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THE EFFECTIVENESS OF COLOR DOT MAPS
IN REGION PORTRAYAL

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Richard Groop
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THE EFFECTIVENESS OF COLOR DOT MAPS IN REGION PORTRAYAL

By

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ABSTRACT

THE EFFECTIVENESS OF COLOR DOT MAPS
IN REGION PORTRAYAL

By

Jill Patricia Eilertsen

The ability of map readers to perceive regional information on multipattern dot maps which employ color to differentiate distributions, was examined in this study. The color dot mapping technique was compared to the conventional method of single distribution black and white dot maps, evaluating their effectiveness to communicate regions with transitional boundaries. The effectiveness of each mapping technique was assessed in a psychophysical experiment in which subjects drew regional boundaries around perceived areas of distribution homogeneity and mix. Two quantitative measures were employed to compare the responses; (1) the consistency with which subjects located regions within the map, and (2) the accuracy of dot composition within perceived regions. The region drawing responses indicated that the color dot map was slightly more effective in terms of both consistency and accuracy, however the differences were not statistically significant. It was concluded that the color dot map technique is at least as effective as single distribution black and white dot maps.

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CHAPTER I

INTRODUCTION

The concept of the region is central to geographic understanding. Although the definition of the term 'region' has been subjected to continual debate, ... "regions continue to remain one of the most logical and satisfactory ways of organizing geographical information" (Haggett, et al. 1977). In very general terms, a region is an area with characteristics of internal homogeneity within measured or theorized geographic distributions. Regions are defined by boundaries and, therefore, the map is the most suitable and most used description of regions.

Two kinds of regions are frequently portrayed by map makers. The first type are regions with sharp, well-defined boundaries. The division of the United States and Canada into states and provinces for political administrative purposes are familiar examples. Other examples include merchandising districts established across the country by sales companies, or the division of the United States into commercial-financial regions by the Federal Reserve Bank (Figure 1). These types of regions are precisely defined and can be delimited on a map with a single line. Their portrayal causes few problems for the

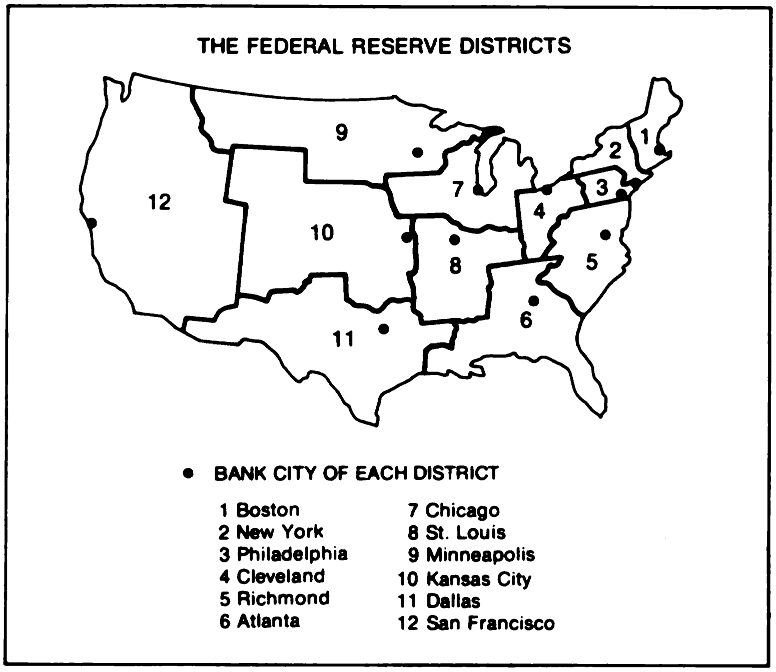


Figure 1. Example of Well-Defined Regional Boundaries. (From Murphey, An Introduction to Geography, 1971)

cartographer.

The second type of region geographers and cartographers must frequently portray are those with transitional boundaries. Regional characteristics of certain geographical distributions change gradually over space between one homogeneous region and another, rather than ending abruptly. The American South and the Corn Belt for example, are regions whose identity depends on characteristics more strongly and unanimously present in central parts of the region than in peripheral areas. The portrayal of these regions which merge in hazy transition zones presents the cartographer with difficult communication problems.

The subject of this research is an empirical examination of the effectiveness of an unconventional thematic mapping technique, multipattern color dot maps, in communicating regional information to the map user. The purpose is to determine whether or not multicolor dot maps offer the cartographer an effective solution to the problem of representing regions with transitional boundaries. This chapter presents a discussion of the development of the research problem, including a review of previous cartographic literature pertaining to color dot maps. Two research questions are introduced relating to the effectiveness of color dot maps in region communication.

Background and Development of the Research Problem

Jenks (1953) states that cartographers frequently rely on mapping techniques which promote misinterpretation of areal relationships on the part of the map reader. One such technique involves the use of bold contrasting lines to represent boundaries which are transitional in nature and, therefore, based upon interpretation. Jenks suggests that these errors result in poor communication of the map message from the map maker to the map reader. While the cartographer who drew the boundary meant it to represent the middle of a much wider zone of transition, the average map reader often misinterprets a line as an abrupt change in regional characteristics.

Comparison of the four maps in Figure 2, borrowed from an introductory geography text, illustrates this

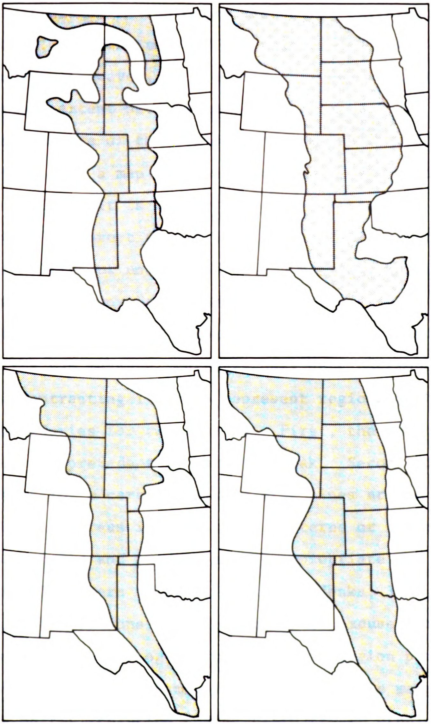


Figure 2. Four Definitions of the Great Plains Region. (From Broek and Webb, A Geography of Mankind, 1973, p.13)

problem in region communication. Each of these maps represents a definition of the Great Plains region, symbolized by a closed, bounding contour and uniform shading within the boundary. However, no two maps fully agree to the area's exact extent because each author has defined the essential feature of the region from a slightly different perspective. If a map user were to view only one of these representations, it is likely he would misinterpret the boundary as an abrupt change in all essential features of the region, without understanding the varying transitional patterns of the many Great Plains characteristics.

Although the method often results in poor communication of the map message, cartographers have continued to use bold contrasting lines to represent regions with transitional boundaries for two reasons. First, the method is accepted, and precedent is hard to break. Second, it is much easier for a cartographer to draw lines around areas and fill these areas in with solid patterns or colors, than it is to compile and produce a more appropriate map by transitional pattern or color blending (Jenks, 1953, p.4). However, these reasons fail to provide an excuse for, or a solution to, this cartographic problem in region portrayal.

The traditional dot map method of thematic mapping offers a partial solution to the cartographic problem of portraying homogeneous regions separated by transition zones. On a simple black and white dot map, spatial data are symbolized by varying numbers of uniform dots, each

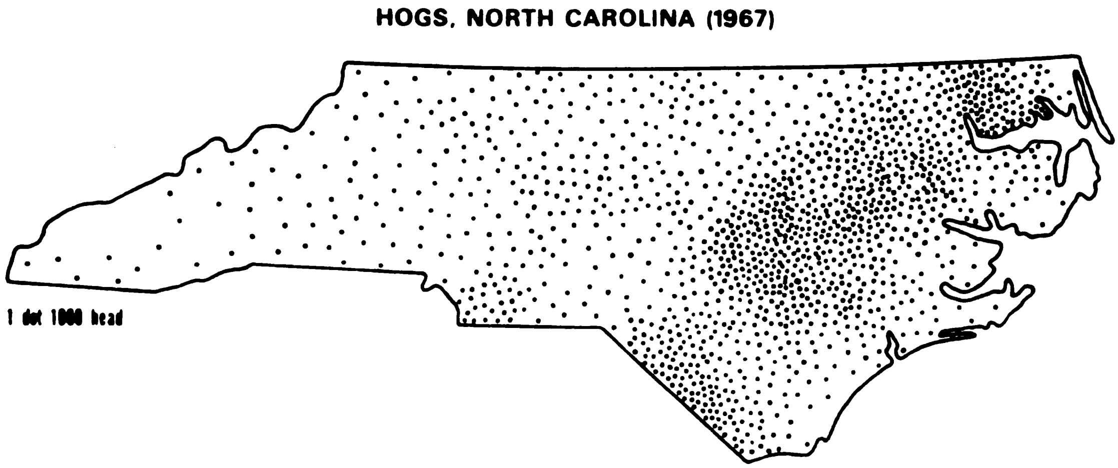


Figure 3. Example of a Conventional Black and White Dot Map. (From Jenks, "Visual Integration in Thematic Mapping - Fact or Fiction", 1973)

representing the same amount of a given phenomenon (Figure 3). The dots are placed as near to the actual location of the phenomenon as the map scale and the detail of the data allows.

While preserving much of the detail of the original spatial distribution, the dot map performs several important comparative functions. A dot map shows the location of individuals and clusters in a distribution, as well as the extent of the phenomenon over space. The approximate range of the phenomenon can be determined by following the outer edge of the dot distribution. Through variations in the spacing between groups of dots, subpatterns can form reflecting the structure of the distribution (Turner, 1977).

In addition, the dot map provides the reader with a visual impression of relative density from place to place. Variations in the dot density over space indicate trends in the rate of change of the distribution in various directions (Robinson, 1978). With a simple dot map, map readers are able to understand the transitional nature of distributions more clearly since the form and extent of the distribution are defined by changes in the 'textural' detail of dot location and density, rather than by sharply defined boundaries. The dot map technique avoids the misleading effects of boundary lines used in regional representations.

A limitation of the simple black and white dot map method of region portrayal, however, is that only one distribution can be shown on each map. This is a disadvantage since, in many instances, it is necessary that the map reader areally compare distributions of a number of related geographic phenomena to fully understand a particular regional concept. By comparing several dot patterns, a map reader may gain a better understanding of why a distribution has the form it does. Although map readers may be partially successful in mentally evaluating the spatial associations between individually mapped dot distributions, it seems probable that the communication of regional patterns and relationships would be improved if individual distributions of related phenomena were recorded in the same map space (Turner, 1977). Results of a study by McCarty and Salisbury (1961) in which the ability of map readers to visually compare isopleth maps was examined, supports this idea. Responses to their psychophysical test indicated that visual comparisons of maps did not provide an effective means of determining the degree of association between individually mapped distributions.

It is possible to represent several distributions on one map if differences in color, size, tone or shape are used to distinguish the various dot patterns. Multipattern dot maps have two potential advantages over single distribution dot maps. First, the multipattern technique reduces the number of individual maps required to portray a regional message. In addition, the method allows the map reader to make judgements about the association of various distributions without having to mentally superimpose them from separate maps. The multipattern dot map is the only statistical mapping technique in which more than two distributions can be overlayed without considerable complexity and clutter (Turner, p.63). However, perceptual and physical limits obviously restrict the cartographer in the number of distributions he can effectively represent on one map.

To date, only a few attempts have been made to experiment with and assess the potential of displaying multiple data sets on a single map using dot-like symbols. Because color and shape are most frequently used to represent nominal differences among point symbols (Robinson, et al, 1978), it is likely that these visual variables would be most effective in representing nominal differences between dot patterns. As a result, cartographic techniques employing color or shape distinctiveness have been the topic of limited research pertaining to multipattern dot maps.

In one such study, Turner (1977) evaluated the role of shape as a variable for distinguishing between point-symbol patterns on black and white maps. Based on psychophysical testing, Turner established a set of three symbol pattern groups from 24 geometric shapes which viewers judged to be maximally different from one another. He recommended that a single symbol could then be selected from each group to distinguish distributions on multipattern dot maps. From these results, Turner attempted to identify any relevant dimensions which might be controlled in order to improve pattern discrimination. Examination of the symbol groups showed that the dimensions of (1) tonal contrast (percent of area inked) and (2) contour variation (complexity) were most important in a symbol's discriminability (Turner, p. 122-3).

To a limited extent, Turner also investigated the degree to which subjects were able to determine the spatial relationship between multiple black and white patterns distinguished by shape. Test subjects were asked to perform a comparison task on target patterns presented alone and later with one and three other symbol patterns. Various combinations of symbol types and pattern densities were tested. The results indicated that people were able to discriminate a target pattern in a mix of up to four distributions differentiated by dissimilar shapes (Turner, p. 186).

In an earlier study, Jenks (1953) experimented with color in an attempt to find a more satisfactory method of blending patterns to represent regions with transitional boundaries. Jenks' work with color was based on the technique of 'pointillism' or juxtapositional color mixture. Color psychologists have demonstrated through experimentation that if a color is broken up into its component parts, and these component colors are presented in small dots, the sensation of the original color will be obtained if the dots are viewed at a distance. In adapting this idea to cartography, separate colors are assigned to each phenomenon mapped on a multipattern dot map. As the mapped distributions of the phenomena change, so does the balance between different colored dots. Ideally, if the color dot map is viewed at a distance, a new distinctive color will be perceived in each map area having its own distributional pattern. Theoretically, juxtapositional mixture of color dots should result in the map readers' perception of larger areal patterns, and provide a possible solution to the cartographic problems of transitional shading and the communication of transitional boundaries.

