THE MAP -- IN THE MIND'S EYE

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INTRODUCTION

The thematic map seems to be a whole that is more important than the sum of its parts. The major body of research that has been conducted over the past half century, however, has dealt with variables related to a map's elements rather than to the information-carrying capacity of the cartographic device. Quite obviously the study of maps is the study of complexes, structures, interactions, and grammars and the most interesting, and at the same time the most neglected, problem is that of map induction particularly hypothesis formation, learning, and concept attainment on the part of the map reader. Although many cartographic studies have been aimed in the direction of these factors they have usually stopped short of the central point which is that perception basically turns raw and unstructured sensed data into coherent wholes.

We may regard perception as a total process that starts with the sensory input of stimuli by the receptors and continues to some high level cortical cognitive transformation. As it stands today the cartographer's knowledge of map perception (as previously defined) is incomplete and we may positively state that the cartographer is obligated to research this topic in order to develop a viable and accurate basis for understanding the map information-transmission process.

The discussion that follows is drawn from research that I have conducted over the past five years on the application of eye movement recording techniques to cartographic research. Due to limitations of time I will not direct myself to explanations of recording techniques to definition of specific terms.* Rather I would like to spend these few moments discussing the interaction between the map and the map reader as manifested by input-output coordination during visual search.

PERCEPTUAL GENERALIZATION

If we assume that we have a map (M) and a person visually examining that display, then we would like to define viewing or the transfer of information as a mapping (F) of the set M to a set I (being the receptors in the viewers eye) in which the following conditions hold:

* The reader is directed to A.L. Yarbus (Eye Movements and Vision, Plenum Press, New York, 1967, 222p) for a comprehensive discussion of eye movement research.

a) For every element Y in I there is an element X in M such that $F(X) = Y$

b) If X and X' are two different elements of M then $F(X) \neq F(X')$.

These two conditions assert that for each element of I there is at least one element of M which is received, and also that different elements of M are not received by the same element of I (See Figure 1.)

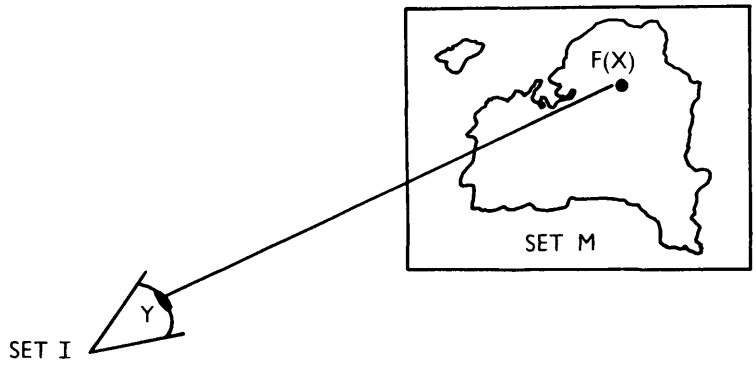

Figure 1. Visual Mapping

Quite obviously this would produce a one-to-one mapping of the visual display and it would be satisfying to know that all of the mapped information was observed by the reader. The human organism, however, operates in such a way as to automatically reduce the information content that it receives. Although it is theoretically possible for the eye to sense up to six million bits of information (a function of the number of visual receptors) the absolute amount of information reaching the brain is reduced because the number of neurons in the visual pathway is significantly smaller than the number of retinal impulses.

This inelegant example is, of course, spurious for several other reasons. First due to spatial variations in the density of the retinal receptor the eye registers only a portion of a scene clearly while the remainder of the display is viewed extrafoveally. As a consequence the reader must foveally attend to specific sections of a display to mentally reconstruct specific aspects of the percept that he is viewing. Acuity, however, is not a steady state as the ability to discriminate objects is some function of the complexity of the display. Although the field of clearest vision can be no broader than physiological limits it apparently does contract under certain circumstances. In any event this feature also necessitates that the reader examine segments of the display in order to perceive the elements of the whole.

The map reader, however, is not a raster scanner or matrix encoder. Rather he attends to selected display items in some sequence. Examine the following illustrations (See Figures 2, 3, and 4.) These are graphic representations of scanpaths for three subjects who viewed the same map. The arrowheads indicate locations at which the subjects fixated long enough to acquire information (250 milliseconds). The point of the arrow is provided to indicate the direction of the scan.

