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An Evaluation of Unclassed
Choropleth Dot Matrix Mapping

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Richard Groop
Major professor

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AN EVALUATION OF UNCLASSED CHOROPLETH DOT MATRIX MAPPING

By

Kathryn Geraldine Frohnert

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ABSTRACT

AN EVALUATION OF UNCLASSED CHOROPLETH DOT MATRIX MAPPING

By

Kathryn Geraldine Frohnert

This research examined methods of mapping statistical surfaces and the problems involved with their symbolization. A symbol system was introduced which utilizes dot matrix technology to produce areal symbols for choropleth maps. The topics addressed include a description of the symbolization, the visual characteristics of dot matrix patterns and the production of such patterns. The evaluation of the unclassed choropleth dot matrix method focused on the problem of determining the effectiveness of two variations of the symbolization (systematic and random) in conveying regional patterns to map readers. Two map reading tests were used in this research. The first was a region drawing experiment in which test subjects drew boundaries around regions of high, medium and low density on maps. The second testing experiment involved pattern recall, in which subjects attempted to remember regional map patterns. Two quantitative measures were used to evaluate (1) the consistency with which subjects located regions on maps, and (2) the accuracy with which subjects recalled regional patterns. The results indicated no significant difference between the two symbologies, and it was concluded that neither the systematic nor the random symbology was more effective than the other in conveying regional patterns to map readers.

To my parents for their confidence and encouragement throughout my education.

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CHAPTER I

MAPPING STATISTICAL SURFACES

Thematic maps employ graphic symbols in a variety of ways to show the characteristics of a geographical distribution. Many thematic maps, "... deal with statistics derived from censuses and the like, and are therefore called 'statistical maps'" (Robinson, et al, 1978, p. 181). They involve the concept of a statistical surface, a useful device for conceptualizing the spatial distribution of a series of data values. This surface consists of data points raised above a datum plane with the height of each point proportional to its corresponding data value.

There are two types of surfaces recognized by cartographers: smooth statistical surfaces and stepped surfaces. Smooth surfaces portray distributions from which data values were sampled at points. Interpolation allows inference of the whole, smooth, undulating surface from those sample points. Examples of phenomena that fit this definition include precipitation, temperature, air pressure and elevation. This type of surface is commonly represented by a three-dimensional data model (Figure 1a), or as a two-dimensional isarithmic map (Figure 1b).

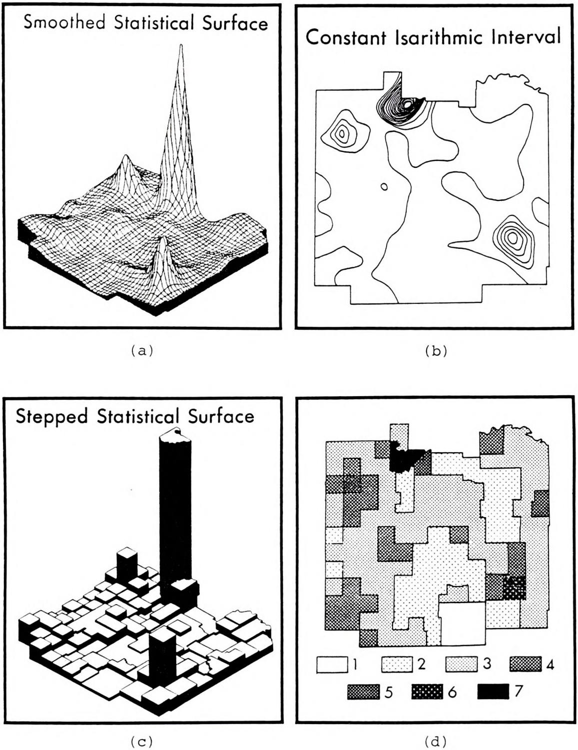


Figure 1. Smooth and Stepped Statistical Surfaces and their Two-Dimensional Counterparts (From Jenks, "Generalization in Statistical Mapping", 1963).

Stepped surfaces are those for which values are available for areal units such as states, counties or census tracts, rather than specific points. The value is constant across the area and changes only at unit boundaries. Sharp changes or voids in the data create a surface consisting of varying levels of steps or columns. Examples of discontinuous surfaces may include population density, per capita income or value of farm products sold per farm. These phenomena can also be viewed as continuous and may be mapped by the isopleth technique. A stepped surface can be portrayed by a three-dimensional block diagram (Figure 1c) or a two-dimensional choropleth map (Figure 1d).

Classed Choropleth Mapping

The most common method of mapping stepped statistical surfaces in two dimensions is the choropleth technique. The principal objective of choropleth mapping is to symbolize the magnitudes of the data values as they occur within the boundaries of enumeration areas like counties or states (Robinson, et al, 1978, p. 244). The data are usually in the form of densities, averages or ratios. These averages are assumed to refer to the entire unit area, even though this assumption is rarely true. Since enumeration areas tend to vary in size, and since there is often a high correlation between size and number of data items, absolute numbers are not usually presented on choropleth maps (Jenks, 1977; Groop, 1980). A strict definition of choropleth may

even eliminate this type of map from inclusion, but here the definition includes any map with values shown for well-defined enumeration units.

The conventional choropleth map is normally generalized by the process of classification which divides the data values into several groups or categories (Figure 2). Jenks (1963) stated that different levels of generalization can be achieved by changing the number of classes on a map and that the degree of generalization is inversely related to the number of classes. Thus, the map becomes more generalized as the number of classes is reduced. Choropleth map data are usually generalized for two reasons. First, there are limitations on the number of areal gray tone symbols that can be manually produced to represent data magnitudes. Second, certain psychological limitations exist due to the inability of map readers to differentiate between a great number of gray tones or hues. These limitations in symbolization have somewhat necessitated the generalization of data for mapping purposes.

There are many methods available for classing choropleth map data. Some of the more conventional methods of classing include equal step, equal frequency, mean and standard deviation and natural breaks (Robinson, 1978). Choosing the proper classification method is an important design problem in choropleth mapping since each technique varies considerably with the distribution of the data (Chang, 1979, p. 1). Any kind of classification scheme must generalize the

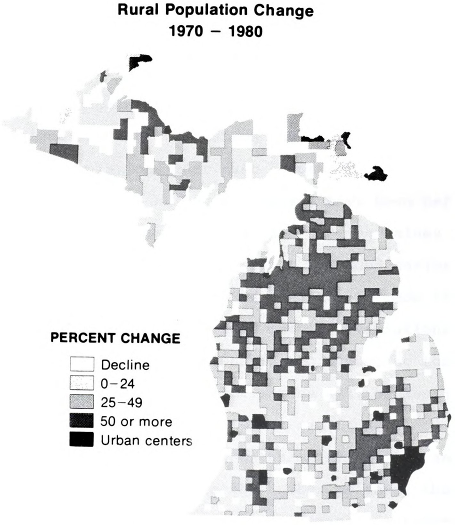


Figure 2. A Classed Choropleth Map

original data values and therefore introduce some quantization error.

A technique using variance criteria may be the best solution to the classing problem, because the classes contain the least amount of error when compared to the original data values (Jenks, 1977; Groop, 1980). The iterative technique is based on analysis of variance. The objective of this classing method is to minimize within class variance and to maximize between class variance. The only disadvantage to this technique is that it requires computer assistance due to the complex calculations that must be performed.

After a limited number of classes have been defined, different patterns (dots or lines) and varying values (from light to dark) are selected to produce a graded series of tones or hues, depending on whether the map is made in black and white or color. In choropleth mapping, variations in value generally convey variations in magnitude, so that areas with denser population or greater income will be assigned darker tones than the areas of lesser magnitude.

Several problems occur when using gray tones and hues. The cartographer is limited to the number of tones that can be made with printed patterns and photographic screens. It is also difficult for map readers to differentiate between many gray tones or hues. Jenks and Knos (1961) stated that the use of more than seven gray tone shadings can not be distinguished by the human eye. Another problem is creating equal visual steps between gray tone values. Many studies have been conducted to establish areal gray tones with equal visual steps from white to black (Williams, 1958; Jenks and Knos, 1961; Kimerling, 1975). Uniform textures should also be maintained throughout a given series of shadings. Unfortunately, gray tone patterns with uniform texture are not always available, and the cartographer must sometimes choose patterns that appear out of order (Jenks and Knos, 1961).

Unclassed Choropleth Mapping

Recent developments in automated cartography have produced new variations in choropleth mapping. Tobler (1973) introduced a computer program that created a continuous array of gray tones using crossed-line symbols (Figure 3). This method eliminates the need to classify the data since the cartographer can produce a different shading density for each value. Tobler's method is referred to in the literature as the "unclassed" or "unquantized" technique of choropleth mapping. The unclassed choropleth method eliminates the need to choose class intervals and number of classes. Therefore, there is no quantization error due to classification (Tobler, 1973, p. 262).