Jenks experimented with the cartographic application of pointillism by producing a unique map of crops harvested in the United States in 1949. The sample map employed eleven different colors to represent the dot distributions of eleven major crops. Colors were chosen to represent each crop based on three factors. First, colors should remind the map reader of the crop they represent. Second, high value, low acreage crops such as tobacco or truck farming crops, should be a more intense hue than the widely grown crops. Finally, selected minor crops which tend to change the crop character of broader areas should be represented by colors of moderately high intensity (Jenks, 1953, p.5). Table 1 lists the colors which were chosen to represent each major crop.

Table 1

Color Choices for Jenks' Color Dot Map

Yellow - small grains	Brown - peanuts
Orange - corn	Red - tobacco
Tan - sorghum	Purple - fruit
Light green - hay	Black - truck crops
Light blue - cotton	Gray - other crops
Dark green - soybeans	

The map was constructed at a scale of 1:2,500,000 allowing acreages for each crop to be plotted at the county level. Each dot on the map represented 10,000 acres of a harvested crop.

Although Jenks found that his color dot map of crop production demonstrated color blending at various viewing distances, he encountered a number of design and production problems requiring further examination. First, Jenks suggested that the technique might be improved by experimenting with different colors. With his choice of pastel colors for some crops, the loss of color intensity was too great in areas where dots were isolated. Additionally, he suggested the map might be more effective if the number of distributions was reduced from eleven. As is the case with gray tone shadings, there is a perceptual limit to the number of colors that viewers can distinguish in a map reading context. Jenks also believed that the scale of the map was too large, causing extreme detail to distract from the perception of larger areal patterns. Finally, Jenks' greatest criticism of the map resulted from problems in the printing process. The technique requires extremely accurate registration, especially if four-color process printing is used. Poor registration was a problem on the crop map, as well as a lack of consistency in the hues and values of the printed colors.

Despite these design and production problems involving color selection, scaling, and difficulties with the printing process, Jenks recommended further experimentation with the color dot map technique because it fulfils several different needs of the map reader. Color dot maps provide excellent detail about distributions when viewed close enough so individual dots are clearly visible. Transitions between distributions are also accurately rendered by changing balances of dots, portraying the larger areal pattern and offering a possible solution to the problem of representing regions with transitional boundaries. It was Jenks' belief that, "the technique could do much to improve the map user's understanding of both interpretative boundaries and the transitional nature of many distributions" (Jenks, 1953, p.5).

In the 27 years since Jenks completed his initial research and recommendations, multipattern color dot maps have received minimal attention in cartographic literature. While this technique may offer a possible solution to the problem of region portrayal, to date it has not been evaluated experimentally to determine whether it is an effective solution. The true value of the color dot map as a communication device will only be realized after potential color problems and region perception problems are studied.

Among the major color problems involved in multipattern dot maps is that of color selection. Thomas (1955) suggested that color dot maps may result in faulty visual impressions if three requirements necessary to maintain the proper relationships, or 'balance', between hues, value and chroma are not fulfilled. The requirements are: (1) each color must be distinctive (different in hue) and therefore easily differentiated from surrounding colors; (2) contrast between each color and the background must be equal (identical value); and (3) all colors must be equally vivid (equal chroma) so that no color covering an area of the map can overpower other colors covering an equal area. As many as five colors can be selected with essentially the same visual impact for use on a color dot map. Thomas recommended the use of red, yellow, green, blue and purple hues, each with a value and chroma of 50 percent. He conducted an experiment with fifteen college students which indicated that these colors were balanced and met his requirements for use on multicolor dot maps. However, his precise recommendations have yet to be evaluated in a map context.

Potential region perception problems must also be considered with respect to the effectiveness of color dot maps. It is important to determine whether map readers are capable of seeing regions by recognizing variations in the balance of different colored dots across the map, and whether the maps communicate the transitional nature of distributions to the reader. In addition, if it is found that map readers do see regions, how consistent as a group are their perceptions, and do their perceptions correspond to the intent of the map message?

Problem Statement

This study examines the ability of map readers to perceive regions on multipattern dot maps which employ color to differentiate distributions. The innovative color dot mapping technique is compared to the conventional method of black and white single distribution dot maps, evaluating their effectiveness to communicate regional information, and the transitional nature of geographic distributions, to the map user. Psychophysical testing techniques are employed to measure and evaluate communication effectiveness.

The examination of the mapping techniques focuses on two questions:

(1) Does the average map reader see regions of homogeneity better with single distribution black and white dot maps, or with one multipattern color dot map?

(2) With which of the two mapping techniques, black and white or color dot maps, does the average map reader more easily see regions of mix, or transition?

Measures of consistency and accuracy in regional perceptions are employed to evaluate the effectiveness of the two mapping techniques.

Previous literature by Jenks (1953) and Turner (1977) suggests that map readers are likely to be more consistent and accurate in perceiving regional information with multipattern dot maps. Their reasoning is based on the fact that with multipattern maps the reader can make spatial associations without having to mentally superimpose different dot distributions from separate maps. By addressing these two research questions in a psychophysical testing experiment, it is hoped to determine, if in fact, color dot maps are a more effective method of region communication than the conventional black and white dot map.

CHAPTER II

EXPERIMENTAL DESIGN AND METHODOLOGY

Introduction

A number of different psychophysical testing procedures are possible, however, many of these are not fully understood and, therefore, have been misinterpreted and used inappropriately by cartographers. McCleary (1975) believes that in many recent examples of cartographic research the investigators have begun by asking the wrong questions. He cites faulty procedures in a number of psychophysical experiments dealing with the establishment of gray scale curves and the study of graduated symbol size. The message of McCleary's discussion is that questions asked in test tasks should not parallel the cartographer's method for choosing or producing a symbol, but rather match what the user will do when he confronts the map. In other words, an experiment should be structured to approximate the map using situation with consideration given to the intent of the map message. In terms of region perception, this is a demanding requirement (Lavin, 1979, p.143).

Thematic maps are designed to communicate two general classes of information to the map reader. The first is tabular information which can be extracted, fact by fact, from individual map symbols. The second class of information which can be transferred is the integrative type. This information is not gained by examining individual symbols, but rather from a combining process wherein symbols are merged into fields to form patterns or regions (Jenks, 1973, p.27).

The majority of psychophysical studies in cartography to date have examined the physical properties of individual symbols and the effects of individual symbols on map reading tasks, usually involving the transmission of tabular data. Very little research has been done to examine the perception of patterns on maps and the transmission of integrative data. This research gap is a serious one since the primary use of thematic maps is to illustrate integrative or regional patterns and distributions to the map reader.

One reason for this inequity in psychophysical cartographic research is suggested by Lavin (1979) in his examination of region perception variability on choropleth maps. He states that, "...unlike the case of symbol properties, the cartographer frequently has no clear vision of the distributional message he wishes to communicate" (Lavin, p.144). Without a precise definition of the intended map message, the relationship between the information extended, and that actually received by the viewer, cannot be examined in total.

The presentation and perception of regional information on maps is a prime example of this problem. Until cartographers can identify precise definitions of the regions they wish to portray, studies concerning the region communication process must be restricted to an analysis of perceptions of the map user. Such an analysis might involve how the map user's perceptions relate to the stimulus (in this study, black and white or color dot maps); and how his perceptions compare with those of other map users (region perception variability) (Lavin, p.145).

Based upon the recommendations of McCleary (1975), psychophysical experiments which are a part of region communication studies should be designed to approximate the region perception experience. Since... "it is assumed that the perception of regions involves the establishment of lines of demarcation between mapped areas which are somehow seen as being internally homogeneous, an appropriate experimental task is to request that the map user physically reproduce those boundary lines on maps presented to him" (Lavin, p.145). In the present study, test subjects were asked to draw boundary lines around specified areas of distributional purity and mix within dot patterns. This testing technique assumed a direct link between the regions subjects form mentally, and their ability to reproduce these mental constructs.

Region drawing has been used as an experimental task by a few cartographers. In an attempt to increase cartographic understanding about different forms of map generalization, Jenks (1973) examined subject consistency in outlining areas of high, medium and low density on a dot map (Figure 4). Although the responses were highly varied, he found each to be a logical generalization of the test map. McCleary (1975) also asked subjects to separate differences in dot density in a regionalization experiment. Two styles of region drawing emerged in his test responses, and are referred to as the 'atomist' and the 'generalist'. The atomist is obsessed with great detail,regardless of the overall pattern of density, while the generalist is concerned with portraying major regional trends. Region drawing was also employed by Lavin (1979) to determine the effect pattern complexity of a choropleth map has on regional perceptions. Results indicated that a direct relationship existed between perception variability and pattern complexity. The design and implementation of the color dot map experiment was fashioned after testing methodologies employed in these studies.

Design of the Experimental Maps

In order to make the evaluation of the color dot map technique directly applicable to common cartographic assignments involving region portrayal, real world data were used to construct the test maps. Because religious distributions are representative of the complex patterns cartographers must often portray, data from a recent survey of

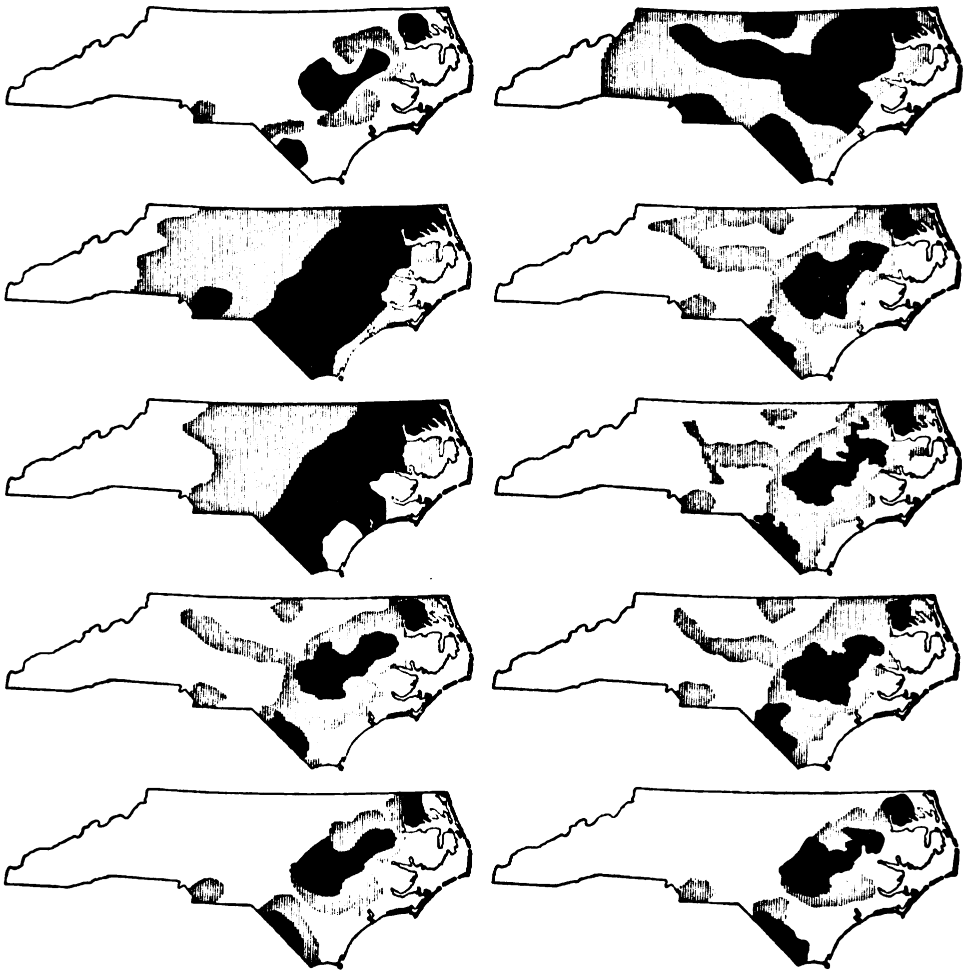


Figure 4. Examples of Region Drawing Responses. These ten very different generalizations of a dot map were created by students who were asked to subdivide the map into areas of high, medium and low density. (From Jenks, "Visual Integration in Thematic Mapping - Fact or Fiction", 1973)

church membership in the United States (Johnson, et al. 1974) were chosen to produce the experimental test maps. The survey was administered by the Glenmary Research Center on a county level in 1971. Over 50 religious denominations were included in the study.

The three-state area of Indiana, Ohio and Kentucky was selected as the geographic base for the test maps due to a number of factors. First, examination of the county membership statistics in these states showed that three dominant religious affiliations exist: the Catholic Church, the United Methodist Church, and the Southern Baptist Convention. This was a practical number of distributions to represent on a multipattern color dot map given perceptual limitations and color production costs. In addition, it seemed reasonable to ask test subjects to mentally compare three separate black and white dot distributions. A second reason for selecting this geographic area was that the dominant religious distributions have characteristics of all three theoretical classes of point symbols: clustered, random and uniform. Finally, within Indiana, Ohio and Kentucky, the three distributions have areas of relative purity, and also areas which are highly mixed between two or three of the religions.

Only the religious affiliations of the rural population in the three-state area were mapped for practical purposes. The smaller range in data values among the rural population was more suited for representation on a dot map than the dramatic value changes over space for the total population. Had the urban population been included, the resulting maps would either have had hundreds of overlapping symbols around the urban areas (use of a small dot value) or very few dots in sparsely settled areas (use of a large dot value). The numbers of rural members were calculated by multiplying the percent rural population (City and County Data Book, 1977) with the total number of adherants belonging to each religious group for every county. This data manipulation technique assumed that within the counties, the religious distributions were the same for both the urban and rural populations.

