an activity must be selected which is performed in actual ordinary map use. This activity must be one which uses typography and is measurable in some objective way. Then it must be determined whether typographic variation, in fact, can differentially affect this activity; that is, if it can affect the speed, accuracy, or ease with which the task is performed. If we are able to do this, we shall have one measure available to us which we can use to compare the effectiveness of various typographic arrangements in cartographic context (See Figure 1).

It seems reasonable to assume that finding a name is one of the more common tasks performed with a place name reference map. Before a name can be found, however, there must be a period of search. It is likely that a sensation of "ease" in finding a particular name will be correlated with the amount of time required for the search-and-find procedure. It further seems reasonable to assume that the characteristics of the map typography might have an effect on the rate at which this search-and-find procedure takes place. This would then provide us with a realistic task in cartographic context, and the amount of time it takes to find a name can be easily and objectively measured. Different cartographic type use situations could thus be evaluated and compared.

The search task (and associated timing measures) are not commonly found in the type legibility literature. We can arrive at some notion of its applicability and utility by examining some of the other experimental settings in which it has been applied. Several of these are considered in more detail because they suggest fresh approaches to the study of typographic coding in general. Search time can be affected by variables in the visual display, by the conditions surrounding the viewer performing the search task, and by the variable characteristics of the subjects themselves. Search-time measurement has appeared in the literature since about 1950, and is commonly used for three purposes:

(1) To investigate various techniques for coding targets,
(2) To study human searching patterns, in such applications as scanning for aircraft, and
(3) To study the searching process, either for its own sake or because

it is related to more general notions of pattern recognition, information processing, and other perceptual mechanisms.[3]

Map names, unlike words in text, frequently differ from one another on one or more visual dimensions. One would expect this to affect search times in some way, probably in rather complex fashion. The visual displays used for investigating coding dimensions with search times are often very simple, compared to the average reference map. Even then, results are not unambiguous. Eriksen, for example, investigated the effects of four coding dimensions (form, hue, size, and brightness) on the measurement of the amount of time it took to locate the target items. For one group of investigations, the objects on the display differed from one another on only one of the four dimensions; for the other group, the objects differed from one another on three of these dimensions. The visual display consisted of four-inch object cards on a 7×7 matrix. Eriksen was interested in the relation between the discriminability of an object and the number of dimensions on which it differed from the other objects in the field. "For example, in visual perception, can an object be more quickly located if it differs from the other objects in the field in form, brightness, and hue than if it differs only in form?"[4] His results were not such that this could be answered in a perfectly straightforward fashion. "For the single dimension, location time for hue differences was significantly faster than either brightness or size. The location times for the compounds of two or three dimensions were found to correspond to a weighted geometric mean of the single dimension of which they were composed. Compounds involving both the form and size dimensions were an exception due to interaction between these two dimensions."[5]

In another article, Green and Anderson used search time to investigate an aspect of target color coding. They had this to say of the search task in general: "Since almost any visual code can be tested in a visual search task, we suggest that codes can be evaluated in terms of search times. We would expect search times to be sensitive to such factors as the discriminability of coded symbols, the difficulty in learning the code, etc."[6] They conducted two experiments in which search times for colored symbols (two-digit numbers) on a visual display (again a matrix) were measured as a function of the relative number of symbols of each color, and the number of different colors used. They

found that when the subjects knew the color of the target beforehand, the search time for the target was approximately proportional to the number of symbols of the target's color. There was, however, a slight increment in search time due to the presence of the wrong-colored targets. When the subjects did not know the target's color, search time seemed to depend upon the total number of symbols on the display. "However, search times are slightly longer for multi-colored displays than for the comparable single-colored displays."[7]

Williams observed that when a person searches for a target in a cluttered visual field, his eye fixations typically fall on objects. He then studied the effect of target specification on the probability of fixating different classes of objects. "For fields containing objects differing widely in size, color, and shape, a high proportion of searcher's fixations were on objects of a specified size, and a slight proportion of their fixations were on objects of a specified shape. When two or more target characteristics were specified, fixations were generally based on a single characteristic. It is proposed that the specification of a target creates a perceptual structure which the searcher explores. The study of visual fixations, in effect, is the study of perceptual structure."[8]

He discusses this pattern of fixation in more detail, and observes that, "Overtly, search consists of a sequence of fixations which typically fall on objects. The process can be viewed as a sequence of two alternating activities, identification and acquisition. Identification is the classification of the foveally-imaged object as being the target or not (usually it is not). Acquisition is the selection of the new object from the extrafoveal field to fixate and the movement of the eyes to actually fixate that object."[9] This two-fold analysis of the process will be seen later to correspond fairly closely to the focal attentive and pre-attentive stages of visual processing proposed by Neisser and Beller. We stress this in some detail here, for the concern in map type "reading" would seem to be with this type of eye-movement pattern, rather than the more regular fixation-saccade-to-the-right pattern which is used in reading text. Eye movement in more complex visual displays, such as maps, is of a quite different, far less predictable character.