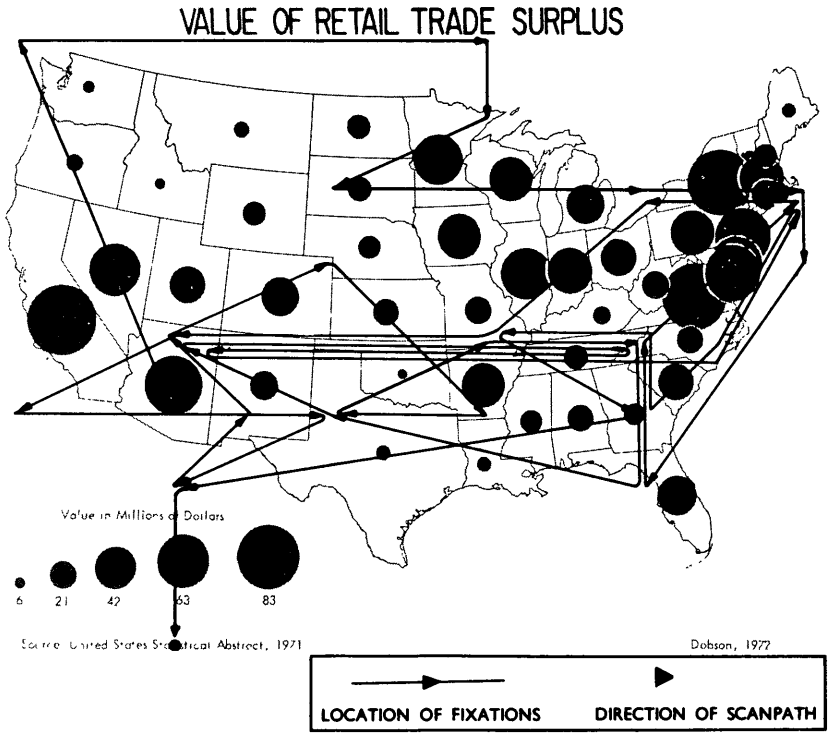

Figure 2. Map Reading: The Sequence of Fixations. This display illustrates the sequence of fixations that one subject used to scan the display. The following two illustrations show scans for two other subjects.