Two sets of test maps were produced from the religious data for use in the region drawing experiment. The first set consisted of three black and white dot maps, one map of each of the three dominant religions in Indiana, Ohio and Kentucky (Figures 5a, 5b and 5c). The second consisted of a single multipattern dot map portraying the same three religious distributions, each distinguished by a different color (Figure 6). The Catholics were mapped with blue dots, the United Methodists with red dots, and the Southern Baptists with green dots. To ensure direct comparability between the black and white maps and the color dot map, consistency in scale, dot size, dot value, and exact dot placement was maintained. All maps were constructed within an 8½" x 11" page format, using dots of .05" diameter for each 1000 church members. In addition, no dots were allowed to

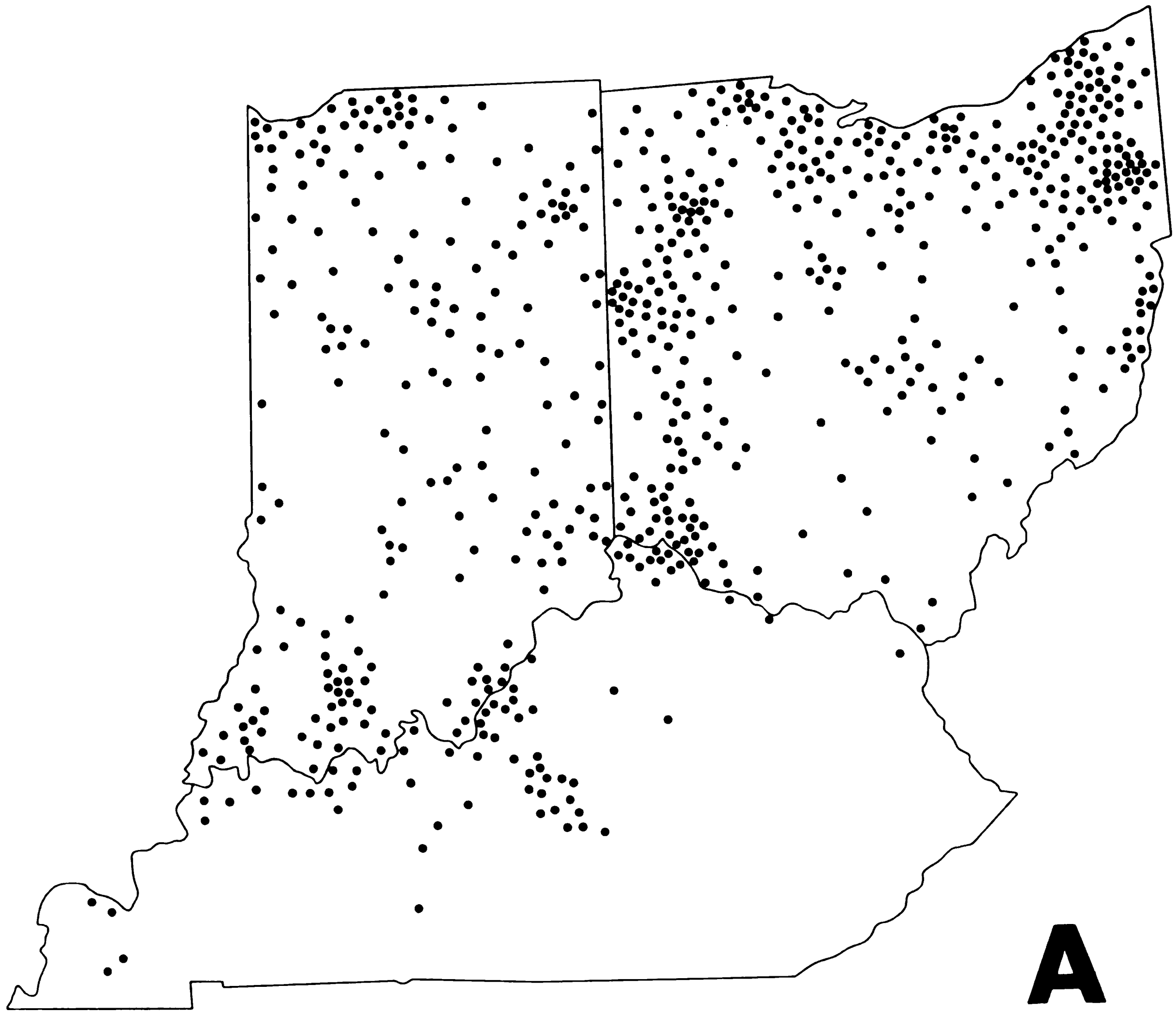
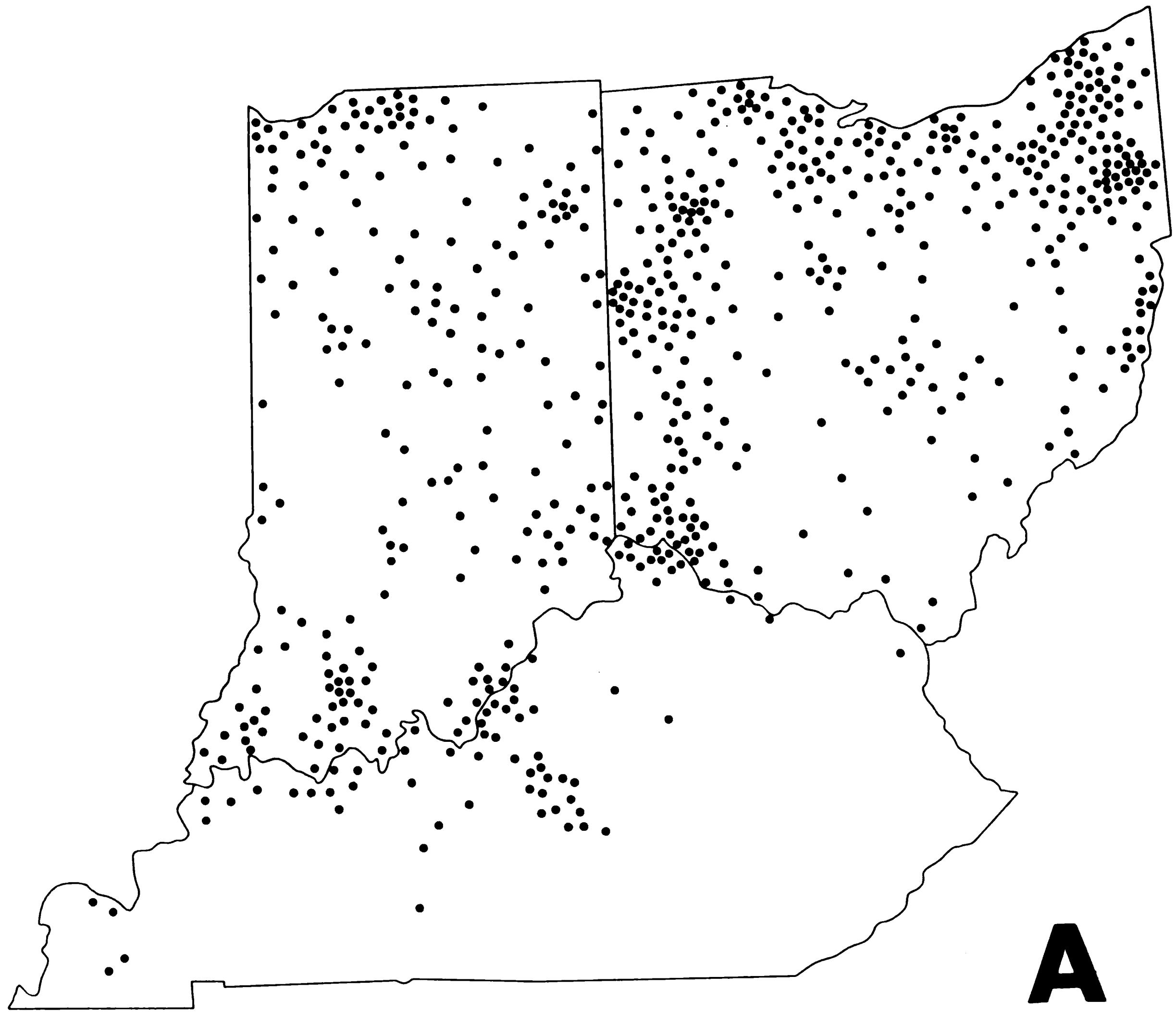


Figure 5a. Black and White Test Maps. Note: All test maps (with exception of the color map) are reproduced here at 90 percent of the originals.



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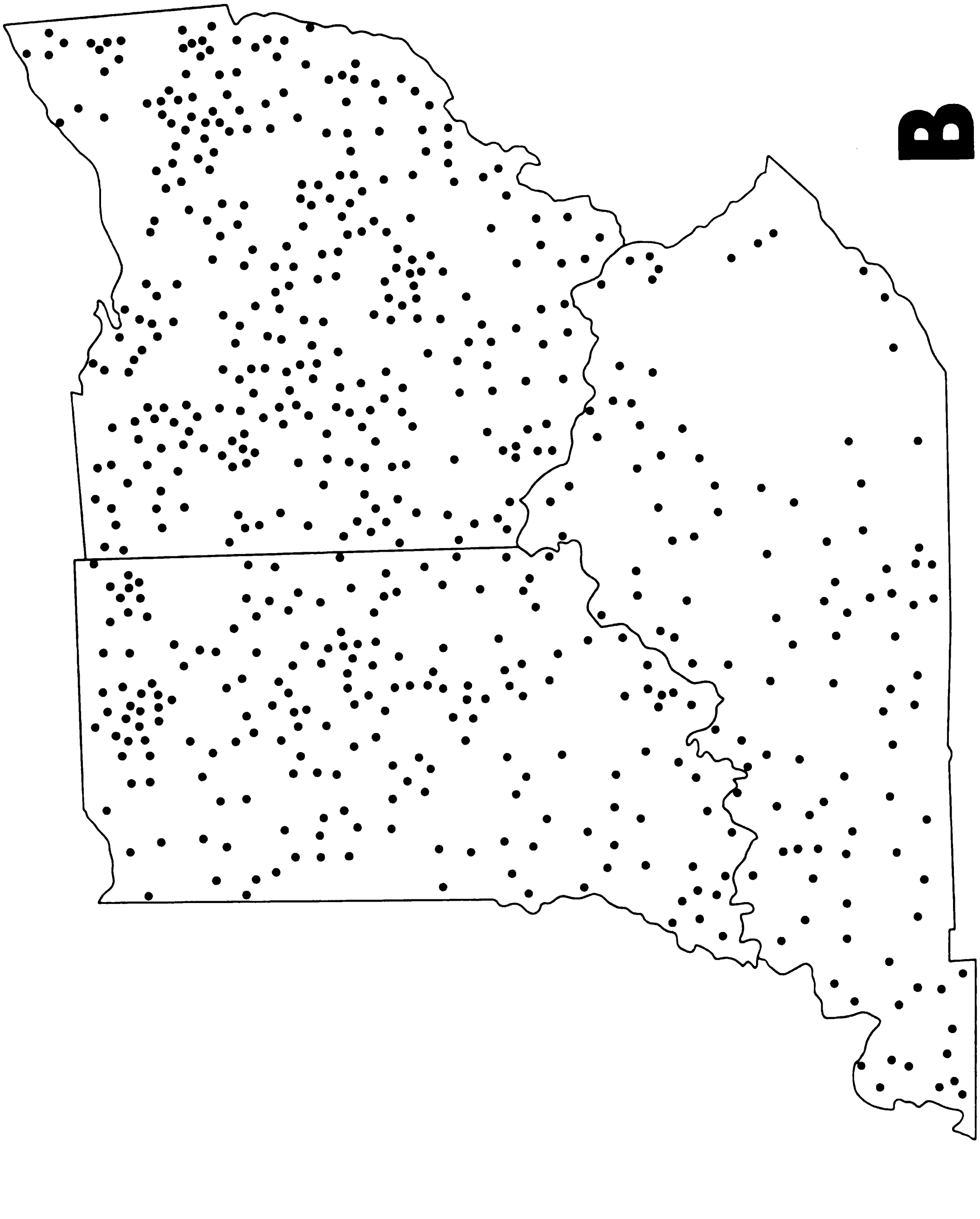


Figure 5b. Black and White Test Maps.