This innovation has created a controversy among cartographers. Dobson (1973) argued that an infinite number of patterns on a choropleth map decreases the reader's ability to understand it. He used research in psychophysics to support his conclusion that while quantization error is reduced, perceptual error increases. According to Monmonier (1977)

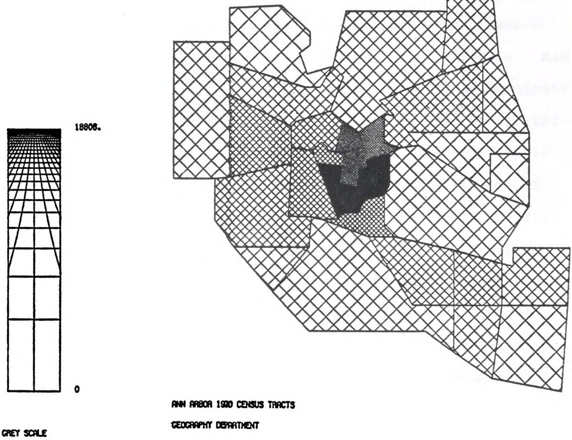


Figure 3. Tobler's Unclassed Choropleth Map (From Tobler, "Choropleth Maps Without Class Intervals?", 1973).

classification assists the map reader since it presents a regionalization of the mapped variable. He believes that the purpose of a cartographer is to highlight important aspects of the pattern in a thematic map. The reader should be able to regionalize visually the data without classification, but the intended message may be missed, or so the argument goes. Monmonier suggested that the unclassed method is only appropriate for individual areas and that an areal table would probably be more practical than a map for that purpose. Many cartographers feel that their main purpose is to communicate an overall pattern to the map reader, facilitated by classification or generalization of the data, despite the inevitable problems in choosing class intervals, the number of classes and progressive shading patterns (Peterson, 1979).

Despite criticism of unclassed mapping, several cartographers have evaluated, tested and refined this method. Peterson (1979) conducted research on Tobler's unclassed crossed-line choropleth mapping technique. Through subject testing, he determined an exponent in order to improve the relationship between crossed-line shadings and corresponding perceived values. A comparative evaluation between the unclassed and classed methods of mapping revealed that the unclassed map conveyed values more accurately to most subjects than the classed map. Subjects were able to detect very small differences in the crossed-line patterns and also interpolate values represented by the shadings. Peterson concluded that the classification of choropleth data may not

be necessary in order to communicate effectively the information on maps.

Brassel and Utano (1979) presented three design modifications to promote more effective communication with unclassed choropleth maps. These design considerations included a revised legend, an alternative placement of data values to corresponding map symbols and a new symbolization scheme consisting of Tobler's crosshatch line pattern mixed with cross and systematic dot patterns.

Muller and Honsaker (1978) described a continuous-tone choropleth map made by facsimile, a method capable of producing a map with up to 255 continuous gray tones. It eliminated the coarse pattern texture of most automated choropleth maps produced on line printers and plotters.

Muller (1979) further tested the facsimile map on human subjects evaluating their perceptions of continuous-tones. Using a map of rural population density in Kentucky, map readers were asked to regionalize visually the areas of high, medium and low density. He found that people were able to perceive general patterns on an unclassed map and that the resulting patterns were very similar to those on a choropleth map using the variance classing technique. Muller concluded that map readers can visualize and organize an unclassed map in a logical manner.

Monmonier (1979) discussed how line growth, a common graphic distortion of continuous-tone areal symbols, can occur during the photographic, plate-etching and printing stages of map reproduction. He recommends a simulation model which assists the cartographer in selecting an appropriate range of gray tones to avoid distorted patterns. Monmonier emphasized that continuous-tone symbolization may have eliminated classification decisions by creating an array of visually distinct gray tones, but the cartographer must still compensate for the non-linear response of the human eye, specify graphic parameters for drawing shading patterns and be aware of line growth during map reproduction.

Throughout the above-mentioned research, there has been no conclusive evidence for or against unclassed choropleth maps. Regardless of the controversy, cartographers will continue to design and produce unclassed maps, and perhaps new computer techniques will refine the visual qualities of the symbolization. There is still a need for further research into and improvement of this relatively new method of choropleth mapping.

This research looks into a different kind of symbol system which utilizes dot matrix technology to produce areal symbols for choropleth maps. It examines the effectiveness of two variations of this symbolization scheme (systematic and random) in conveying regional patterns to map readers.

CHAPTER II

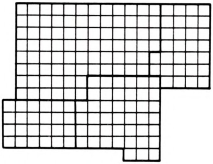
AN UNCLASSED CHOROPLETH DOT MATRIX METHOD

This chapter describes the use of dot matrix technology to produce areal gray tone symbols for unclassed choropleth maps. The topics addressed include a description of the symbolization, the visual characteristics of dot matrix patterns and the production of such patterns. The dot matrix method may be a viable alternative among unclassed mapping techniques for several reasons. First, the dot patterns may be visually more pleasing to map readers than line patterns. Preference tests by Jenks and Knos (1961) indicate that readers tend to prefer dot patterns over line patterns when gray tone shadings are used on maps. Second, dot matrix symbols allow smoother gradations between tones, since a smaller increment of blackness is possible with dots than with lines. Third, although Brassel and Utano's design modifications using cross and dot patterns, as well as crosshatching, are an improvement on the crosshatched map, the use of the different pattern constructions on one map may convey qualitative change to map readers, rather than continuous quantitative change. Pattern construction is held constant with the dot matrix method, and data magnitudes are depicted by varying gray tone value. Fourth, dot matrix symbols can be manipulated so that coarseness of pattern is minimized. An advantage, from a production aspect, is that this method utilizes a micro-computer graphics system which is more accessible at most universities and mapping agencies than expensive and special equipment such as Muller's facsimile recorder. Although Muller's map may be superior in visual qualities, the necessary equipment for its production is not readily available for most cartographers.

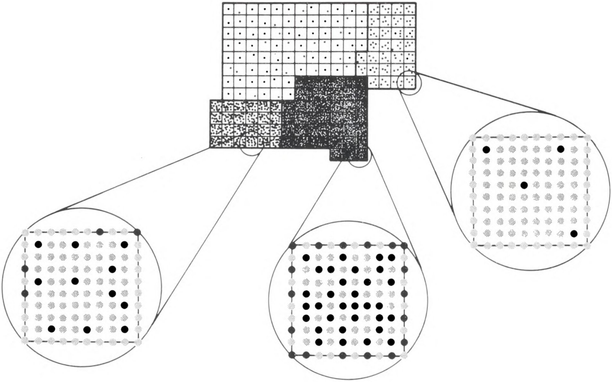
Symbolization

The dot matrix technique produces an array of gray tones by employing a fine matrix of dots within individual cells of enumeration units. It is assumed that each enumeration unit (county or census tract) on a choropleth map consists of a number of hypothetical cells (Figure 4a). Each cell is divided into a matrix of finely spaced dots, which can be turned "on" to add blackness to a shading pattern (Figure 4b). As the number of dots increase in each matrix, the tone of the pattern increases in darkness, because more area becomes inked.

The number of dots turned "on" in each matrix is determined by scaling the data value range. For example, 50 gray tone shadings may be chosen for a particular map. The county with the highest data value would receive 50 dots in each matrix, and the county with the lowest data value 1 dot in each matrix. The remainder of the data values would be assigned dot numbers according to the position of the value within the range. Therefore, the distribution of data values



(a) Cells Within Enumeration Units



(b) Dot Placement Within Each Matrix

Figure 4. Dot Matrix Symbolization on a Choropleth Map

determines the specific set within the 50 gray tones that actually appear on the map.

The size of the cell containing the matrix affects the number of gray tones that are possible on a map. A wider range of tones can be created with a larger cell size, because there are more matrix dots available to turn on. A smaller cell would limit the number of dots and therefore the number of tones. For example, a 10 x 10 matrix has 100 dots that can be used, so 100 different gray tones are possible (Figure 5a), whereas a 5 x 5 matrix has the potential of creating only 25 tones (Figure 5b).

An increase in cell size also increases the coarseness of texture in a shading pattern. With large cell sizes, less cells fit in an enumeration unit, and the number of individual symbols per inch decreases (Figure 5c). By using smaller cell sizes, texture becomes finer since more cells fit into a unit (Figure 5d). However, as texture is doubled with smaller cells, the number of tones are limited. In order to obtain a wider range of gray tones, a finer pattern texture must be sacrificed and vice versa.