Neisser and his colleagues have used the search task as a basic tool in the development of certain arguments for a system of human pat-

tern recognition (stimulus equivalence). Neisser is, for example, interested in how one perceives a and *a* as "a," though the physical form is greatly different. If a subject is shown a list of letters, and verbally instructed to look for an "a," he will recognize it under greatly different conditions, and he will have to recognize a great many other letters as "not-a" on his way to locating "a." Search time (actually the amount of time it takes to ascertain the non-a configurations) can provide a great deal of information about the information-processing which is going on in this task of pattern recognition.[10]

In a doctoral thesis, Beller used search-time information to test a model of human pattern recognition. The model he proposed consists of two independent sequential stages of processing, pre-attentive and focal attentive. "The former is responsible for isolating and maintaining the *next* object of attention. The latter is responsible for identifying the presented object."[11] He proposed that these two stages would operate upon distinct, independent classes of information, *irrelevant* and *relevant*. "The irrelevant class of information is sufficient to elicit attention but not necessarily sufficient to enable object identification. The relevant class of information is sufficient to enable object identification but not necessarily sufficient to elicit attention."[12]

Beller designed a visual search experiment to test three hypotheses:
1. The time to process an irrelevant item would be less than the time to process a relevant item.
2. While relevant item time might be expected to increase with increased complexity of the stimulus, irrelevant time should not so increase.
3. The time to process an irrelevant item would increase with the difficulty of discriminating irrelevant from relevant items.

The results were in accord with the predictions.

To illustrate the nature of these implications with a concrete example, we can consider the instance of a name on a map. When one is searching through a number of other names on the map, in order to find a target name (that is, the name being looked for), one can process the non-target names so that (a) you know that they are not the name you are looking for, but (b) you could not tell what they actually were.

In other words, there is a preliminary partial processing which

rather quickly provides the information that "this is not the target name," but an actual identification, such as, "this is Greenbog," is a more complete process and takes more time. Further, if half the names on the map being searched were black, and half were red, and the subject knew that the target name would appear in red, red names would be considered "relevant" and black names would be "irrelevant." The time needed to process black names would be less than that needed to process red names; the processing of red names when they were not the target would be less thorough, in turn, than that which would finally produce positive identification of the desired name in red.

An important distinction is made in some near-cartographic research between the two activities, *search* and *recognition*. Nearly all of a 1961 issue of *Human Factors*[13] is concerned with problems of coding information for a map-like display. In general, the research reports do the following things:

(1) Outline some of the display variables relevant to map use analysis.
(2) Analyze and define possible map use tasks in a very specific way.
(3) Find that tasks which may *appear* to be very similar (such as *locate* and *identify*) are actually different, in that they may be differentially affected by coding variables.

The last point is of particular interest here. Hitt[14] was concerned to study the relative effectiveness of selected abstract coding methods, based upon their effects on various operator tasks. Five different coding methods were selected: numeral, letter, geometric shape, color, and configuration. Secondary variables included in this study were: target density, number of code levels, and operator tasks. The operator tasks included identifying, locating, counting, comparing, and verifying. Since the distinction between the first two is not always immediately apparent, an example should serve to make it clear. In an "identify" question, the subject was asked to perform a task which would be equivalent to, "Read off the city which is located in the upper-right hand corner of the map." For "locate" questions, the subject is asked to find a particular place name. "Locate" here is equivalent to "search" as it has been used throughout this paper.

Hitt statistically analyzed the degree of relation between these operator tasks, and concluded: "It is clearly seen from this figure that locating and identifying (or *search* and *recognition*) represent two in-

dependent operator tasks. On the other hand, the verifying, counting, and comparing tasks are loaded on both of these factors."[15] Hitt felt that this was one of the most important findings of the study, for it seemed to explain many seemingly discrepant results in earlier research with coding of visual displays. Further, ". . . it strongly implies that recommendations given to the design engineer concerning the design of visual displays must be based upon knowledge of the tasks involved in the system. Then finally, the identification of basic task factors would help establish a more rigorous framework for future research on visual displays."[16] Such concern with basic task characteristics has frequently been overlooked in much type legibility research, and particularly in the cartographic application of non-cartographic research. It is of fundamental concern in defining a "new" notion of cartographic type legibility.

The selection of the search task for use in assessing cartographic type variation seems both realistic and useful. The search task has been shown to be sensitive to variations in display coding variables; it seems reasonable to assume that it might also be so to the specific variable, typography. One aspect of "legibility" then, would be the speed with which a map can be searched.

The search task was used in research conducted by this author to evaluate selected lettering characteristics on a series of maps. The data so obtained are examined to evaluate the utility of such a task in the formulation of a more general definition of cartographic type legibility. The research is based upon the following assumptions about the use and users of place name reference maps:

(1) Such maps will be approached by a wide variety of users, under greatly varying circumstances.
(2) The majority of these users will most often want to learn where a particular place is by way of location of its name and symbol. In this respect, they have a specific task and goal in mind.
(3) The merit of the map for this purpose may be judged on the basis of (a) whether or not they can find a name they are looking for, and (b) how quickly and easily they can find it.