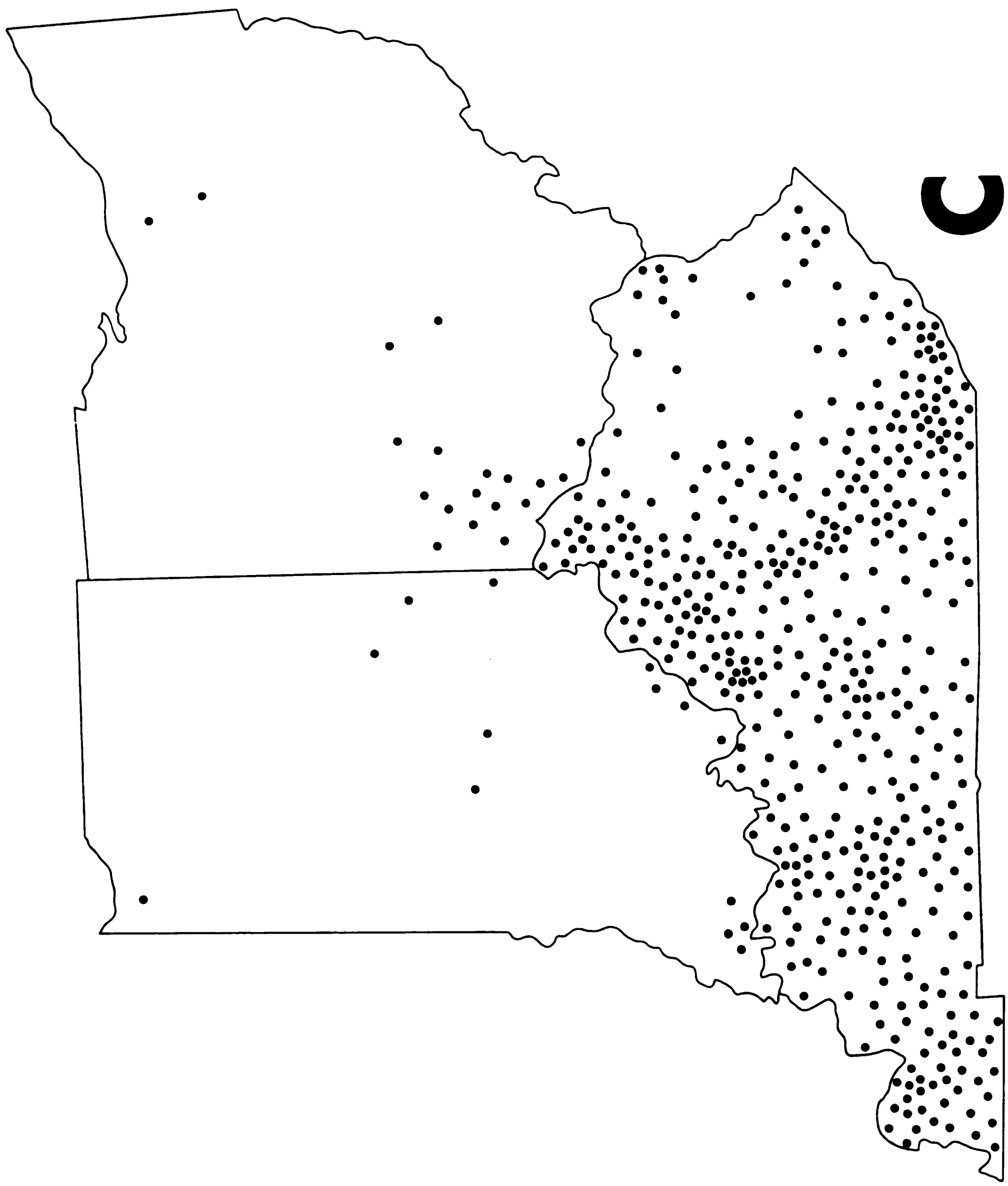


Figure 5c. Black and White Test Maps.

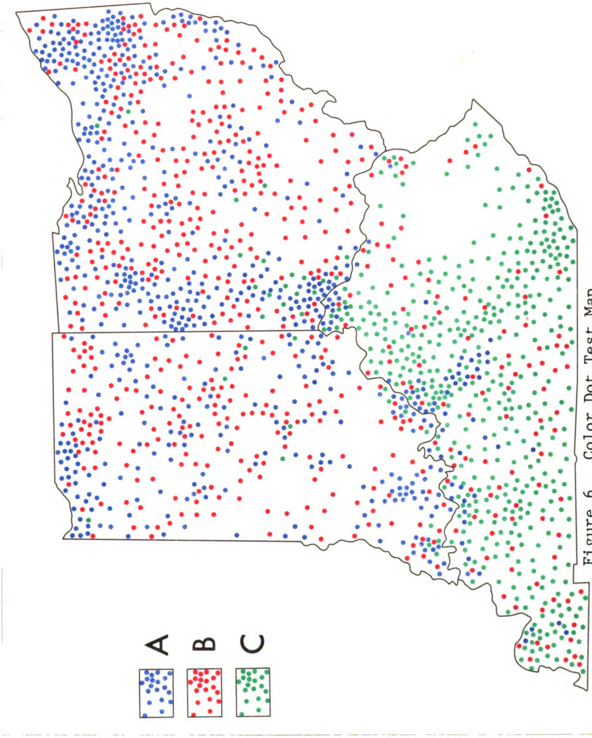


Figure 6. Color Dot Test Map.

overlap between the three distributions in order to maintain distinct colors on the multipattern map.

Map titles and legends identifying the three religious distributions were eliminated to avoid any bias in region perception responses on the part of the test subjects. Had the distributions been explained, it is possible that previously formed concepts about the religions might have influenced the test results. Instead, each distribution was identified by an upper case letter. On the black and white maps the letters were placed in the lower right-hand corner. The color dot map included a simple legend consisting of three boxes, each containing the same random pattern of dots in a different color. The blue dots representing the Catholics were identified by the letter 'A', the red dots showing the United Methodists by a 'B', and the green dots showing the Southern Baptists by a 'C'. The same letters were used to distinguish the distributions on the black and white maps.

In order to avoid many of the registration problems encountered by Jenks on his color dot map of crop production, flat color printing was used to reproduce the color test maps rather than four-color process printing. Process printing uses four specific colors -- yellow, magenta, cyan and black -- to produce a full range of colors by overprinting. When printed, the four process colors appear as dots of solid color which combine in various sizes and patterns to duplicate the desired colors. The colors are not created by physically mixing inks, but by the optical mixing of the four process colors by the viewer's eyes (Craig, 1974). If perfect registration is not maintained in printing color dot maps, the process colors will not meet exactly around the dot edges leaving a halo effect. This problem can be avoided by using flat color printing wherein inks are mixed to match the map designer's color choices. However, a cost comparison should be considered. Because each color used in flat color printing requires a separate printing plate and a separate run on the press, the more colors used, the more expensive the job. As a result, since process printing requires a maximum of four press runs, it is best to print a color dot map of four colors or less (representation of two or three distributions, and black) with flat color. If more than four colors are needed, the cartographer must compromise either quality or cost in choosing the printing method.

Color selections for the multipattern dot map were based on suggestions made by Thomas (1955), and on cost limitations imposed by the flat color printing process. Three distinct hues, blue, red and green, were chosen from Thomas' recommendations, but his value and chroma guidelines could not be followed exactly due to cost considerations. Printing costs were reduced by choosing commonly used ink tones which were in stock and did not have to be specially mixed. However, these tones did give the appearance of being equally vivid and equally distinct from the white background as Thomas advised. Exact color selections are listed in Table 2.

Table 2

Color Choices for the Color Dot Test Map

Distribution	Religion	Color
A	Catholics	Pantone Blue #293U
B	United Methodists	Pantone Red #185U
C	Southern Baptists	Pantone Green #347U

Testing Methodology

Task Design

Two test instruments were used in the psychophysical test design. The black and white version consisted of a set of numbered, step-by-step instructions to complete the test task; three separate black and white dot maps of the religious distributions, Maps A, B, and C; and two black and white maps of the combined dot distributions for recording purposes, Maps T and X (Figures 7a and 7b). The second test instrument, or color version, was similar. It consisted of a set of numbered instructions; a single multicolor dot map of the three religious distributions; and the same two black and white maps of the combined dot distributions, Maps T and X. The directions accompanying each test instrument were almost identical. The only difference was in the identification of the test pieces.

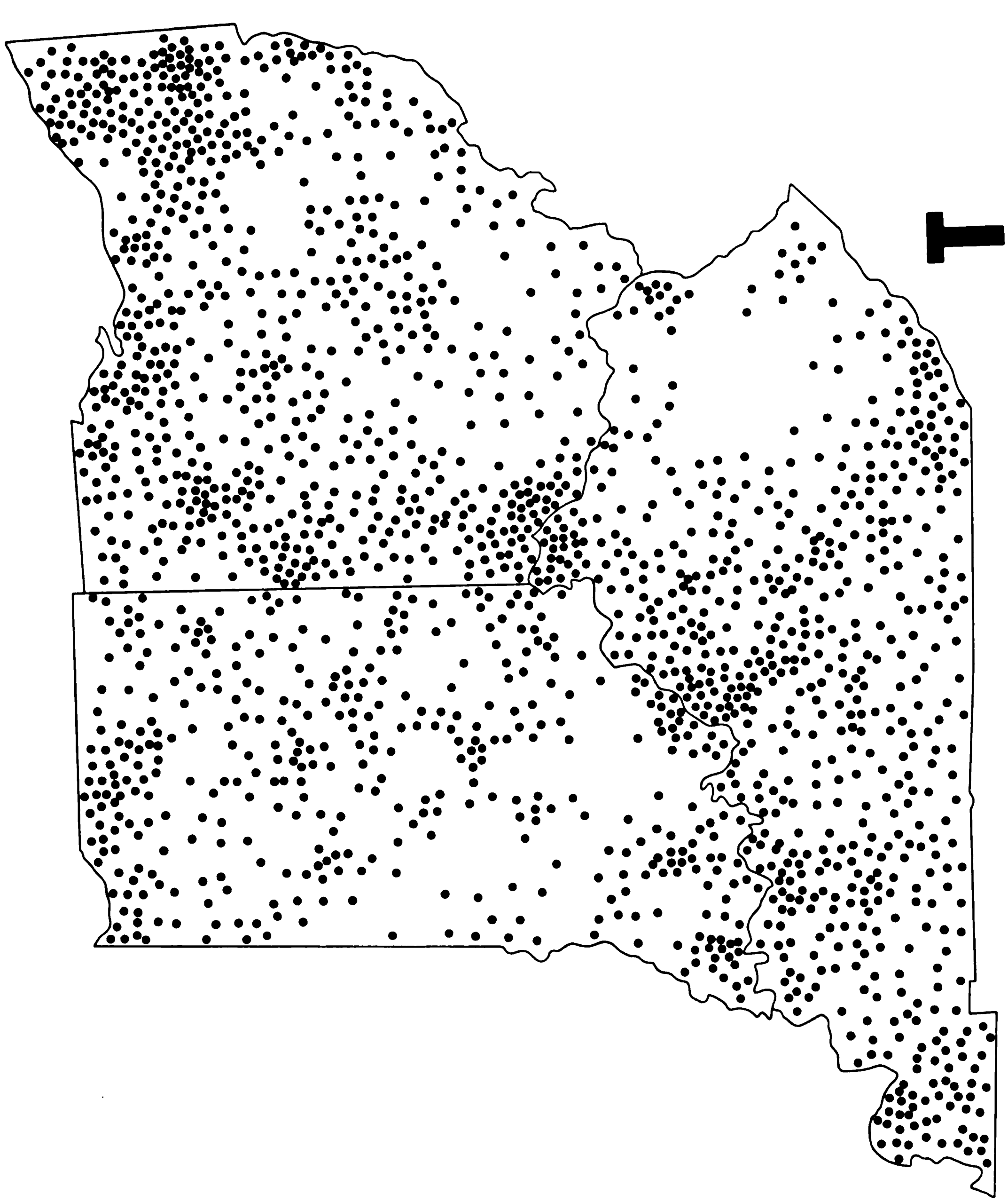


Figure 7a. Black and White Maps of the Combined Dot Distributions.

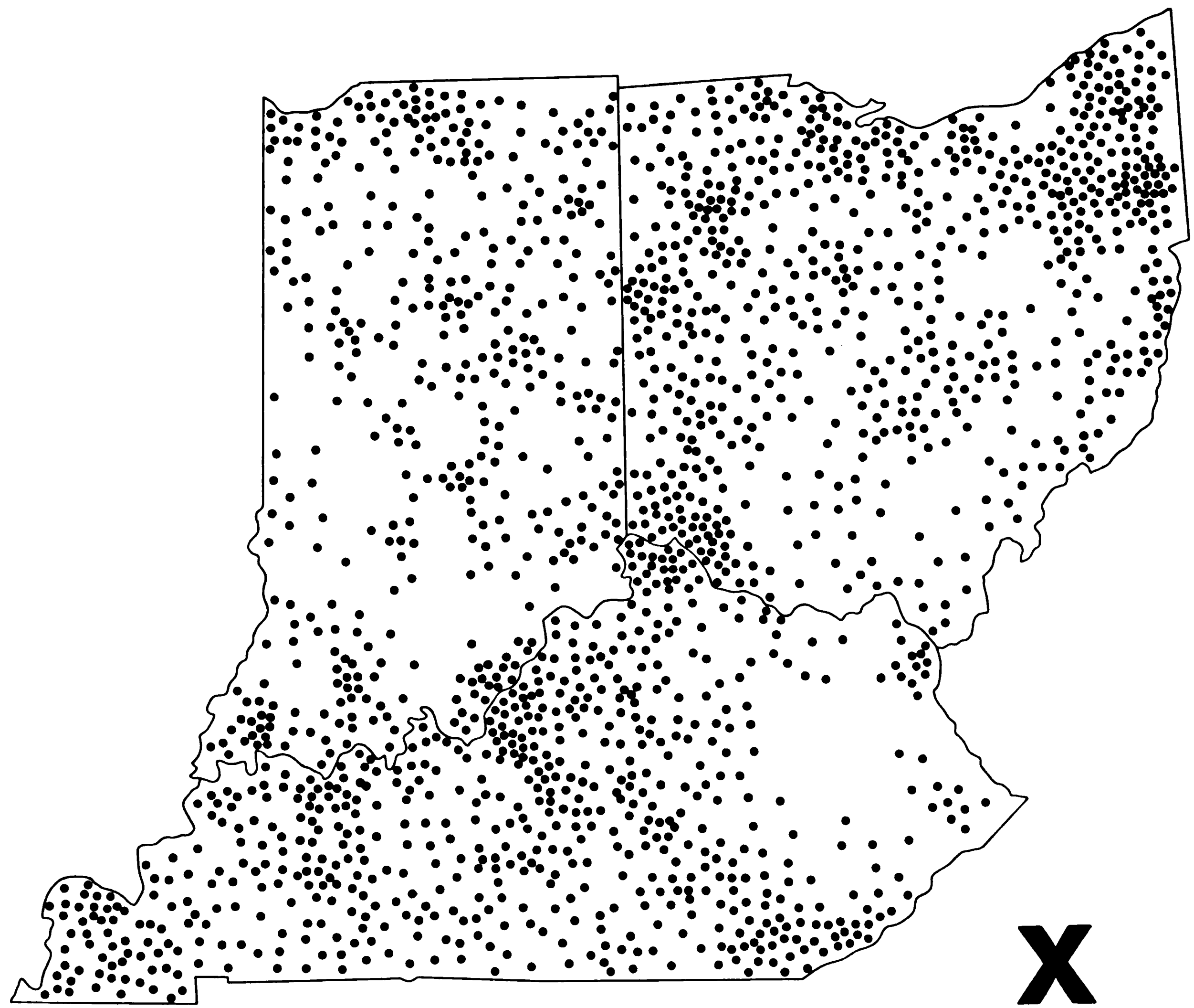


Figure 7b. Black and White Maps of the Combined Dot Distributions.