By varying the dot placement within a matrix, different patterns can be constructed. This technique can produce choropleth symbols in two ways - systematic and random (Figure 6). The systematic pattern consists of a systematic arrangement of dots in each matrix. Figure 7 illustrates the positions and numbers of dots in individual matrices for 1 to 50 gray tones. The random design differs from the

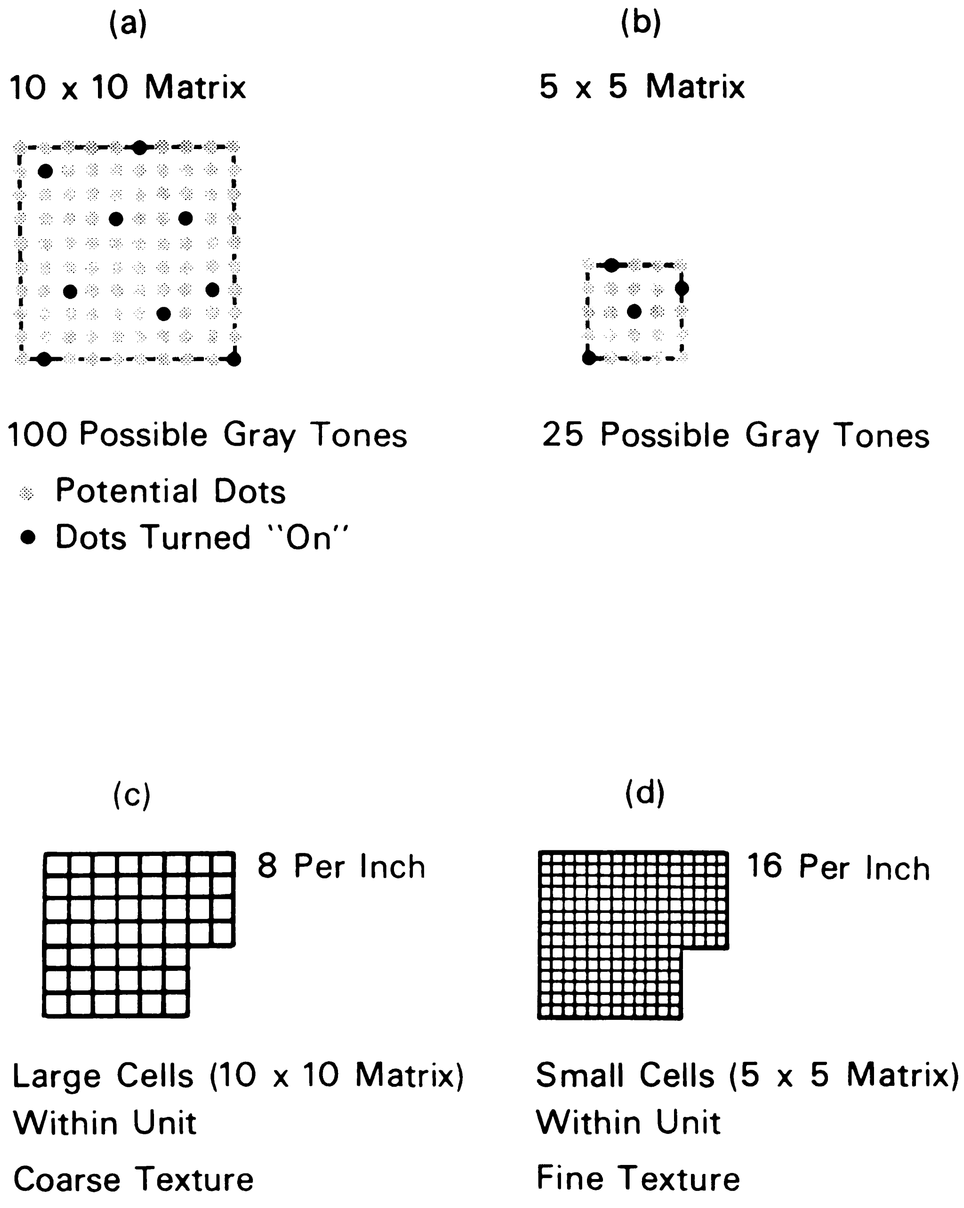
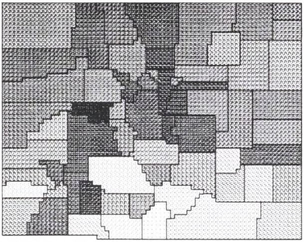
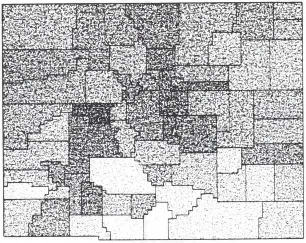


Figure 5. The Effects of Cell Size on Dot Matrix Patterns



(a) Systematic



(b) Random

Figure 6. Alternative Pattern Constructions

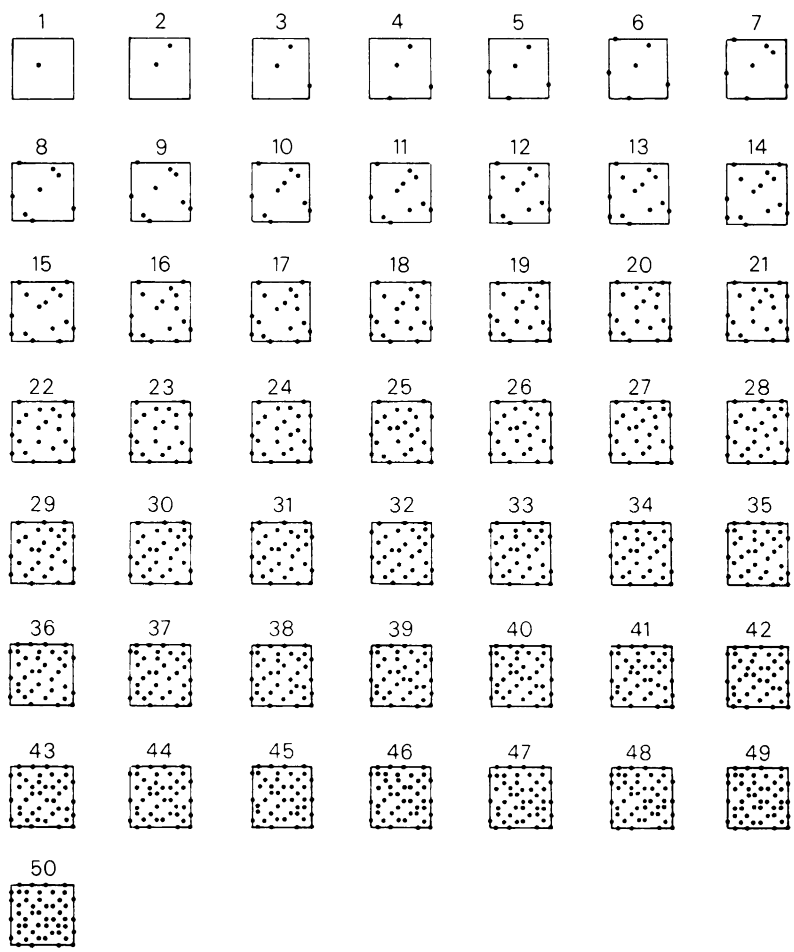


Figure 7. The Position and Number of Dots Within Each Matrix for the Systematic Symbology (50 Tones).

systematic, because it is composed of a random arrangement of dots in each matrix.

Visual Characteristics

There are several visual characteristics of the dot matrix patterns, some of which are affected by variables such as cell size, dot position within the matrix, pen size and photographic reduction. A wide range of gray tone shading patterns can be produced depending on cell size. Matrix patterns used in this study range from 1 dot to 50 dots. Therefore, 50 different gray tones may be presented on the map depending on the distribution of the data. Each tone is separated by an increment of 1 dot providing a smooth progression of gray tones across the surface.

Two different pattern constructions (systematic and random) are possible by varying dot placement within the matrix. Since dot locations are fixed by the matrix, the style of each pattern remains consistent throughout the map. When visually comparing the systematic and random patterns, the gray tones of the systematic symbols appear slightly darker at the higher end of the scale, than the random design. This may be attributed to the systematic placement of dots eventually filling up the entire matrix evenly, whereas the random dots are likely to overlap or leave open spaces within the pattern. A reflection densitometer was used to measure the optical density for high, medium and low density regions on the systematic and random maps. A series of density readings were averaged and converted to dot percentages. These measurements indicated that systematic patterns did have slightly higher percentages of area inked by dots than random designs. High density areas on the systematic maps were about 4.5% higher in dot percentage than the same areas on random maps. Medium density areas on the systematic maps were approximately 3.5% higher and low density areas 2.0% higher in dot percentage.

The texture of the patterns can vary according to cell size, pen size and the amount of photographic reduction. Smaller cell sizes and smaller pen sizes both contribute to finer pattern texture. Dot density and fineness of texture are also increased with photographic reduction. The systematic and random symbols differ most markedly in regularity of pattern. Even with a 50% reduction in size, this regularity is still apparent with the systematic pattern. However, by randomizing the dots, this regularity is eliminated.

Production

A computer program written in BASIC and executed on a Tektronix computer-graphics system was used to produce the maps discussed in this thesis (Groop, 1982). A series of geographic base files and data files were stored on a magnetic tape in vector mode. A digital plotter was used to draw the dot shading patterns by starting at the lower left corner of each county and moving along the x-axis from cell to cell adding dots within each matrix. The gray tones or numbers of dots are determined by an algorithm that scales the data range such that the county with the highest data value may receive 50 dots in each matrix and the county with the lowest data value 1 dot in each matrix. Since plotting time took approximately 5-6 hours to plot 30 tones and 7-9 hours to plot 50 tones, using the Tektronix system was not very efficient. However, it is an inexpensive system to use and many different maps can be designed experimentally without involving expensive computing costs. A "00" (.30mm) ink pen, rather than a larger size, was used to plot the maps, because it resulted in a finer and more pleasing image. After the maps were plotted, they were photographically reduced to 50% of their original size. This reduction increased dot density, reduced pattern texture and contributed to the visual impression of gray tone shadings.

CHAPTER III

PROBLEM STATEMENT AND METHODOLOGY

The Problem

Statistical maps are designed to communicate two types of information. The first is tabular information, which can be obtained, value by value, from individual symbols on the map. The second type of information is integrative. This kind of information is not conveyed from studying individual symbols, but rather from a combining process wherein symbols are merged into fields to form patterns or regions (Jenks, 1973, p. 27).