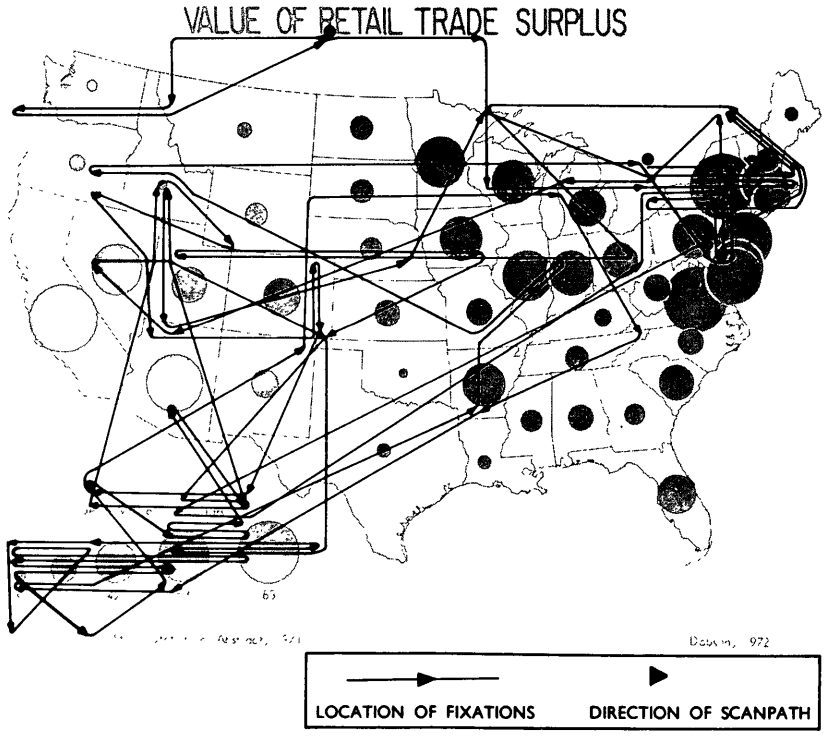

Figure 3

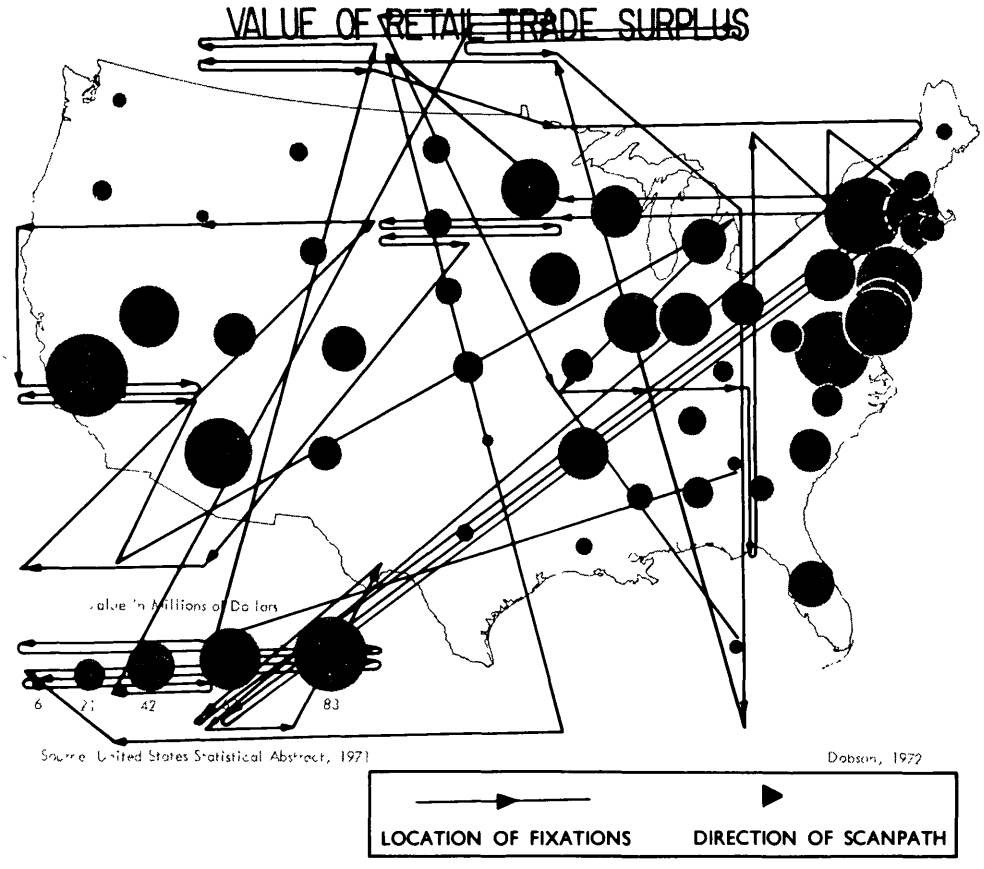

Figure 4

The initial phase of map reading consisted of a brief analysis of the look of the map. Attention was paid to the title, legend, and the data symbolized in the map body. Fundamentally, the initial scans were of a reconnaissance nature. After this exploratory behavior the readers settled down to a more comprehensive investigation of the variations in symbology. The major portions of the search time were spent in the more complex areas of the display. Specifically, those locations where symbol size and spacing were most variable were fixated most often with the eye movement patterns evidencing a strategy of sampling only particular locations on the map information matrix. It is quite obvious from an analysis of these scanpaths that these map readers were not processing the graphic image in the same sequence and also not always processing the same information.

GOAL SPECIFICATION

It is in this sense that we must realize that maps as systems are slaves. That is, they depend on outside sources for goal specification. The cartographer

has a prominent role in goal specification yet we must additionally consider the map reader as a meta-organizer, that is, he determines and orders the priorities or the goals to be perceived. Typically perceptual tasks are those of discrimination, classification, and matching and we must assume that the viewer examines a map in one or all of these contexts. This in turn suggests that map reading is a decision making process during which the reader assigns some internal meaning to the perceptual experience. For instance if an experienced and a naive map reader were examining the exact same location on a display the pattern falling onto their retinal-neural systems is coded into a set of features that are not influenced by memory or any type of prior experience with the display. Thus both the naive and experienced readers have a retinal map of the same features. Once these bits of information are transduced and placed in storage, continued acquisition of pattern which we can call visual search, varies due to cognitive and experiential differences between subjects.

As cartographers we are, to some extent, unaware of the expertise or map reading ability that our prospective audience possesses. We would like to think that we know our audience and have a conceptual grasp of their abilities. Obviously we must accept that whatever population we address the aforementioned cognitive and experiential differences between map readers will stimulate different patterns of visual search. Nevertheless, as cartographers we would hope that our goal in producing the graphic is conveyed to the reader.

SUBJECT EVOKED VARIABILITY IN VISUAL SEARCH

Although we have postulated that the communication of the map message is hindered as a result of differences in goal specification by the map maker and the map reader it is obvious that the three subjects responded similarly to the displays that they viewed. At the same time there were individually oriented minor deviations in all aspects of visual search that were analyzed. Indeed there appears to be a constancy of performance induced by the "look" of the map and simultaneously a variability in performance evoked by the individual reader. The relationship of these two factors is critical since explanation of this interaction can provide an operational theory that can be used to explain the patterns of visual behavior observed in this example.