There was no difference in the regions the subjects were asked to draw for either test version (Appendix A).

The written instructions were very detailed to eliminate as many misinterpretations and incomplete responses by test subjects as possible. First, subjects were asked to look at, and compare the three distributions A, B and C. For those subjects taking the black and white version of the test, this meant mentally superimposing the distributions from separate maps. Next, using the black and white maps, or the color dot distributions as general references, the subjects were asked to draw lines around areas they saw as predominantly homogeneous on a black and white map of the combined dot distributions (Map T). For example, first they were asked to outline and label areas which they perceived as predominantly distribution A, then distribution B, and finally distribution C (Figure 8). On the second map of the combined dot distributions (Map X), subjects were instructed to draw boundaries around areas which they perceived as predominantly mixed, for example, a combination of distributions AB, AC, BC or ABC (Figure 9). Upon completion of the region drawing task, test subjects were presented two multiple choice questions. The first rated the difficulty of identifying regions on the test maps. The second question asked which type of region was easiest to see.

Subjects were instructed to draw their regional boundaries on the black and white maps of the combined dot

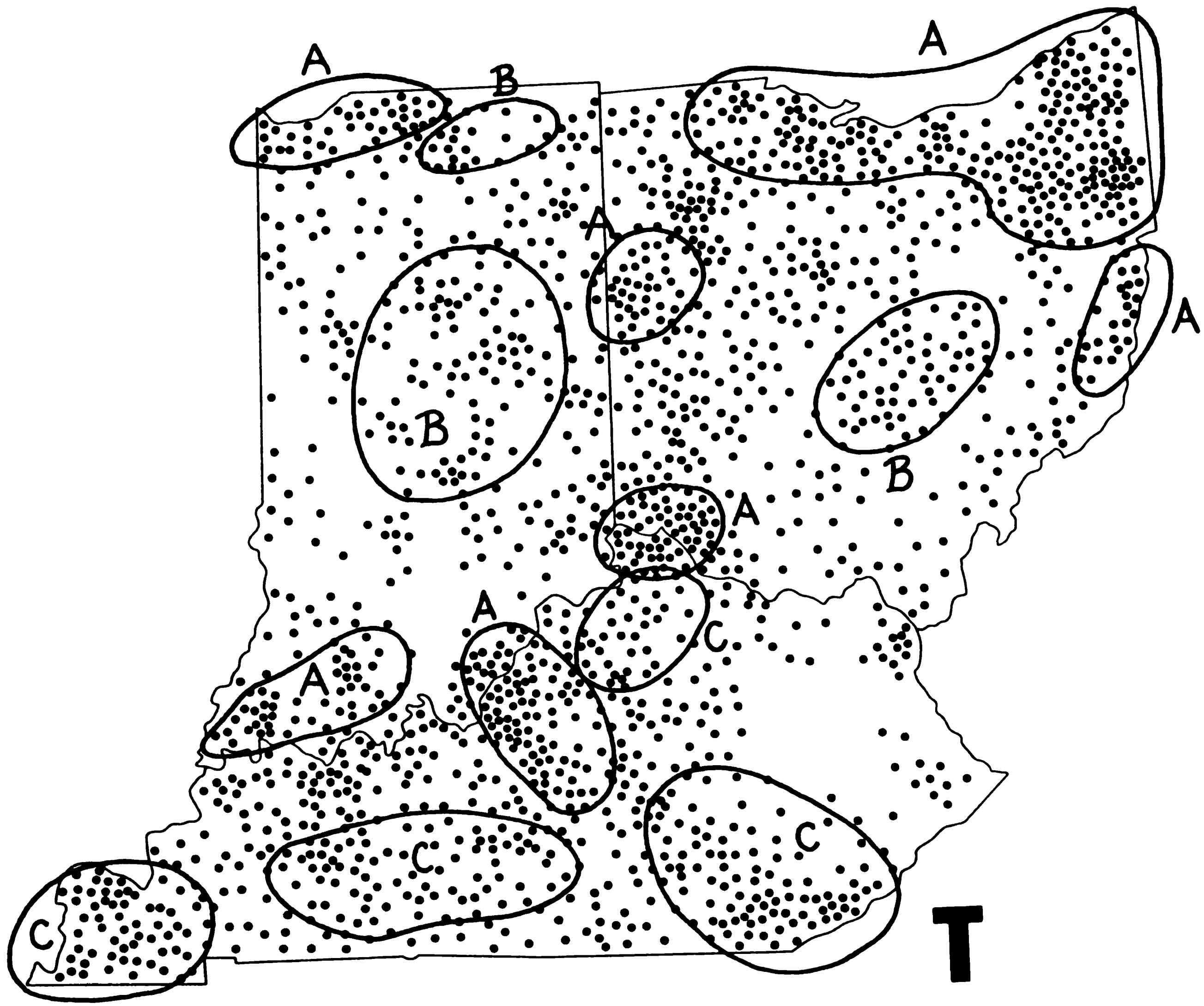


Figure 8. Sample Response of Perceived Homogeneous Regions.

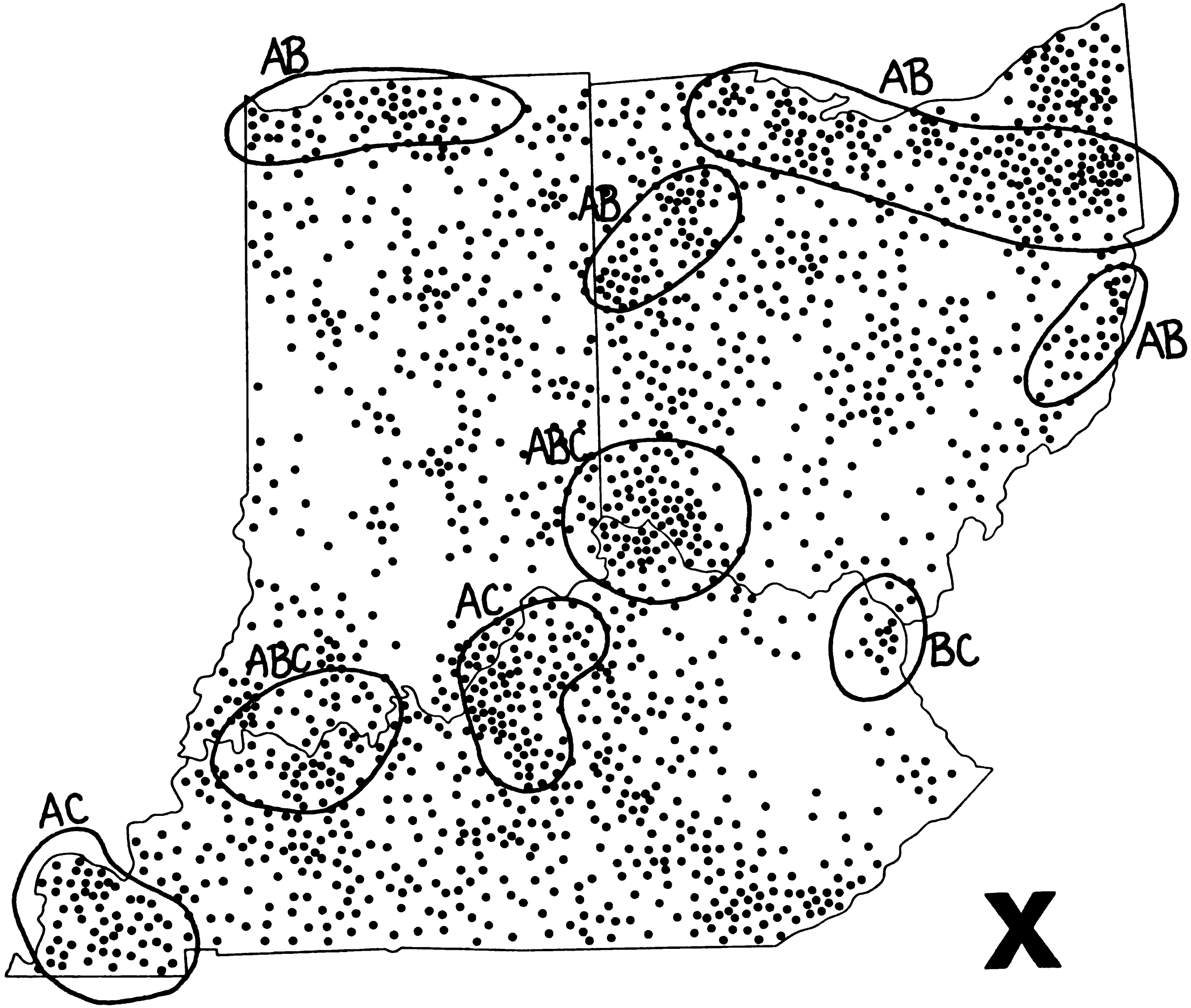


Figure 9. Sample Response of Perceived Mixed Regions.

distributions, rather than on the test maps, so responses from the two test instruments would be directly comparable. The reason for this decision was that subjects viewing the black and white maps had to mentally superimpose the separate dot distributions to compare them. Had the boundary lines been reproduced directly on one of the black and white test maps, error derived from mentally relocating the other distributions onto that map, and drawing regions based on those mental relocations, would have biased the comparison of the conventional and color dot mapping techniques. Error caused by mental relocation of distributions would not have occurred had lines been drawn directly on the color dot map because the distributions were all located and distinguished on the one map. By drawing all regions on the maps of the combined dot distributions, error due to the relocation of distributions and perceived regions, and that caused by subject ability to draw these regions, was similar for both test instruments. Therefore, it was assumed that response variation between the test instruments would be due to differences in the effectiveness of the two mapping techniques as regional communication devices, and not caused by the experimental test design.

A small preliminary test with eight subjects was conducted to determine whether the region drawing experiment was reasonable in terms of difficulty and the average time required to complete the test task. The pre-test was also used to determine if the types of responses which would result would be appropriate for evaluation of the proposed research questions. It was found that subjects had little difficulty understanding the instructions, and in most cases were able to complete the experiment within 10 to 15 minutes. Examination of a number of responses indicated that the interior state boundaries might have influenced region drawing. However, pre-test subjects advised that the boundaries be included because they served as necessary reference lines during mental comparisons of the dot distributions.

Test Administration

Each test instrument was administered to a separate group of 43 graduate and undergraduate students enrolled in geography laboratory courses at Michigan State University. None of the subjects dealt with both the black and white dot maps and the color dot map. The tests were conducted under normal viewing conditions in small laboratory classes where subjects had room to spread the maps out for visual comparison. No previous map reading experience was required of the subjects.

A brief oral introduction was given to each group of subjects before distributing the test instruments. The introduction included a short description of dots maps and their uses, and an explanation of the purpose of the experiment. The importance of reading the instructions carefully, and following the numbered instructions step-by-step was stressed to the subjects, as well as the fact they could make changes in their boundaries if they wished. Subjects were also advised that they were working under no time constraints. It was felt that a time limit represented an unrealistic map reading situation. Finally, colorblind subjects were asked to identify themselves as the tests were being distributed so they could be given the black and white test version.

Upon completion of the region drawing experiment, tests with incomplete responses, and those in which the instructions were not followed, were discarded. Five tests were eliminated from the black and white group leaving a total of 38 responses, while three were discarded from the color group resulting in 40 responses.

CHAPTER III

DATA ANALYSIS

Introduction

The general problem in this research was to determine which technique of dot mapping, single distribution black and white maps or multipattern color dot maps, was more effective in communicating regional information to the average map user. Two quantitative measures of regions drawn by test subjects were employed to compare the communication effectiveness of the mapping techniques. The first was the consistency with which regions were located within the map. The second was the accuracy of dot composition within the regions. These measures are examined in detail in this chapter.

Consistency within the Map

Data were collected from the response maps as frequencies in the following manner. First, a quarter-inch grid was placed over all test responses. This size format was chosen so the grid cells would be smaller than the smallest regions identified by test subjects. The grid was registered in the same position over all responses. Next, a frequency count was compiled for each grid cell within the map (444 total cells) indicating the number of subjects who placed the cell in a particular region. A cell was considered as part of a region if more than half of its area fell inside the boundary line. These frequencies were referred to as consensual response maps (Lavin, 1979, p.161). Fourteen separate consensual response maps were compiled, one for each of the seven classes of regions drawn by subjects (A, B, C, AB, AC, BC and ABC) for both the black and white, and color test maps. Figure 10 illustrates the consensual response map of region A compiled from responses of 40 subjects viewing the color dot map. On this map, large frequency values near 40 indicate that nearly all subjects included the cells within an 'A' region. Cell values near zero show that subjects agreed that the cells were not part of an 'A' region. Disagreement in regional perception is indicated by frequency values in the mid-range near 20. In these cases, approximately half of the subjects saw the cell as part of an 'A' region, while the others did not.