The communication of integrative patterns is the primary purpose of statistical mapping. The map reader should be able to look at a map and see general patterns from the combination of individual symbols. Determining the effectiveness of a map to convey these patterns to the reader is perhaps one of the highest criteria by which the graphic symbolization, thus the mapping method, may be evaluated (Peterson, 1979).

The evaluation of the unclassed choropleth dot matrix method focuses on the problem of determining the effectiveness of two variations of the symbolization (systematic and random) in conveying regional patterns to map readers.

The examination of this problem centers more specifically on two questions:

1. With which of the two symbol-producing techniques, systematic or random, are regional patterns more consistent among map readers?

2. With which of the two symbologies do map readers more accurately recall regional patterns?

The null hypothesis to be tested states that there is no difference in the effectiveness of the two symbol-producing techniques and that neither the random nor systematic symbologies will result in more consistent and more accurate responses from map readers.

Methods of Testing

Most research in cartography has concentrated on the psychophysical testing of individual symbols on maps. A multitude of studies exist on the magnitude scaling of point and line symbols according to human perceptions and only recently has there been more emphasis on the perception of integrative map patterns.

One method for studying the effectiveness of maps in portraying integrative patterns is the region-drawing experiment. Readers are asked to draw boundaries separating the regions they perceive on maps. This task is designed to approximate the mental formation of regions experienced by the reader when examining a map. While there is some evidence suggesting that individuals are inhibited by tasks which involve a graphic response, until a method is developed to obtain perceptual images from a reader's brain, the region-drawing task is probably the best solution (Jenks, 1974).

Several cartographers have employed this methodology in studying the perception of regional patterns on dot, proportional circle and choropleth maps. Jenks (1973) asked map readers to locate areas of high, medium and low density on a dot map. The results were not very consistent, but he concluded that each response was a logical generalization of the original map. Jenks (1975) also employed the region-drawing task on proportional circle maps with a wide range of patterns and different degrees of clustering. He concluded that readers do see regions consistently on proportional circle maps, especially those that contained clustered circles. McCleary (1975) asked readers to draw boundaries between different densities of dots in a regionalization test. He found that where differences in density were great, readers were consistent in drawing regional boundaries. On illustrations where the density differences were minimal, readers were not very consistent in drawing similar boundary lines. McCleary also discovered two different styles of region drawing among test subjects. Readers who were overly concerned with detail and drew boundaries around every slight change in density were called atomists. Those who drew lines around only general patterns of density were called generalists. Muller (1979) instructed map readers to categorize areas of high, medium and low density on a continuously shaded choropleth map. He concluded that map readers can organize the elements of an unclassed map in a consistent and logical manner. Lavin (1979) used the region-drawing experiment to investigate the effects of pattern complexity on the regional perceptions of choropleth maps. He found that readers were less consistent in locating regions on maps as the complexity of the patterns increased. Rogers and Groop (1981) studied the effectiveness of color dot maps in region portrayal. Test subjects were asked to draw boundary lines around specific areas within color and black and white dot maps. Map readers were slightly more consistent in drawing regions on the color dot map, and they concluded that the color dot mapping technique was at least as effective as the black and white mapping method.

In this study map readers were asked to draw boundaries separating regions of high, medium and low density on unclassed choropleth dot matrix maps. It was assumed that the consistency among subjects in locating regions on maps is indicative of the effectiveness of the symbols (systematic or random) produced by this mapping technique. Some critics may question why we would want map readers to regionalize or in a sense classify unclassed maps. If so, they claim, why not class the maps in the first place? There is evidence that map readers organize map patterns into groups or "chunks" of information to be stored in memory

(Eastman, 1982). Instructing readers to draw boundaries around perceived regions may be similar to this mental process. Also, it is important to discover whether map readers can organize visually unclassed maps in a consistent and logical fashion. If so, perhaps classification is not an essential phase of map design.

Another source of controversy among critics is the concept of consistency in the region-drawing experiment. The consistency with which readers mark regions is used as a measure of whether that particular mapping method is an effective communication device. Why is consistency important, and what does it mean? Perhaps an analogy can be drawn with language. It is vitally important that we all understand a common language and that we speak, write and read in a consistent manner. This consistency in comprehending the symbols, numbers and letters which make up a language should exist in map communication as well. If we are in total disagreement over the spatial information on a map, then the map has failed in communicating its message. We are striving to create a common map language in cartography, and the measure of consistency shows how successful we are in reaching this goal.

Two additional methods used for evaluating the effectiveness of maps to convey regional patterns are pattern recognition and pattern recall. Pattern recognition is mostly a comparative process between map patterns, whereas pattern recall requires the reader to remember spatial information.

While pattern recognition has been widely employed in cartographic studies involving map comparison (Muehrcke, 1973; Muller, 1975; Lloyd and Steinke, 1977), pattern recall has been limited to only a few studies. Steinke (1975) conducted a map reconstruction test which involved pattern recall. Eye movements were recorded as subjects looked at a graduated circle map. After subjects finished observing the map, he asked each to prepare a replication of the pattern using a base map and adhesive circles. Steinke found that there was little relationship between the time spent looking at a map and the ability of the reader to reconstruct it. Downs and Stea (1973) tested subjects on their abilities to recall cognitive maps of their environment. It becomes difficult to compare the results of these experiments since age, map training, artistic skills and socio-economic background of the test subjects influence their abilities to recall and sketch this spatial information. Cole (1979) evaluated psychophysical testing methodology by studying specificity in map reading instructions and the tasks of pattern recognition and pattern recall. Cole found that recall always produced greater response error than recognition. Although the use of recognition is greater than recall in cartographic testing, recall is conceptually more important. In map reading, readers seldom refer back to a previously viewed map. Instead, they rely on recollections of the map pattern when viewing a second map; therefore, unless the maps are adjacent to each other, recall may assume the dominant position in map reading tasks (Cole, 1979, p. 5).

In this research, the second half of the map reading test involves pattern recall. Map readers were instructed to examine six shaded isoline maps on a page and to choose the one which most closely resembled the map pattern they viewed in the region-drawing experiment. It was assumed that the accuracy with which subjects recalled regional patterns was reflective of the effectiveness of the symbolization (systematic or random) produced by the mapping method.

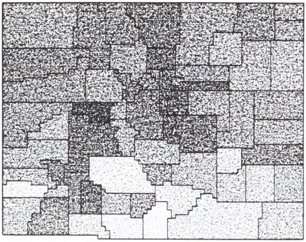
Design of the Experimental Maps

The test maps were constructed with real world data in order to make the map reading task more realistic. The data were taken from the 1970 Census of General Social and Economic Characteristics. The two variables chosen were the percentage of high school graduates and the percentage of unemployed persons, both on a county level for the state of Colorado. After producing experimental maps with a variety of data sets, these two variables were chosen for several reasons. First, the data were in the form of percentages, which was appropriate for choropleth mapping. Second, data values exhibited a fairly uniform statistical distribution allowing a uniform distribution of gray tones on the maps. Third, the two data sets displayed totally different patterns from each other.

The state of Colorado was selected as the geographic base for the test maps for several reasons. First, the square outline of the state and most of the counties facilitated easier production using the dot matrix method, since every enumeration unit (county) must consist of a number of square grid cells. Second, the number of counties in the state (63) was a practical number of counties to work with, allowing a reasonably complex pattern to be produced. Third, the bias of map readers was minimized since the majority of the readers, students at Michigan State University, would be unfamiliar with Colorado. Finally, there were a variety of socio-economic regions in the state such as the Denver metropolitan area, ski resorts, mining areas, farmlands, and Indian reservations that created interesting and diverse regional patterns.

The test maps consisted of a systematic and random version of the education data and a systematic and random version of the unemployment data. On each map the data are assigned tones from the 50 available, according to the position of the data within the range. In order to enhance the visual quality of the gray tones, the maps were reduced to 50% of their original size (from approximately 6" x 5" to 3" x 2.5"). Multiple copies of the final maps were photographically produced, since xeroxing did not maintain the quality of the pattern. The scale of the maps was 100 miles to an inch. The test maps are shown in Figures 8 and 9. Map titles, legends and scales were not included on the test maps to avoid bias in region perception responses from the map readers. The objective of the region-drawing experiment

Random



Systematic

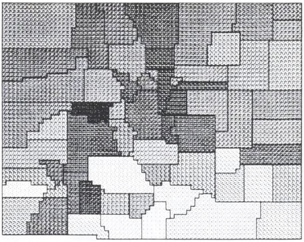
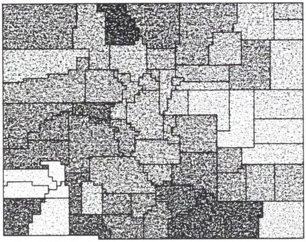


Figure 8. An Example of Two Choropleth Test Maps Reduced to Final Size (Education Data).

Random



Systematic

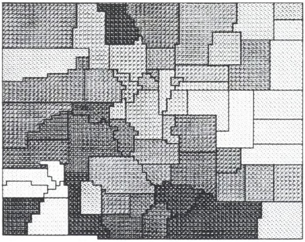


Figure 9. An Example of Two Choropleth Test Maps Reduced to Final Size (Unemployment Data).

was to have readers look for general regional patterns, not specific tabular information.