Aspects of the Search Task: 1. Total Map Versus Individual Names. It must be made clear that even restriction of our investigation to variation in type characteristics and their possible effect on search

time is not sufficient. There are at least two possible kinds of questions to be answered about type usage in this context, and these two kinds of questions could conceivably provide contradictory information. An illustration will clarify this point.

All previous type-reading research has indicated that an exceptionally intricate and conspicuous typeface, as for example Goudy Text, will greatly retard text-reading rates. This might be compared to searching a map with all names set in Goudy Text, where many names must be "read" before the searcher can find the desired target name. We might suspect that Goudy Text would impede the search for one name because all the names on the map will require more processing time. In other words, if all the names on the map are set in the same typeface, the question becomes: What typeface variation can affect the *search time for the entire map*?

On the other hand, if all the names on the map being searched are set in a light sans-serif face, and only the target name is set in Goudy Text, it would seem likely that the target name could be found very quickly since it would tend to stand out from the background. Thus, by choosing the same Goudy Text face, we might make *one name easier to find*. We see that there can be no one answer to the question: What typeface variations will make a map easier to search? We must decide whether we want all names on the map to be of equal "findability," or whether a few selected names should be more "findable."

It follows, then, that in establishing the conditions under which the research discussed here was done, the following two questions were asked:

1. Are there type characteristic variations which might affect search time for an *entire map*?
2. Are there type characteristic variations which might affect search time for *individual names*?

Aspects of the Search Task: 2. Expectation versus Non-Expectation Condition. There was an additional variable (condition) which seemed to be relevant and closely related to an analysis of cartographic type variation, namely, the nature of the attitude of the map searcher. That is, there would seem to be the distinct possibility that expectation[17] might affect the ease or difficulty with which names can be found on

a map. In simple question form, if the searcher expects a name to appear on a map in a *particular* typeface, will this expectation also affect search time? Are there cartographic type variations such that expectation might impede or facilitate search? In this research project, an attitude of expectation was controlled by having the subjects search from two forms of lists. Some subjects searched from typewritten lists (and since the names on the maps are hypothetical, this can be assumed to be a "no expectation" condition); other subjects searched from lists set to match the type in which the name appeared on the map, and they can be assumed to have an expectation about the appearance of the name on the map. Thus we are not only investigating the effect of type characteristic variation on search time, but are also comparing the magnitude of such effects with the magnitude of the effects produced by variation in the searcher's typographic expectation.

Testing was conducted in 1966 with about 300 participating seventh and eighth grade students in Chicago, Illinois, and Lakewood, Ohio. Test instruments, testing conditions, and results obtained will be discussed in a forthcoming article.

1. A summary of this research is contained in Barbara S. Bartz, *Type Variation and the Problem of Cartographic Type Legibility* (Madison: Ph.D. Dissertation, University of Wisconsin, 1969).
2. Barbara S. Bartz, "Type Variation and the Problem of Cartographic Type Legibility," *Journal of Typographic Research*, III (1969), 127–144.
3. Ulric Neisser has used it extensively for this purpose in *Cognitive Psychology* (New York: Appleton-Century-Crofts, 1967).
4. Charles W. Eriksen, "Location of Objects in a Visual Display as a Function of the Number of Dimensions on Which the Objects Differ," *Journal of Experimental Psychology*, LXIV (1956), 23.
5. *Ibid.*, pp. 59–60.
6. Bert F. Green and Lois K. Anderson, "Color Coding in a Visual Search Task," *Journal of Experimental Psychology*, LI (1956), p. 23.
7. *Ibid.*, p. 24.
8. L. G. Williams, "The Effect of Target Specification on Objects Fixated During Visual Search," *Acta Psychologica*, XXVII (1967), p. 355.
9. *Ibid.*, p. 355.

10. Neisser makes this comment about the visual scanning-search technique: "The method of visual scanning was employed in . . . experiments to obtain direct measures of the processing time of human information. The results indicate that the method is reliable, and permit several tentative conclusions about the organization of cognitive processes in the identification of printed letters." (Ulric Neisser, "Decision-Time Without Reaction-Time: Experiments in Visual Scanning," *American Journal of Psychology*, LXXVI (1963), p. 385.

11. Henry K. Beller, *Stages of Processing in Visual Search* (Waltham: Ph.D. Dissertation, Brandeis University, 1968). This quote is from an unpaged "Abstract" portion.

12. *Ibid.*, unpaged.

13. *Human Factors*, III (1961), pp. 86–146.

14. William D. Hitt, "An Evaluation of Five Different Abstract Coding Methods," *Human Factors*, III (1961), pp. 120–130.

15. *Ibid.*, p. 125.

16. *Ibid.*, p. 128.

17. In using the term "expectation" here, we are referring to a very specific expectation of the physical appearance of the type; there is always present a *general* expectation of the letter shapes and the total word "shape," but in this discussion, the use of "expectation" is always limited such that, for example, a subject would know that the target name would occur in bold, black letters of the largest type size, and so on. It is assumed that general expectation would be the same for any one name under all testing conditions.

Response Sheet / October 1969

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