We must consider search as a multi-faceted process that is composed of two distinct components -- acquisition and identification. Identification is largely an internal process that relates to categorizing the stimulus. Acquisition however is a measurable process that includes the search for and isolation of the stimulus. Acquisition of an object for investigation can be an extrafoveal or foveal process as the reader may examine an object seen clearly in the foveal field or he may be attracted to a distant (extrafoveal) target. This necessitates that a reader must attend to the direct and clear signals of foveal vision and simultaneously consider the "noisy" transmission resulting from peripheral signal acquisition. In essence a viewer must both focus and disperse his attention during a fixation. This indicates that the momentary attention level for a point in central vision may vary, with an ensuing variation in acuity for that point (Schioldborg, 1971).

If there are numerous objects in the visual field we must consider that the subject is unable to totally isolate a target or his attention during visual

fixation. As a result a subject's apperception is dynamic in both spatial and temporal terms. For instance while viewing a target the reader may notice what appears to be an informative object in a peripheral field. In order to overcome the uncertainty about this symbol the subject must foveally examine its location and it is possible that the location may have enough informational inertia to redirect the search procedure of the subject while causing him to devalue or forget his original task. Thus, during the search process goal orientation is a dynamic process. Due to the interactions listed above the sequence of search during map reading cannot be expected to be highly similar. More reasonably, one would expect that the sequence of symbol inspection would be temporally dissonant. Significantly a sequence analysis of twenty subjects' scanpaths provided information leading precisely to this conclusion. Although this line of reasoning may seem unpalatable to the cartographer it does not indicate that the subjects examine different areas of the map, only that there is no common sequence to map reading.

MAP INDUCED CONSTANCY IN VISUAL SEARCH

The information matrix on a graphic display is not, however, examined solely as a function of the attentional properties of the reader. Rather, cartographic and data induced variability such as novelty, complexity, and affective tone combine to provide environmental factors that seduce the uncertainty of the reader and propogate an additional process of attention that can be termed "interest". In this light various portions of the display may attain informativeness as some function of their uniqueness in relationship to adjacent symbolic fields. In a sense, then, we may regard part of the matrix of symbols on the map as informative because they reduce the uncertainty of a specific reader, while we may designate other areas of the display informative to all readers because of characteristics inherent in the symbols themselves (pattern, texture, etc.). Subsequently, the reader interprets the display utilizing a dual search procedure interfacing his goals with those of the cartographer.

We must also consider that a map is a set of meaningfully related stimuli and for any set we can form various meaningful subsets. There appears, however, to be constraints that structure a map reader's patterning attempts. Consequently, the generalization that the reader constructs while examining the map consists of two antagonistic pattern variables -- order and complexity. The map is an entity that has some degree of structure as the result of the orderly relationship of its elements and subelements. These components, however, have multiple relationships with other elements which create a degree of complexity directly related to the order or look of the map. In essence map complexity results from each perceptual unit on the map being a whole with respect to its elements but a part with respect to the display informational environment. As a reader views a map he gradually evolves a pattern representation that has a unified character but at the same time consists of a multiplicity of events.

For the reader the patterns on a map are relatively unstructured or amorphous since the degree of perceptual organization is a function of the variability in context or environment. For instance the displays that were viewed consist of a variety of symbols that can be classified as dominant or recessive display elements. It is obvious that various structural attributes (size, shape, position, chroma, etc.) are so overpowering on a display that there will be dominant elements common to all regional patterning attempts. Due to motivational factors on the part of

the subjects some elements are dominant only at individual levels. The eye movement analysis has shown that some of the perceived patterns follow naturally from the structure of the display due to the visual functional dominance of particular elements while other patterns or sub-patterns tend to reflect motivational dominance integrally related to unique subjects. In this context pattern acquisition on maps may be considered as consisting of a number of invariant choices structurally integrated with individually oriented dominant and recessive symbols.

SUMMARY

The interaction of map-induced constancy and subject evoked variability results in different subjects registering highly covaried fixation patterns although the individual map elements are fixated non-harmoniously in terms of sequence. This, of course, raises the interesting problem of viewing context. Display attributes can be rendered sufficiently dominant so that the cartographer can be sure that the reader will examine the element. It has been my experience, however, that no two readers access a display in the same sequence. Can informational equifinality result from non-harmonious acquisition of the same data items? I believe the answer is yes, but discussion of this topic goes far beyond the time we have available today.

REFERENCE

Schioldborg, Per, "Attention and Visual Identification Time," Scandanavian Journal of Psychology, Vol. 12, 1971, pp. 289-294.