Accompanying each choropleth map was a set of six shaded isoline maps corresponding to the appropriate data set (either education or unemployment). The production of these maps began by creating isoline maps from the two data sets using the GEOSYS (Wittick, 1980) computer mapping program. Variations of the actual maps were then created by subjectively rearranging the elements, shapes and tones of the pattern. These maps were designed so as to appear similar to the map reader, yet different enough so that the correct maps could be detected. The final map prints were produced photographically using negative screen tints to provide the gray tone shadings. These prints were xeroxed on a high quality Kodak Ektaprint Copier to produce multiple copies. Examples of the isoline maps are shown in Figures 10 and 11.

Test Instructions

Two variations of the dot matrix symbolization (systematic and random) were used as test instruments in this investigation. The systematic version consisted of a single choropleth map produced with the systematically spread symbology and a set of numbered instructions. This formed the first half of the test. Accompanying the choropleth map was a set of six shaded isoline maps on a page corresponding to the data illustrated on the choropleth map and numbered test

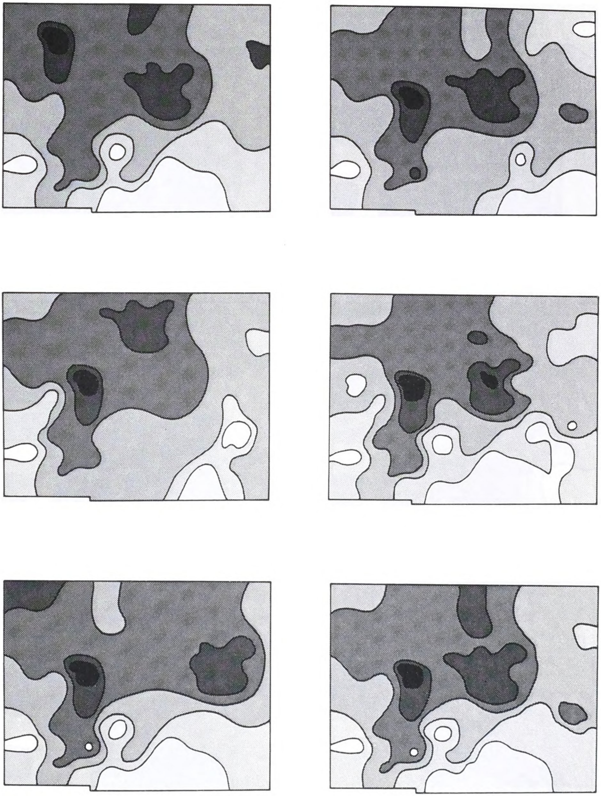


Figure 10. An Example of the Shaded Isoline Maps (Education Data).

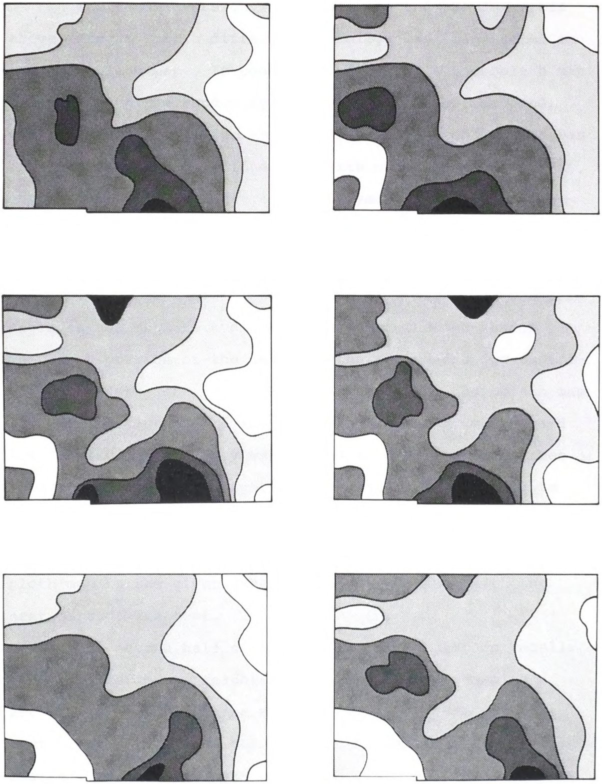


Figure 11. An Example of the Shaded Isoline Maps (Unemployment Data).

instructions. This comprised the second half of the test.

The random version was similar to the one described above, except that a different symbology was illustrated on the choropleth map. It consisted of a single choropleth map produced with the random symbology and a set of numbered test instructions. Also accompanying the choropleth map was a set of six shaded isoline maps with numbered instructions, corresponding to the data set portrayed. The test instructions for both versions were identical (see Appendix A for an example of the test instrument).

The written test instructions were placed on the same pages as the maps to avoid confusion for the map reader. The first portion of the test was the region-drawing experiment. Readers were instructed to examine the choropleth map in their booklet and to locate regions of high, medium and low density. Next, they were asked to draw boundary lines separating regions of high, medium and low density and to label each area with an H, M, or L. After finishing the region-drawing task, they were instructed to put the choropleth map in the given envelope and to continue with the next part of the test.

The second half of the test involved pattern recall. In this experiment, readers were instructed to examine a set of six shaded isoline maps and to choose the one that most closely resembled the map pattern they had observed in Test #1. After completing the pattern recall task, readers were also told to place this page of maps in the envelope.

At the end of the testing, each subject was given three rating tasks. The first task was to rate the difficulty in locating regions on the map in Test #1. The second task was to rate the visual appearance of the choropleth map in Test #1. The third task was to rate the difficulty in remembering the general pattern of the choropleth map in Test #2 (see Appendix A).

Test Administration

The map reading tests were administered to 148 students enrolled in two separate introductory geography courses at Michigan State University. The test subjects were not expected to have had any cartographic training. Certain demographic characteristics of the population such as age, race and sex were not considered in this testing sample. Due to limited time and resources, the sample consisted only of university students.

A brief introduction was given to both groups explaining the task of region-drawing, and a few illustrations were demonstrated using maps that ranged from a simple hand-drawn map to a computer-produced isoline map. The actual choropleth test maps were not displayed in the demonstration. During the region-drawing demonstration, it was made apparent that the subjects should follow along unit boundary lines and not locate lines across units. Since it was assumed that this group of test subjects had little prior map experience, the concept of generalization in statistical mapping was introduced, so that subjects would not draw boundaries around every separate county. The oral testing instructions and the sample maps are contained in Appendix B.

After the introduction, tests were distributed, and each subject received either the systematic-education version, the systematic-unemployment version, the random-education version or the random-unemployment version. Subjects were supplied with color felt-tip pens so that the delineation of the regions could clearly be seen. There were no time limits imposed on the readers, but most of them had completed the testing in 10 minutes or less.

When the completed test booklets were examined, 10 tests were eliminated from the total, because the subjects failed to follow instructions correctly. This adjustment resulted in a total of 138 responses, with 67 in the systematic group and 71 in the random group.

CHAPTER IV

DATA ANALYSIS

In order to determine whether one of the map symbologies (systematic or random) was more effective in conveying regional patterns, comparisons were made of the following: 1) subjects' agreement in locating regional patterns of density on maps, and 2) their ability to recall those patterns. The data analysis is thus divided into two sections - consistency of region response and accuracy of pattern recall.

Consistency in Region Response

The first step in measuring the consistency in region response was to collect data in the form of frequencies from the region-drawing experiment. A transparent overlay of the 63 counties in Colorado was placed over each response map (a sample response map is shown in Figure 12). The number of subjects who placed a particular county within a region (either high, medium or low) was recorded on a tally sheet. A separate tally of responses was collected for each type of region (high, medium and low) for each map. Thus, a total of twelve frequency maps were compiled. Lavin (1979) refers to these maps as consensual response maps. An example of the consensual response map for high density regions on the

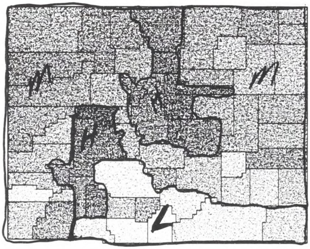


Figure 12. A Sample Response Map

systematic - education map is shown in Figure 13. Zeros indicate no response to a county, but they are included in the calculations described below.