Measures of the consistency of region location within the map were determined by individually calculating the statistical variance of the frequencies compiled on consensual response maps for each region type. Normally, variance is considered as an indicator of variability. However, in this study, it is important to understand that variance has an unusual relationship to region drawing. High variance indicates low region perception variability and,

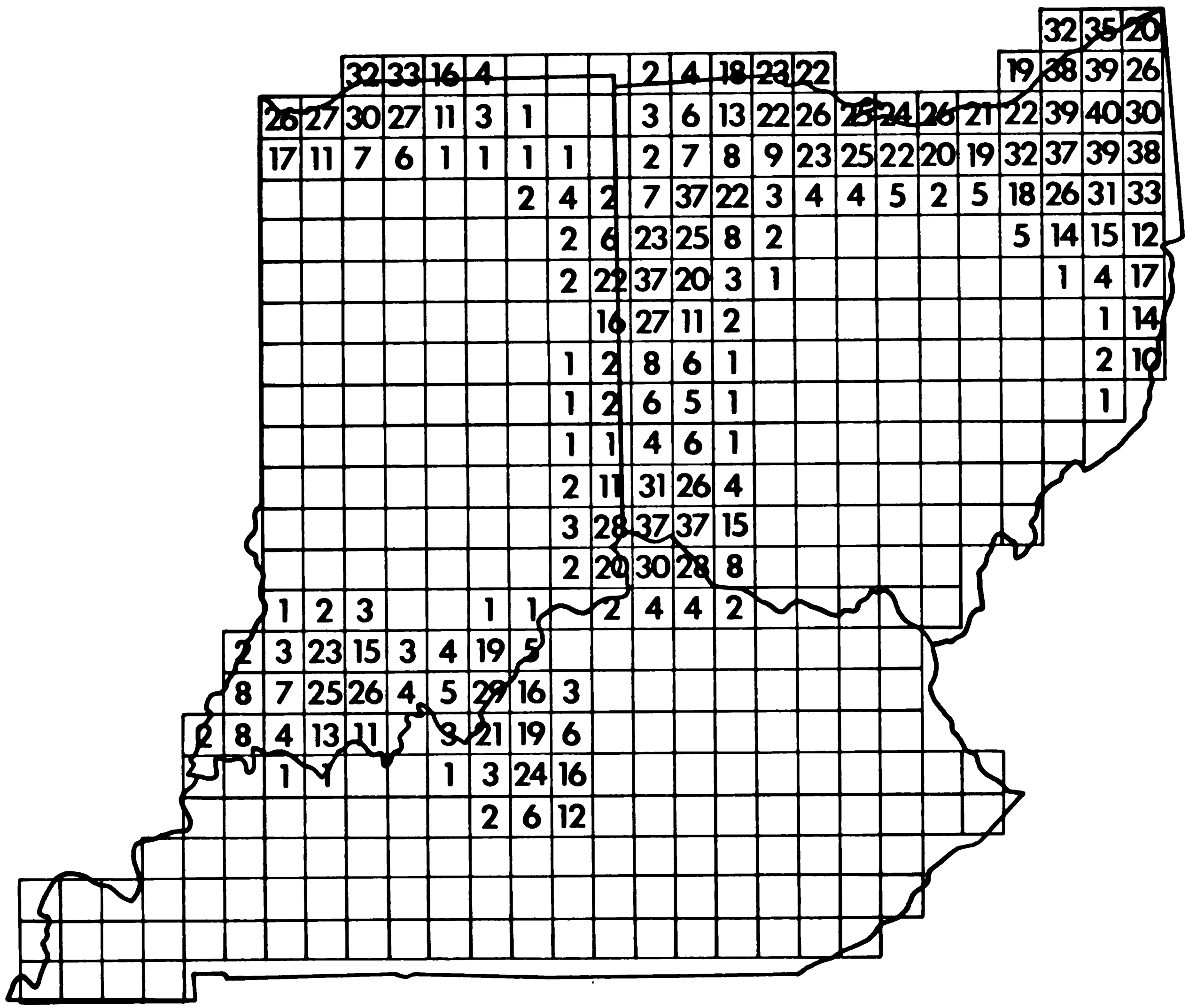


Figure 10. Consensual Response Map - Region A, Color Dot Map.

subjects generally agree on their placement of regional boundaries. They are consistent in locating regions within the map. The reverse is true of low variance. Low variance indicates high variability in which subjects disagree on the location of boundaries and are inconsistent in their regional perceptions (Lavin, 1979, p.166-7). The reason for this relationship lies in the distributional characteristics of the consensual frequency maps. Figure 11 compares hypothetical examples of two consensual response maps. Map A represents complete agreement, or consistency, in the regional perceptions of ten subjects. A high degree of disagreement, or inconsistency, is reflected on Map B. Variance, a measure of the dispersion of a numerical distribution, is calculated for each map using a standard variance formula with bias correction:

$$S^2 = \frac{\Sigma(X_i - X)^2}{n - 1}$$

where: X_i = frequency response to a cell

X = mean frequency of response

n = total number of cells

Zeros indicate no response to the cell, but they are included in the calculation of S^2. Since the frequency responses on Map A (consistency) are more dispersed than the responses on Map B (inconsistency), the variance of

10	10	0	0
10	10	10	0
10	10	10	0
0	0	0	0

MAP A

Consistency

$S^2 = 26.67$

5	4	3	1
6	7	1	3
3	3	5	6
7	4	4	2

MAP B

Inconsistency

$S^2 = 3.60$

CONSENSUAL RESPONSE MAPS

OBSERVED VARIANCE

Figure 11. Relationship between Region Drawing and Variance.

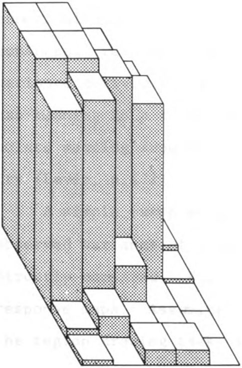
Map A is greater. In other words, a more uniform distribution of response frequencies leads to a lower computational variance.

The relationship between variance and region perception variability can be visualized by representing differences between the frequency responses of grid cells as three-dimensional frequency surfaces (Figure 12). A surface which is comprised of very high and very low prisms has high variance, indicating a high level of consistency in the subjects' regional perceptions. A surface whose cells have fairly uniform frequencies results in low computational variance and indicates inconsistency in regional perceptions. Variations in frequency values compiled on the

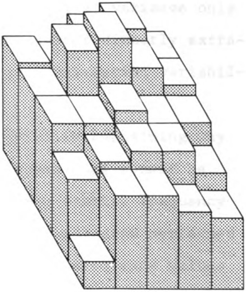
40	40	36	30	2
40	40	37	32	1
36	38	8	1	0
2	4	2	1	0
1	0	3	3	0

21	20	25	27	22
20	28	30	25	22
20	20	22	20	20
15	18	20	20	16
5	17	17	14	13

Frequency Surfaces



Consistent



Inconsistent

Figure 12. Region Perception Variability Visualized as Three-Dimensional Frequency Surfaces.

consensual response map presented in Figure 10 can be visualized as a three-dimensional surface in Figure 13. The highest and lowest prisms illustrate areas in which subjects were most consistent in locating 'A' regions.

Variance Standardization

Lavin (1979) suggests that observed variance of raw frequency scores may not be the best measure of region perception variability. One disadvantage is that variability as measured from subject responses by variance has no clear numerical limits. As a result, a computed variance for one consensual response map may not be directly comparable to a variance derived for another. Additionally, variance only has meaning in a relative sense; one cannot directly extrapolate meaning from variance to region perception variability (Lavin, p.172).

A simple example may prove helpful in explaining why observed variance of consensual response maps cannot be directly compared. Figure 14 shows two example frequency response maps. Assuming a total of ten subjects performed the region drawing task, within each map frequency values indicate that subjects were in total agreement in the placement of regional boundaries. However, results of the response variance calculations differ, even though the subject responses show no variability within either map. Consequently, the variances are not directly comparable. The cause of the variance difference is a function of the total

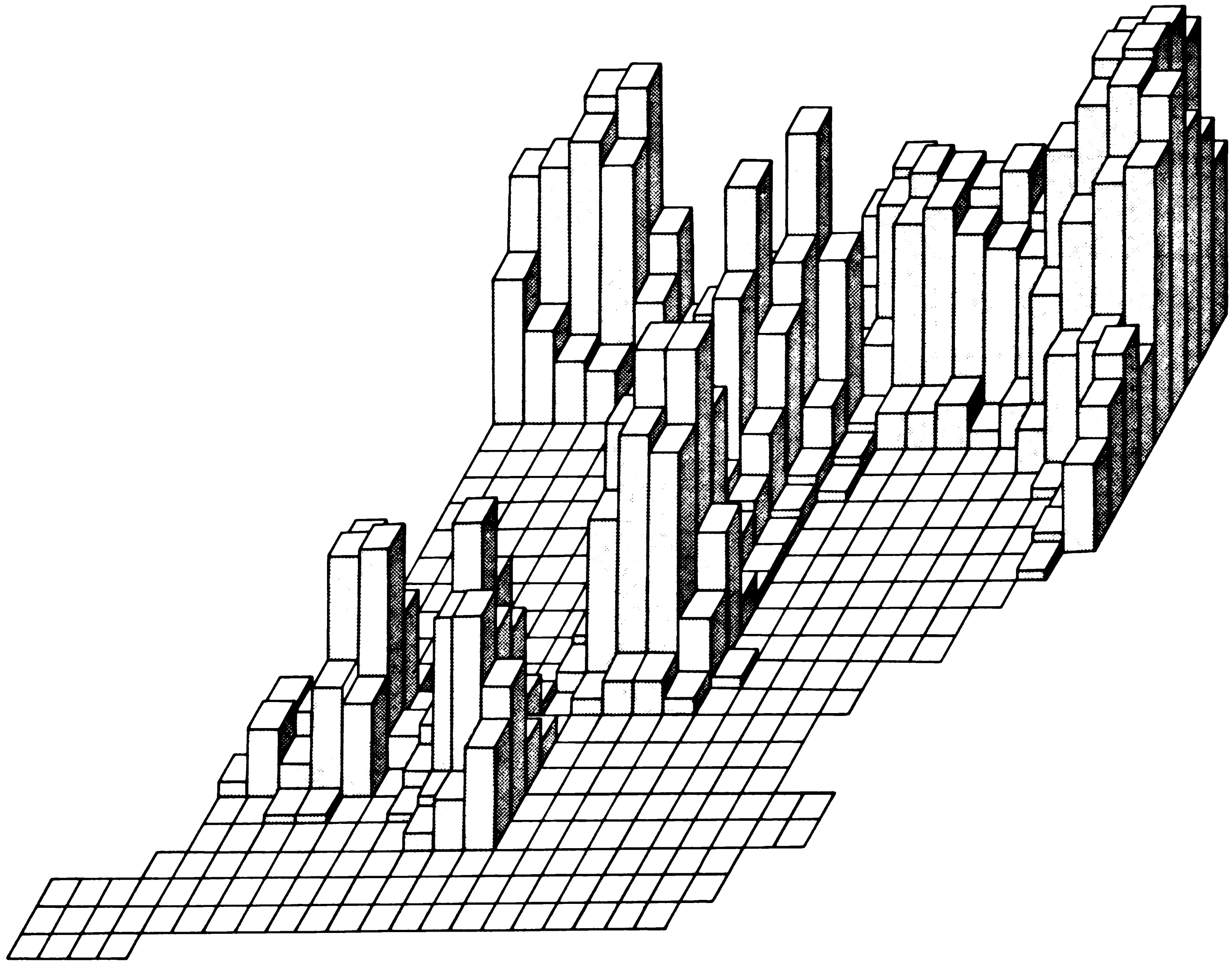


Figure 13. Frequency Surface of the Consensual Response Map Presented in Figure 10.

10	10	0	0
10	10	10	0
10	10	10	0
0	0	0	0

0	0	0	0
0	0	0	0
0	0	0	10
0	0	10	10

MAP A — CONSENSUAL RESPONSE MAPS — MAP B

TOTAL RESPONSE FREQUENCY

80 — 30

$$S^2 = (1/n-1)\ (\Sigma X^2 - ((\Sigma X)^2/n))$$

	MAP A	MAP B
X	80	30
n	16	16
ΣX^2	800	300
$(\Sigma X)^2$	6400	900
S^2	26.67	16.25

X = frequency of response to a cell

n = total number of cells

$$S_A^2 = .0667\ (800 - (6400/16)) = 26.67$$

$$S_B^2 = .0667\ (300 - (\ 900/16)) = 16.25$$

Figure 14. Total Subject Consensus in Regional Boundary Placement.

response frequency (sum of the times each grid cell was included in the region) and the total number of zero cells (Lavin, p.196-7).

In order to achieve both comparability and meaningful descriptions of differences in region drawing performance, Lavin developed a standardized expression of region perception variability called the variance ratio. The variance ratio, referred to as the Vratio, accounts for differences in total response frequency between consensual response maps making direct comparisons possible. A simplified explanation of the variance ratio is presented in this chapter. For a more complete discussion, Lavin's dissertation should be consulted (1979, p.198-203).