The statistical variance was calculated for each region type from the frequency data using:

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{n-1}$$

Where: x_i = frequency of response to a county

$\bar{x}$ = mean frequency of response

n = total number of counties

Statistical variance is a measure of the dispersion of values about the mean of a frequency distribution. It expresses the amount of variability in a data set. Sample distributions of data are shown in Figure 14. The data for Figure 14a are located close to the mean and statistical variance is low. In Figure 14b the data are spread more evenly throughout the range and the variance is high. Variance can also be used as a measure of consistency in region response. Low variance means that respondents are in disagreement over regional boundaries, while high variance indicates general agreement among respondents (Lavin, 1979, p. 166). This unusual relationship can be illustrated by the distributional characteristics of the two frequency surfaces shown in Figure 14c-d. The frequency surface in Figure 14c has a low measure of observed variance. This diagram consists of frequencies that are evenly distributed across the surface, which indicates variability in subject

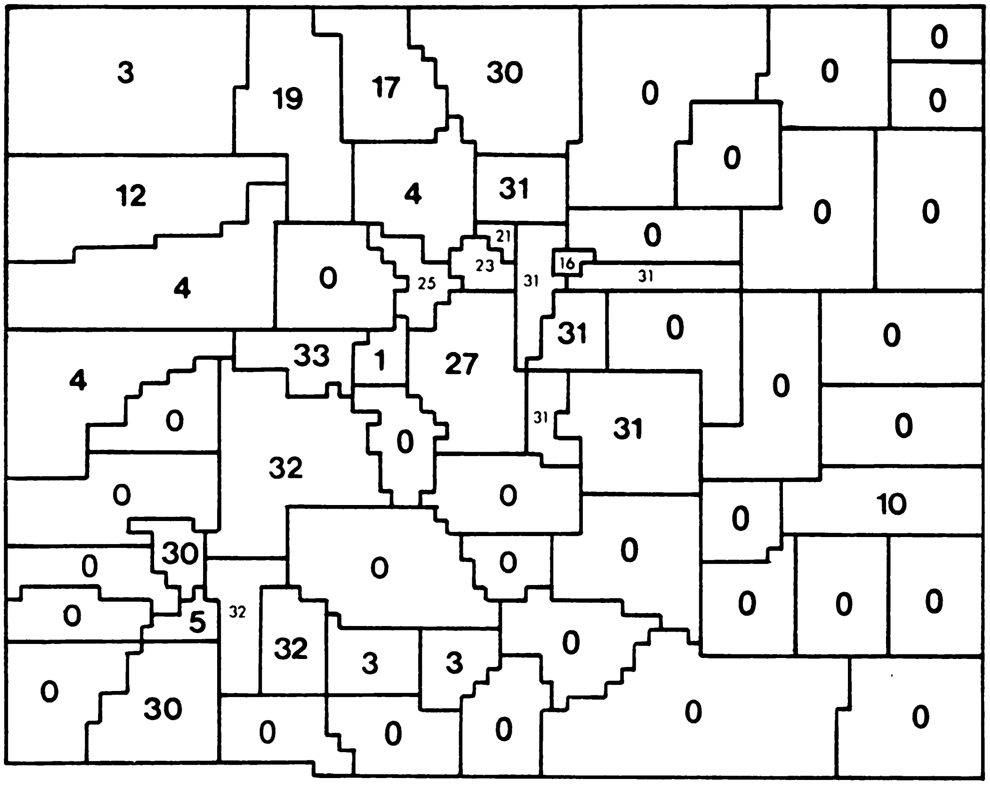


Figure 13. A Consensual Response Map - High Density Regions on the Systematic (Education) Map.

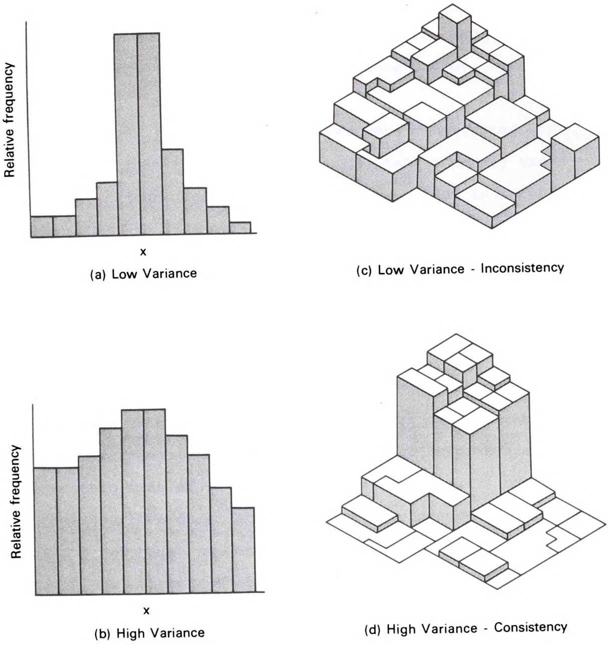


Figure 14. Sample Distributions of Data

response, and respondents tend to be inconsistent in their regional perceptions. The frequency surface shown in Figure 14d has a high measure of variance. This map is composed of high and low frequencies across the surface, which shows little variability in subject response, and respondents are fairly consistent in their placement of regional boundaries.

Consensual frequency surfaces were constructed for each of the four test maps. In a qualitative sense, these three-dimensional frequency surfaces are useful in seeing differences and similarities in regional responses between maps. Figures 15 and 16 show frequency response surfaces of high, medium and low density regions for random and systematic - education maps. At first glance the random response surfaces appear similar to the systematic response surfaces, however, closer inspection reveals more consistency among random maps in particular areas. The high density random response surface indicates more consistent responses along the western side of the state. The medium density random response surface shows slightly more consistency in the central and northwestern corner. More agreement among respondents in the northern half of the state is evident on the low density random response surface. Figures 17 and 18 show frequency surfaces of the three density regions for random and systematic - unemployment maps. Low density response surfaces are quite similar and neither appears more consistent than the other. However, the high and medium density

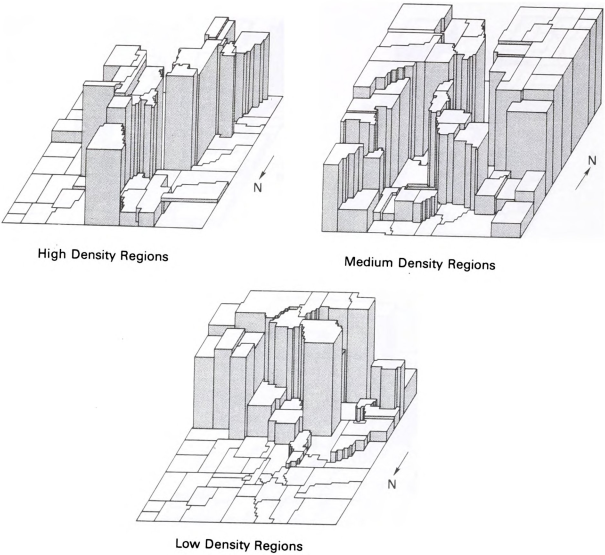


Figure 15. Frequency Response Surfaces of Random - Education Maps.

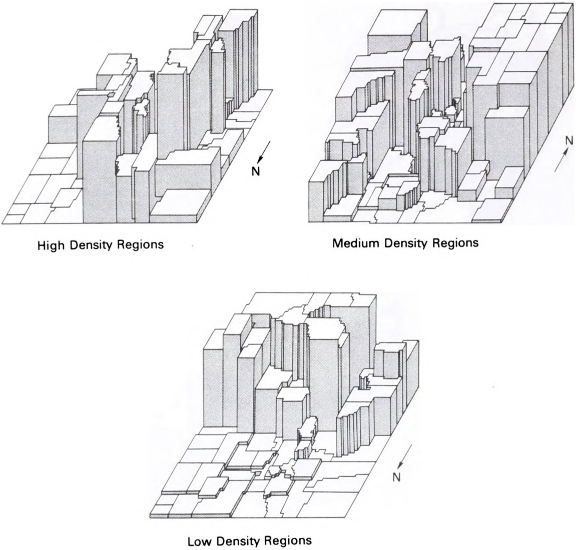


Figure 16. Frequency Response Surfaces of Systematic - Education Maps.

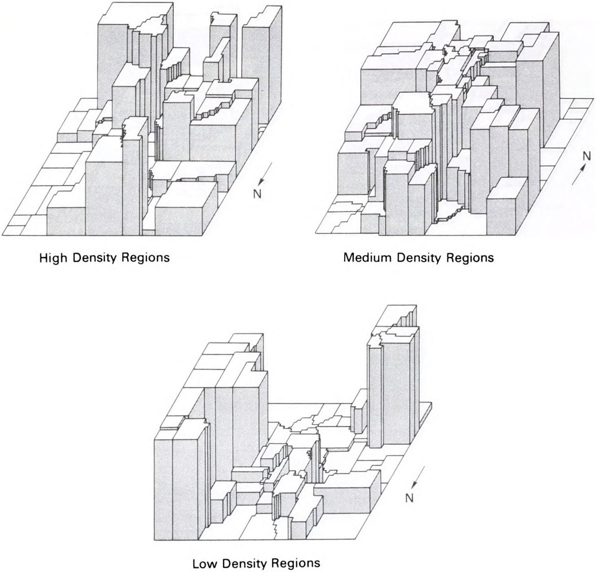
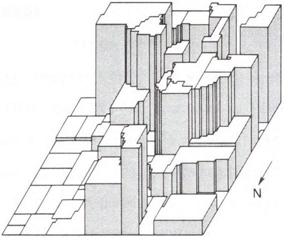
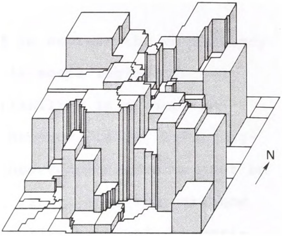


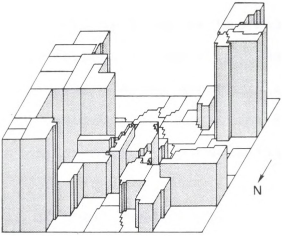
Figure 17. Frequency Response Surfaces of Random - Unemployment Maps.



High Density Regions



Medium Density Regions



Low Density Regions

Figure 18. Frequency Response Surfaces of Systematic - Unemployment Maps.

systematic response surfaces exhibit slightly more high and low frequencies throughout the maps indicating more agreement among respondents. It is also apparent that map readers tend to be more consistent in locating high and low density regions rather than medium density regions on all the maps.