The equation for the variance ratio is given below:

$$\text{Vratio} = \frac{\text{observed variance (Vobserved)}}{\text{maximum possible variance (Vmax)}}$$

Observed variance is the actual response variance of the consensual frequency maps. Maximum possible variance (Vmax) occurs when all subjects are in perfect agreement in the placement of regional boundaries. Vmax can be calculated if the total response frequency and total number of subjects are known. The formula for Vmax is:

$$\text{Vmax} = \frac{\frac{\Sigma X}{N}\left(N - \frac{\Sigma X}{n}\right)^2 + \left(n - \frac{\Sigma X}{N}\right)\left(\frac{\Sigma X}{n}\right)^2}{n - 1}$$

where: X = frequency of response to a cell

n = total number of cells

N = number of subjects

$\frac{\Sigma X}{n}$ = mean response per cell

$\frac{\Sigma X}{N}$ = expected number of cells

The use of the variance ratio in this study has two advantages. First, the values derived from the Vratio equation range from zero (theoretically) to 1.0, with higher values indicating more consistency in subject location of regions within the map. The Vratio standardizes observed variance, allowing direct comparisons between the consensual frequency maps derived from the black and white test responses and the color dot responses. Second, Vratio values are directly related to region perception variability. For example, a value of .78 can be interpreted as meaning 78 percent of the maximum possible agreement among subjects was achieved (Lavin, p.203). No such interpretation can be given observed variance.

Lavin suggests several reservations concerning the use of the variance ratio. First, the measure is not a general solution because the computation of the Vratio is dependent upon the sample size and the total response frequency. The variance ratio is experiment dependent. A new Vmax and Vratio would have to be calculated if any change in sample size was made. In addition, Vmax is derived empirically. Lavin contends that its computation provides maximum possible variance, however this has not yet been mathematically established (Lavin, p.212).

Variance Ratio Comparisons

Variance ratios calculated from region drawing responses can be compared to determine which mapping technique, the black and white dot maps or the multipattern color dot map, resulted in more consistent regional perceptions. Table 3 lists the Vratios for all homogeneous and mixed region types identified by subjects for both test instruments.

Table 3

Comparison of Variance Ratios

Black and White Dot Maps	Color Dot Map
A = .453	A = .533
B = .192	B = .263
C = .556	C = .664
AB = .295	AB = .341
AC = .299	AC = .265
BC = .325	BC = .386
ABC = .089	ABC = .170

With the exception of region AC, there was less region perception variability in responses on the part of subjects viewing the color dot map. Only in locating region AC, was perception variability slightly lower for subjects viewing the black and white dot maps. Overall, color test subjects had an average of six percent higher agreement in their placement of regional boundaries than black and white subjects. The results indicate that color dot maps may be more effective in communicating regional information to map users, however the difference in variance ratios is fairly small. Simple statistical tests cannot be applied to determine whether the Vratios are significantly different because individual responses cannot be sorted within the frequency data.

Variance ratios in Table 3 can also be examined to compare region perception variability among region types. As expected, the Vratios of homogeneous regions are generally higher than those of mixed region types. Subjects viewing both the black and white, and color dot maps were more consistent in identifying regions of predominantly single distributions. Of the homogeneous region types, regions A and C were seen with much more consistency than region B. In fact, region A on the color dot map and region C on both test instruments were the only region types in which greater than 50 percent of the maximum possible agreement in boundary placement was achieved. In comparison to the perception of region B, a substantial average of 32 percent more agreement occurred in the boundary lines drawn around regions A and C. This difference is related to the varying characteristics of the dot distributions. Distribution A was clustered to a large degree, while distribution C was localized in the southern portion of the map; both characteristics making these regions fairly easy to see. Distribution B, however, was spread almost uniformly throughout the map causing the perception of any predominantly pure regions to be much more variable (Figure 6).

Among mixed region types, the highest region perception variability occurred in the identification of region ABC. While between 25 and 40 percent boundary agreement was achieved for mixed regions of two distributions, only 17 percent agreement on the color dot map and 8 percent agreement on the black and white maps resulted for the region of complete mix.

Accuracy within Regions

The second portion of the data analysis compares the accuracy of distributional composition within regions identified from the black and white maps with that of regions drawn from the color dot map. Data for this analysis were collected in the following manner. First, for every region identified by test subjects, the number of dots belonging to each of the three religious distributions were counted. The composition of the regions were determined from these values by calculating the percentage of each region's total dots that represented distributions A, B and C. Next, the total error in each region's distributional composition from what would be the 'ideal' composition of its particular region type was figured. For example, the ideal composition for a mixed region labeled 'AB' would be comprised of 50 percent A dots, 50 percent B dots, and no C dots. If an AB region drawn by a subject was found to consist of 55 percent A dots, 35 percent B dots, and 10 percent C dots, its total error index, or deviation from perfect composition would equal 30. This value is figured by adding the absolute values of the difference between ideal and actual dot composition percentages for each distribution. In the case of the AB region, the percentage of A dots was 5 percent greater than the ideal mix, the percentage of B dots 15 percent less, and the percentage of C dots 10 percent greater; adding up to a total error index of 30.

The error in distributional composition within regions can be visualized by plotting the mix of dot distribution percentages on a triangular graph similar to the commonly used soils texture graph. In the case of this analysis, the percentage of total dots belonging to each of the three religious distributions are scaled along the three sides of the triangular graph (Figure 15). The error from complete accuracy in regional composition for each area drawn by subjects is proportional to the length of the vector from the plotted point representing its actual dot mix to the point of ideal mix for the particular region type. Therefore,

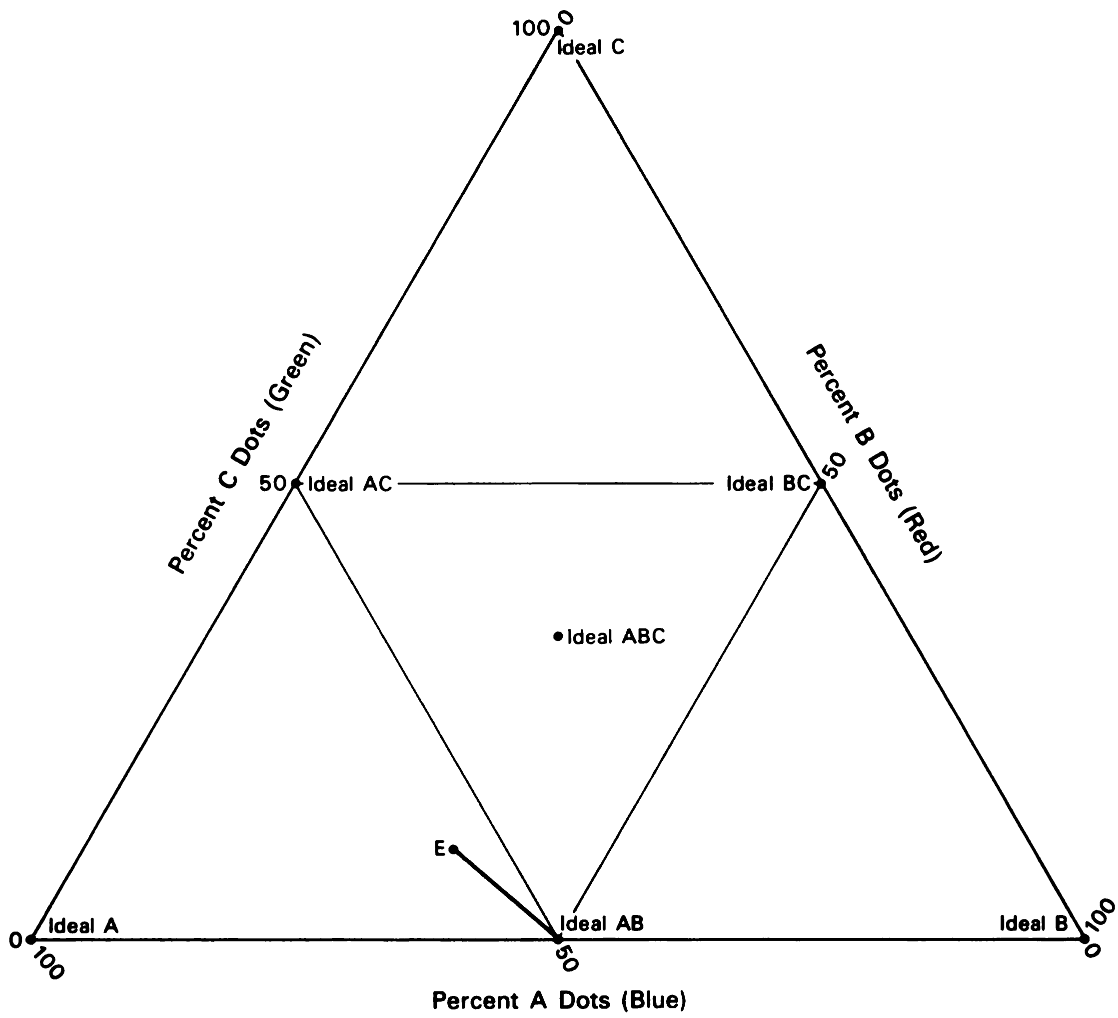


Figure 15. Triangular Graph Used in the Accuracy Analysis.

the farther away a response is plotted from its ideal dot mix, the less accurate the subject's regional perception. The error vector for the AB region described in the previous paragraph is illustrated at point E on the triangular graph in Figure 15.

The dot mix of all region types drawn by test subjects were plotted on triangular graphs. Figure 16 illustrates one set of test responses; the compositional mix of A regions perceived by subjects viewing the color dot map. It appears that the majority of A regions identified are clustered near the ideal 'A' dot mix location and consist of greater than 70 percent A dots, less than 30 percent B dots, and very few C dots. However, the overall group error in perceptual accuracy is increased by regions with a lower percentage of A dots, located further from the ideal mix. A visual comparison of triangular graphs such as Figure 16 between the two test groups indicated that no substantial differences existed in their response accuracy.

Simple statistical techniques were employed to determine if, in fact, no significant differences existed in the accuracy of regional perceptions between the two test groups. The indices of compositional error for each region were used to calculate the mean error of individual subjects' perceptions for each region type. The individual subjects' means were determined in order to avoid the perceptions of subjects who identified a comparatively large number of regions from weighting the results of the comparison between

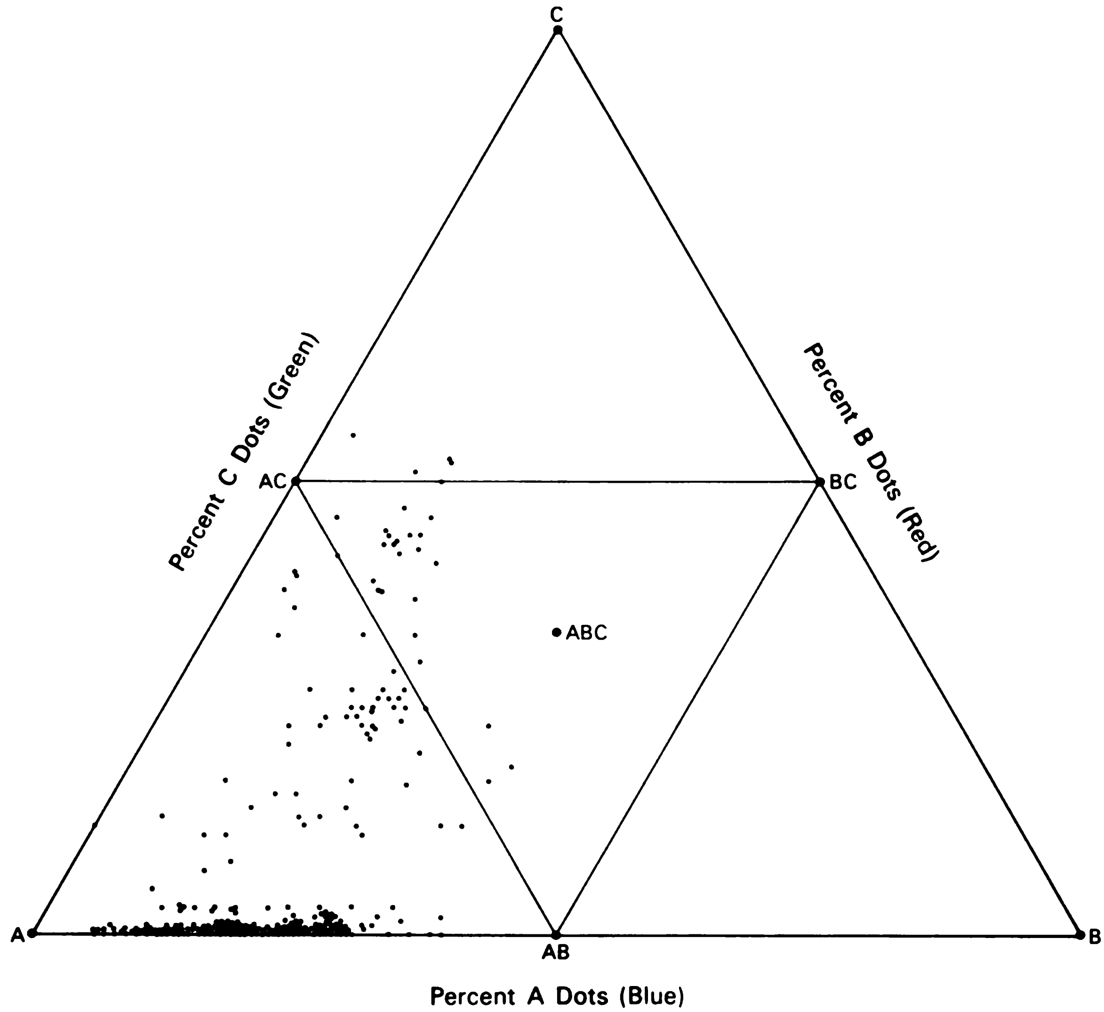


Figure 16. Sample Triangular Graph - Region A, Color Group.

the two mapping techniques. Next, the mean 'group' error and standard deviation of distributional mix were calculated for each of the seven region types from individual subjects' mean errors, for both the black and white, and color test instruments. The values are listed in Table 4. It should be noted that in the calculation of mean error and standard deviation for each region type, the number of subjects decreased by one for every person who did not identify any regions of the type in question.

An inverse relationship exists between mean error and the effectiveness of a mapping technique in portraying regional information. The smaller the mean error, the more accurate the distributional composition within regions. The mapping technique which results in a higher level of accuracy in perception responses is assumed to be more effective in communicating regional information to the average map user. Additionally, standard deviation measures the consistency with which subjects perceive regions at the accuracy level indicated by the group mean error. The smaller the standard deviation, the more consistent the subjects' regional perceptions are as a group.

A general comparison of the two mapping techniques through the data in Table 4 shows that for all homogeneous region types, color subjects as a group were more accurate in their regional perceptions. For mixed region types, with the exception of region ABC, the mean errors for each test group are very close to one another indicating there was

Table 4

Comparison of Mean Error and Standard Deviation

Black and White Dot Maps:

Region	Mean Error	Standard Deviation	Number Subjects (38 Total)
A	64.82	16.71	38
B	70.11	18.66	32
C	48.71	6.42	38
AB	22.94	11.44	37
AC	34.12	10.15	33
BC	51.46	15.20	35
ABC	38.43	14.66	23

Color Dot Map:

Region	Mean Error	Standard Deviation	Number Subjects (40 Total)
A	57.45	16.09	40
B	63.99	17.45	37
C	45.58	8.28	40
AB	19.70	9.48	40
AC	33.56	11.36	35
BC	51.67	9.74	35
ABC	45.12	14.58	35

little difference in the accuracy of their perceptions. In the identification of region ABC, the region of total mix between the three distributions, black and white subjects were more accurate as a group. However, it should be noted that subjects viewing the black and white maps were able to see far fewer ABC regions (29) than those viewing the color dot map (81 ABC regions drawn). Finally, no identifiable pattern is apparent in Table 4 between the standard deviation values of the two test groups among different region types. Overall, it appears that the color mapping technique resulted in slightly more consistent regional responses.

The F test for analysis of variance was performed to determine if the variability in response for any one region type was significantly different between the black and white, and color test groups. In theory, if a significant difference did exist in the variances, the mapping technique with the smaller variance would be assumed to portray more consistent regionalizations to viewers. The following F ratio formula was used to test the equality of variances:

$$F = \frac{\dfrac{n_1 s_1^2}{(n_1 - 1)}}{\dfrac{n_2 s_2^2}{(n_2 - 1)}}$$

where: s = standard deviation

n = number of subjects

Results of the F test show that at a .05 significance level, no significant difference in variances existed between the black and white, and color test groups for any region types except regions C and BC (Table 5). In the perception of region C, the variance for the black and white group was significantly smaller than the variance of the color group, but its mean group error was slightly larger. In other words, subjects viewing the black and white maps were more consistent in their perceptions of region C, but at a less accurate level. The mean error for both groups identifying region BC was approximately equal. However, the color group was significantly more consistent in their regional perceptions in terms of distributional composition at this accuracy level. Color subjects drew regions with fewer extremes in error from the ideal 'BC' dot mix. When all region types are considered though, the F test results confirm the null hypothesis that neither mapping technique resulted in more consistent viewer responses.

A second statistical test was employed to determine whether any differences between the mean errors of each test group for the seven region types were significant. The comparison of the means was accomplished by subjecting the mean group errors to the student's t test using the following formulas:

Table 5

Analysis of Variances F Test

a = .05 H_o: ${s_{b/w}}^2 = {s_c}^2$

Region	Degrees of Freedom	Critical F		
A	37,39	1.53	F = 1.08	Accept H_o
B	31,36	1.59	F = 1.15	Accept H_o
C	37,39	1.53	F = 1.66	Reject H_o
AB	36,39	1.53	F = 1.46	Accept H_o
AC	32,34	1.59	F = 1.25	Accept H_o
BC	34,34	1.57	F = 2.44	Reject H_o
ABC	22,34	1.84	F = 1.03	Accept H_o

For those region types in which no significant difference in sample variance was found between responses of the two test groups (A, B, AB, AC and ABC), the pooled variance estimate was used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1\, s^2{}_1 + n_2\, s^2{}_2}{n_1 + n_2 - 2} * \left(\frac{n_1 + n_2}{n_1 * n_2}\right)}}$$

For those region types in which a significant difference in sample variance was found between responses of the two test groups (C and BC), the separate t estimate was used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s^2_1}{n_1 - 1} + \frac{s^2_2}{n_2 - 1}}}$$

where for both equations:

$\bar{x}$ = mean group error

s = standard deviation

n = number of subjects

$df = n_1 + n_2 - 2$

Results of the student's t test indicate that at a .05 level of significance there was no significant difference in the mean group errors between the black and white, and color test instruments for any of the seven region types (Table 6). Although it was mentioned earlier that the mean errors for homogeneous regions perceived by color test subjects were smaller than the mean errors of the black and white group, the t test indicates that the differences were not statistically significant. As a result, one cannot say that subjects viewing the color dot map perceived regions which were more accurate in dot distribution composition than those viewing the three separate black and white dot maps.

Table 6

Student's t Comparison of Means

a = .05/2 tailed Critical t = 2.00			
H_o: $u_{b/w} = u_c$			
Region:	A (pooled est.)	t = 1.99	Accept H_o
	B (pooled est.)	t = 1.36	Accept H_o
	C (separate est.)	t = 1.85	Accept H_o
	AB (pooled est.)	t = 1.37	Accept H_o
	AC (pooled est.)	t = 0.21	Accept H_o
	BC (separate est.)	t = 0.07	Accept H_o
	ABC (pooled est.)	t = 1.70	Accept H_o

Additional Data Analysis

In addition to the two measures of region communication effectiveness already employed in this study, consistency within the map and accuracy within the regions, a number of other statistical comparisons can be made with the region drawing data to increase our understanding of the effectiveness of the two dot mapping techniques. Table 7 compares the average number of regions outlined per subject on each test instrument. The most apparent message in this table is the fact that both the color and black and white test groups perceived a far greater number of A regions than any other region type. This difference in the average number of A

Table 7

Average Number of Regions Outlined per Subject

Black and White Dot Maps	Color Dot Map
A = 5.21	A = 6.60
B = 2.08	B = 3.15
C = 2.61	C = 1.78
AB = 2.79	AB = 2.65
AC = 1.42	AC = 1.55
BC = 1.26	BC = 1.53
ABC = 0.76	ABC = 2.03

regions is highly dependent on the nature of the A dot distribution. The distribution contains small areas of relatively pure clusters of dots which lend themselves to well-defined regionalizations. It was also discovered that the group viewing the color dot map perceived at least an average of one more region per subject than the group viewing the black and white maps, for region types A, B and ABC. There was less variation between the average number of regions outlined by each test group for the remaining region types.

It was apparent in the data collection process that the larger number of A and B regions perceived by color subjects was inversely related to the size of the regions outlined. Because all three distributions were mapped together in the same space on the color map, subjects viewing it were able to clearly see larger numbers of smaller, more defined A and B regions which were characterized by clustering in the upper portion of the test maps. The fact that the group viewing the black and white maps saw fewer ABC regions than the color group was likely the result of many subjects being unable to successfully perform the difficult task of mentally superimposing three separate dot distributions. Subjects viewing the color dot map were able to see regions of complete mix more easily because the dots were mapped together in the same space.

Table 8 presents the results of the multiple choice questions answered by test subjects after completion of the region drawing task. Both test groups tended to rate the difficulty of identifying regions within the mid-range of the ranking scale. Only a few subjects considered the test task either 'very easy' or 'very difficult'. Overall, the subjects viewing the color dot maps considered the region drawing experiment to be easier than those viewing the black and white dot maps. Both test groups indicated that region A was the easiest type of region to identify, probably because of the distribution's clustering characteristics. The ease of perceiving region C was also rated very close to that of region A by the black and white subjects. As expected, more color subjects ranked regions of mix as easiest to identify than subjects viewing the separate black and white dot distributions.

Table 8

Responses to Multiple Choice Questions

Difficulty:	Very Easy	Easy	Difficult	Very Difficult
COLOR (40)	2	25	13	0
B/W (38)	2	18	17	1

Easiest Region to Identify:

	A	B	C	Mixed
COLOR (40)	22	1	10	7
B/W (38)	19	0	18	1

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary of the Research

Geographers commonly use maps as a means of visually representing regions. The successful communication of regions with transitional boundaries often requires the map reader to areally compare two or more spatial distributions of related phenomena. In these cases, cartographers often illustrate each distribution separately with conventional black and white dot maps. As a result, map readers must mentally superimpose distributions from separate maps to judge the degree of association between the phenomena. Although map readers may be partially successful, it appears the task is difficult and many of the more subtle relationships between distributions go unnoticed.

Previous literature suggests that map readers are likely to perceive regional information more consistently and accurately, if related geographic phenemena are mapped together in the same space. Representing several distributions on one map enables map readers to directly compare spatial associations. It is possible to portray several distributions on one dot map if differences in color, size, shape or tone are used to distinguish the various dot patterns.

The ability of map readers to perceive regional information on multipattern dot maps which employ color to differentiate distributions, was examined in this study. The goal was to determine if the mapping technique offers an effective solution to the cartographic problem of portraying regions with transitional boundaries. More specifically, in a psychophysical experiment, the color dot mapping technique was compared to the conventional method of single distribution black and white dot maps, evaluating their effectiveness to communicate regional information to the average map user.

Two general research questions were posed:

(1) Are there differences in the consistency or accuracy in which test subjects perceive regions of homogeneity, or purity, between single distribution black and white dot maps and multipattern color dot maps?

(2) Are there differences in the consistency or accuracy in which test subjects perceive regions of mix, or transition, between single distribution black and white dot maps and multipattern color dot maps?

The effectiveness of each mapping technique was assessed by conducting an experiment in which subjects were asked to draw regional boundaries around perceived areas of homogeneity and mix. Two quantitative measures were employed to compare the responses drawn on the black and white, and color test maps; (1) the consistency with which subjects located regions within the map, and (2) the accuracy of dot composition within perceived regions.

Conclusions

Results of the region drawing experiment indicate that the color dot map was slightly more effective in communicating consistent perceptions of both homogeneous and mixed regions. However, the small differences in responses leave open the question of recommending the use of color dot maps over single distribution black and white dot maps.

As expected, the consistency measure also shows that subjects viewing both map types were less consistent in locating complex regions of mixed distributions, than in drawing predominantly pure regions of single distributions. It appears that as the complexity of the region increased (combination of a larger number of dot distributions), subjects found it more difficult to make spatial association judgements. As a result, their regional perceptions as a group became more variable. Regions comprised of dot distributions with a high degree of clustering, or localization in one portion of the map, were easier for subjects to see. These findings suggest that the perceptual limit to the number of distributions map readers can areally compare depends strongly on the characteristics of the individual dot patterns, their complexity and degree of mixing, and the viewer's ability to differentiate dot patterns by color, size or shape on a multipattern map.

Comparison of distributional composition within regions indicates that there was no statistically significant difference between the accuracy of responses gathered from the black and white test version and the color version, for either homogeneous or mixed regions. However, the color mapping technique resulted in more consistent viewer responses in terms of internal regional accuracy. While these differences were small, the color dot technique can be recommended as being at least as effective in terms of internal accuracy.

The results of this study indicate that the innovative color dot map is at least as effective as the commonly used technique of single distribution black and white dot maps. As a result, cartographers should not overlook the color dot map technique when choosing a method to represent regions characterized by transitional boundaries between related geographic distributions. Despite the increased production costs of reproducing color, color dot maps may prove a useful alternative to conventional black and white dot maps for two potential reasons. Not only do color dot maps require less space than individually mapped distributions, but viewers may find the uncommon cartographic product to be more interesting and attractive.

Prior to this study, very little research had been conducted to assess the potential of displaying multiple distributions on one map using color to differentiate dot patterns. Additional examination of a number of research questions must be completed before the full potential of the color dot mapping technique can be fully understood. Among these research topics is the need to investigate in detail, how dot density and other pattern characteristics of dot distributions affect the consistency and accuracy in which map readers see regions. In assessing the perceptual limitations of the color dot map technique, it would also be useful to have a more accurate understanding of the relationship between complexity of distributional dot mix and region perception variability. Finally, extensive research in a map context must be completed to discover the color combinations which are best suited for use on multi-pattern dot maps, and to develop guidelines for determining the perceptual limits to the number of color dot patterns a map reader can distinguish.

APPENDIX A

APPENDIX A

Test Instructions (Black and White Version).

Follow the numbered instructions in order. Complete each step before going to the next step.

1 Maps A, B, and C represent three different distributions in an area. Look at, and compare distributions A, B, and C.

2 Map T is a map where all three distributions, A, B, and C, have been combined. Using Maps A, B, and C as general references, on Map T, draw lines around any areas that you see as predominantly distribution A. Label each of these areas with the letter A.

3 In the same way, on Map T, draw lines around any areas that you see as predominantly distribution B. Label each of these areas with the letter B.

4 In the same way, on Map T, draw lines around any areas that you see as predominantly distribution C. Label each of these areas with the letter C.

5 Place Map T aside.

6 Look at Map X. It is the same map as Map T. Using Maps A, B, and C as general references, on Map X, draw lines around any areas that you see as predominantly a mix of distributions A and B. Label these areas AB.

7 In the same way, on Map X, draw lines around any areas that you see as predominantly a mix of distributions A and C. Label these areas AC.

8 In the same way, on Map X, draw lines around any areas that you see as predominantly a mix of distributions B and C. Label these areas BC.

9 In the same way, on Map X, draw lines around any areas that you see as predominantly a mix of distributions A, B, and C. Label these areas ABC.

Rate the difficulty of identifying the regions on these maps. Circle the appropriate description.

Very Easy Easy Difficult Very Difficult

Which was the easiest type of region to see?

A B C Mixed Areas

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