Since variance may be used to express the consistency in region response within a map, it seems logical to use this measure in comparing the variability in subject response for the two symbologies. However, Lavin (1979) suggests that using the measure of observed variance may not be the best choice for two reasons. First, observed variance has no numerical limits (Lavin, p. 172); therefore, variances between response maps are not directly comparable due to differences in the total frequency of response (sum of the times each county was included in the region) and the total number of zero responses (Lavin, p. 196-8). Second, variance is a meaningless measure except in a relative sense. Thus, it is inappropriate to assume that observed variance reflects region perception variability (Lavin, p. 172).

As a result of these disadvantages, Lavin developed a standardized equation of region perception variability known as the variance ratio:

$$\text{Variance ratio} = \frac{\text{Observed variance } (V_{observed})}{\text{Maximum possible variance } (V_{max})}$$

Maximum possible variance occurs when all subjects are in perfect agreement in the placement of regional boundaries. V_{max} can be computed if the total response frequency and the number of subjects are known (Lavin, p. 199):

$$V_{max} = \frac{\frac{\Sigma x}{N}\left(N - \frac{\Sigma x}{n}\right)^2 + \left(n - \frac{\Sigma x}{N}\right)\left(\frac{\Sigma x}{n}\right)^2}{n - 1}$$

where: x = frequency of response to a county
n = total number of counties
N = number of subjects

The values resulting from the computation of the variance ratio range from zero (complete disagreement on regional boundaries) to one (total agreement on regional boundaries), allowing direct comparison between response maps. Also variance ratio values are more meaningful since they can be directly related to region perception variability. For example, a value of .589 means that approximately 59% of the subjects are in agreement over the location of regional boundaries (Lavin, p. 212).

Lavin also cites several limitations concerning the variance ratio. Computation of the V-ratio is dependent upon sample size and total frequency of response. Any changes in sample sizes would mean that a new V_{max} and V-ratio would have to be computed. Also V_{max} is derived empirically and has not been mathematically justified (Lavin, p. 212).

Comparison of Variance Ratios

Variance ratios allow comparison between symbol types to determine which symbology results in more consistent responses from map readers. Table 1 lists the variance ratios for high, medium and low density regions on the systematic (education and unemployment) and random (education and unemployment) maps.

Table 1

Comparison of Variance Ratios

Systematic (Education)	Random (Education)
High Density = .740	High Density = .804
Medium Density = .583	Medium Density = .698
Low Density = .695	Low Density = .723
Systematic (Unemployment)	**Random (Unemployment)**
High Density = .747	High Density = .542
Medium Density = .566	Medium Density = .516
Low Density = .730	Low Density = .744

It is apparent from the table that with the exception of high and medium density regions on the systematic-unemployment map, there was slightly more agreement among subjects locating regions with random symbology. However, responses from the random maps were an average of only 5% higher than on the systematic maps. Therefore, it is difficult to state that the random symbology may be more effective in conveying regional patterns, since differences are very small and overall results are somewhat mixed.

Overall, variance ratios were higher among the high and low density regions (an average of .708 and .723 respectively) than the medium density regions (an average of .590). The high and low density regions were probably the easiest regions to locate because of darker and lighter gray tones. High and low density regions were also smaller in size and more localized, while medium density regions were larger and more dispersed across the map surface.

Among specific region types, the most consistent response occurred in the identification of high density regions on the random - education map. The most inconsistent response occurred in locating medium density regions on the random - unemployment map.

The F-test for analysis of variance was used to determine if differences in responses between high, medium and low regions for the random and systematic maps were significant at a given probability level. The null hypothesis is that no difference exists between the two variances. The F-ratio at the .05 level of significance was calculated using the formula:

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

Where: s^2 = variance
n = sample size

Results of the F-test are shown in Table 2. Since the resultant F statistics were not greater than the critical F values, the null hypothesis can not be rejected. Thus, there was no significant difference in variances between the systematic and random maps for any of the regions.

Table 2

Analysis of Variance F-Test

a = .05/2 tailed $\qquad H_o: s^2_{random} = s^2_{systematic}$

Region of Density	Degrees of Freedom	Critical F	Resultant F	Decision
Education				
High	33,32	1.84	1.131	Accept H_o
Medium	33,32	1.84	1.291	Accept H_o
Low	33,32	1.84	0.936	Accept H_o
Unemployment				
High	36,33	1.79	0.778	Accept H_o
Medium	36,33	1.79	1.099	Accept H_o
Low	36,33	1.79	1.132	Accept H_o

Based on Number of Respondents

Accuracy in Pattern Recall

The second portion of the data analysis compares the accuracy with which subjects recalled regional patterns between systematic and random maps. Data were collected by counting the number of correct choices made by respondents for each map type. Results are shown in Table 3. Overall, it appears that readers were able to recall the pattern slightly better with random symbols (52% judged correctly) than with systematic symbols (46% judged correctly). The difference between the proportion answering correctly on the random maps and the proportion answering correctly on the systematic maps was 6%. To test whether the difference in the response between the random and systematic maps was significant, the binomial test for differences of proportion was chosen to compare counted data in which individual responses are assigned to one of two categories - in this case, correct responses in the random map category and correct responses in the systematic category.

Table 3

Pattern Recall Test

Individual Responses	Correct	Incorrect	% Correct
Systematic Education (33)	12	21	36
Random Education (34)	12	22	35
Systematic Unemployment (34)	19	15	56
Random Unemployment (37)	25	12	67
Total Responses			
Systematic (67)	31	36	46
Random (71)	37	34	52

The null hypothesis is that there is no difference in pattern recall accuracy between the random and systematic symbology. Since it is not possible to predict which symbology will result in a more accurate response, a two-tailed test was chosen with a significance level of .05. The proportion of correct responses in each sample is regarded as an estimate of the proportion in the total population. The binomial test determines whether or not the difference of 6% was due to chance in the samples. The standard error of the estimate for counted data is calculated as:

$$S.E. = \sqrt{(p\%\ q\%/n)}$$

where: p = % of correct responses
q = % of incorrect responses
n = sample size
(provided that pqn is greater than 9)

The standard error of the difference is:

$$S.E._{diff.} = \sqrt{(S.E._1)^2 + (S.E._2)^2}$$

where: $S.E._1$ and $S.E._2$ = standard errors of the two sample estimates

The actual difference of the estimates is expressed as a z-score:

$$z = \frac{d}{S.E._{diff.}}$$

where: d = difference

Applying these formulae to the data resulted in a z-score of .7. In a two-tailed test the z-value of .7 is not greater than 1.96 (the critical value of z corresponding to the .05 level) and the null hypothesis can not be rejected. Thus, there was no significant difference in the accuracy of responses between the two symbologies.

Additional Analyses

Table 4 displays the results of the multiple choice questions answered by subjects at the end of the testing session. Difficulty in locating regions on maps was rated either 'easy' or 'difficult' with very few responses in the 'very easy' or 'very difficult' categories. Approximately 43% of the systematic map users thought it was easy to locate regions, while 48% thought it was difficult. About 55% of the random map users rated the task of drawing regions as easy, while 38% considered it difficult. In general, subjects viewing the random maps considered the region-drawing task to be easier than subjects viewing the systematic maps.

In rating the visual appearance of the maps, the majority of subjects considered them either 'displeasing' or 'appealing' rather than 'very displeasing' or 'very appealing'. Nearly 48% of the systematic map viewers rated the map's visual appearance as displeasing, while 36% thought it was appealing. While 54% of the subjects viewing the random maps found them displeasing, 25% considered them appealing. It is interesting to note that 13% of those viewing the systematic maps and 17% of those observing the random maps chose the 'don't know' response for this question. In general, subjects found both the systematic and random maps displeasing. However, about 6% more random map viewers chose the 'displeasing' response.

The last question rated the difficulty in remembering the map pattern from the region-drawing experiment. Most subjects found it either 'easy' or 'difficult' and some thought it was 'very difficult'. Approximately 55% of the subjects using the systematic maps found it difficult to recall the pattern, while 30% thought it was easy. Nearly 56% of the random map users considered the task of pattern recall difficult, while only 27% found it easy. About 11% of both the systematic and random map users thought it was very difficult to recall the map pattern. Overall, subjects viewing either the random or the systematic maps found it difficult to remember the map pattern used in the region-drawing task. It must be emphasized that these figures are not entirely comparable since they did not necessarily come from the same population.

Table 4

Responses to Multiple Choice Questions

Difficulty in Locating Regions:

Individual Responses	Very Easy	Easy	Difficult	Very Difficult	Don't Know
Systematic Education (33)	0	15	18	0	0
Random Education (34)	0	21	12	1	0
Systematic Unemployment (34)	2	14	14	0	4
Random Unemployment (37)	1	18	15	2	1
Total Responses					
Systematic (67)	2	29	32	0	4
Random (71)	1	39	27	3	1

Visual Appearance of the Map:

Individual Responses	Very Displeasing	Displeasing	Appealing	Very Appealing	Don't Know
Systematic Education (33)	1	17	14	0	1
Random Education (34)	1	15	9	1	8
Systematic Unemployment (34)	1	15	10	0	8
Random Unemployment (37)	1	23	9	0	4
Total Responses					
Systematic (67)	2	32	24	0	9
Random (71)	2	38	18	1	12

Table 4 (continued)

Individual Responses	Difficulty in Remembering the Pattern: Very Easy	Easy	Difficult	Very Difficult	Don't Know
Systematic Education (33)	0	9	18	6	0
Random Education (34)	2	6	22	3	1
Systematic Unemployment (34)	1	11	19	2	1
Random Unemployment (37)	0	13	18	5	1
Total Responses					
Systematic (67)	1	20	37	8	1
Random (71)	2	19	40	8	2

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Several methods of portraying stepped statistical surfaces exist, two of which are classed and unclassed maps. The unclassed technique eliminates problems involved with choosing class intervals and number of classes. Recent literature suggests that unclassed choropleth maps are viable alternatives to traditional ones, and that map readers can organize visually the elements of an unclassed map in a logical and consistent manner.

A computer-generated symbol system utilizing dot matrix technology can be used to produce areal symbols on choropleth maps. The unclassed dot matrix method may be an alternative among unclassed mapping techniques for several reasons. First, dot patterns rather than lines are used to create tones which may be more visually pleasing to map readers. Second, a wide range of gray tones can be produced. Third, dot matrix symbols allow smooth gradations between tones. Fourth, the symbols can be manipulated so that coarseness of pattern is minimized. Additionally, this method is produced using a micro-computer graphics system that is readily available at most computer installations.

The effectiveness of two types of dot matrix symbols, systematic and random, in conveying regional patterns to map readers centered on two questions concerning consistency of region recognition and accuracy of region recall. Two map reading tests were conducted, the first a region-drawing experiment in which subjects drew boundaries separating regions of high, medium and low density on unclassed maps, and the second a pattern recall test requiring subjects to remember regions. The null hypothesis stated that there was no difference in the effectiveness of the two symbologies and that neither the random nor systematic symbologies would result in more consistent and more accurate responses from map readers.

Results of the region-drawing test showed that map readers tended to be slightly more consistent in locating regions on test maps with random symbology, although the difference between the two symbologies was not statistically significant. Subjects viewing both symbologies were more consistent in locating high and low density regions rather than the medium density regions. Perhaps the high and low density regions were the easiest regions to see because of light and dark gray tones, smaller size and more localized placement on the map surface. The outcome of the pattern recall test showed that readers were able to recall patterns slightly better with random symbology. However, the difference between the proportion answering correctly with systematic symbology and random symbology was not statistically significant.

Conclusions

Results of this study indicate that the random symbology produced slightly more consistent and accurate responses from map readers. However, the very small differences in responses for both measures of consistency and accuracy make it difficult to conclude that the random symbology may be slightly more effective than the systematic symbology. The additional evidence that random map users found the maps visually displeasing further increases the difficulty in recommending the use of random maps over systematic maps. Therefore, it was concluded that neither symbology is more effective than the other in conveying regional patterns to map readers.

The dot matrix technique itself should not be overlooked as an alternative choice among unclassed mapping methods, since more than 50% agreement was achieved for each region of density on both random and systematic maps. In general, it may be concluded that readers can locate regions on these unclassed maps in a fairly consistent manner. If map readers had been totally inconsistent and confused in their responses, perhaps the validity of this technique might be questioned. However, these results suggest that the dot matrix method holds potential as an effective mapping technique and needs further investigation. The present study has introduced a different kind of mapping method and contributed to an initial understanding of the effectiveness of two map symbologies in conveying regional patterns. Before one can accept or reject this method, more research needs to be conducted.

Some changes and improvements in the present methodology are suggested below. Individual readers could have observed more than one type of map at a time; therefore allowing direct comparison between random and systematic maps when answering questions on aesthetic qualities. The creation of the shaded isoline maps used in the pattern recall test could have been more objectively designed, thus eliminating any possible bias on the part of the cartographer. Different groups of samples could have been tested and then compared, such as trained cartographers, geographers, non-geographers, young, old, minorities, etc. to discover whether map training or exposure influences readers' abilities to perform the testing tasks.

Additional research on the symbolization might include the possible discrepancy between perceived and actual values and the determination of an exponent to adjust for the nonlinear response of the human eye. A comparative evaluation between this unclassed method and a conventional class-interval method could be undertaken. Maps with different characteristics of texture, dot size and number of gray tones could be produced for map readers to compare and judge. Perhaps maps in full display with legend, title and scale would appear more interesting and appealing to readers, rather than experimental maps devoid of all explanatory material. Computer hardware should also be investigated to find a more efficient method of production.

The dot matrix method can be applied to both stepped and smooth statistical surfaces (Groop and Smith, 1982) and allows data to be classed or unclassed. Another application that needs to be studied is the unclassed choropleth two-variable color map. This technique over-prints the tones of two separate unclassed choropleth maps. The resulting tones are composed of the patterns from both maps. An example of this map is shown in Figure 19 using the random symbology. Color keys were made from the negatives of the original maps, one in cyan and the other in magenta. The two color transparencies were overlayed, and the different shades of cyan, magenta and purple are a result of the juxtaposition of the small colored dots. Jenks states that, "Color psychologists have demonstrated by experimentation that if a color is broken up into component parts and these component colors are presented in small dots, the sensation of the original color will be obtained ..." (Jenks, 1953, p. 4). Whether this map is effective in portraying the relationship between two-variables is a problem which needs examination.

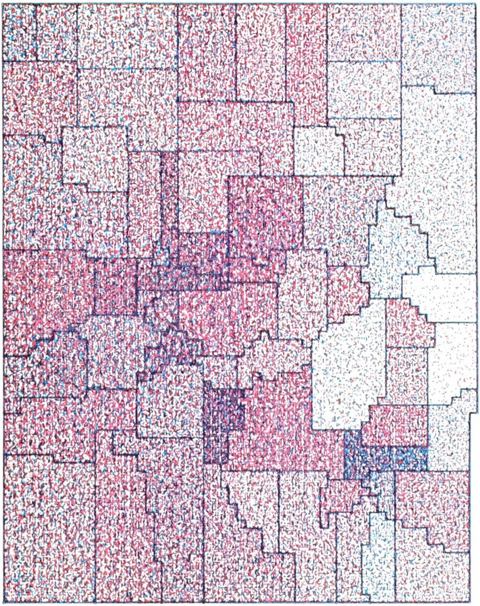


Figure 19. An Unclassed Choropleth Color Two-Variable Map

APPENDIX A

TEST INSTRUMENT

APPENDIX A

TEST INSTRUMENT

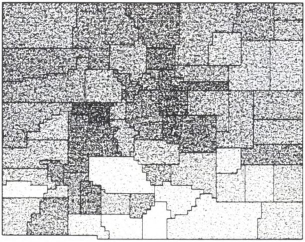
DO NOT OPEN TEST BOOKLET UNTIL INSTRUCTED TO DO SO

I understand the nature of and procedures used in this experiment, and I freely consent to participate. I may discontinue this experiment at any time. All results will remain anonymous, and I may review the results when they are completed. My participation will in no way affect my grades in this course.

Please turn.....

TEST #1

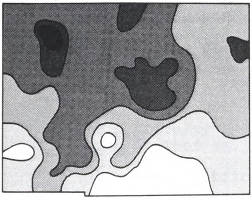
1. Examine the map below and locate regions of high, medium and low density (the darker the shade, the higher the density).
2. Draw boundary lines separating regions of high, medium and low density and label each area with an H, M, L (for high, medium and low).
3. If you feel that you have made a mistake in drawing lines, clearly make crosses over the line and redraw the correct line.

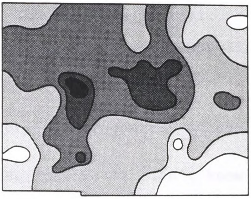


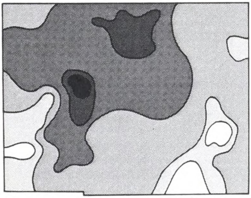
4. When you are satisfied with the regions you have drawn, place this page in the envelope and proceed with the next part of the test.

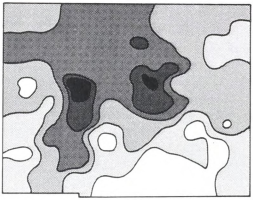
TEST #2

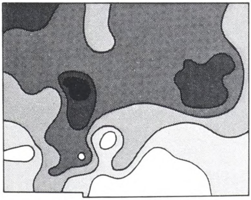
1. Examine the group of maps on this page.
2. Place an "X" on the map which most closely resembles the map pattern you observed in Test #1 (DO NOT LOOK BACK AT THE MAP FROM TEST #1).

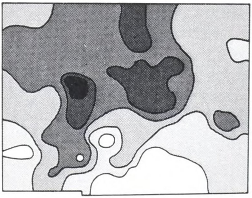












3. When finished, place this page in the envelope and continue to the next page.

Answer the following questions:

1. Rate the difficulty in locating regions on the map from Test #1.

   very easy   easy   difficult   very difficult   don't know

2. Rate the visual appearance of the map from Test #1.

   very displeasing   displeasing   appealing   very appealing

   don't know

3. Rate the difficulty in remembering the general pattern of the map in Test #2.

   very easy   easy   difficult   very difficult   don't know

When you are finished, please place all the materials in the envelope.

Thank you.

APPENDIX B

ORAL TESTING INSTRUCTIONS AND DEMONSTRATION MAPS

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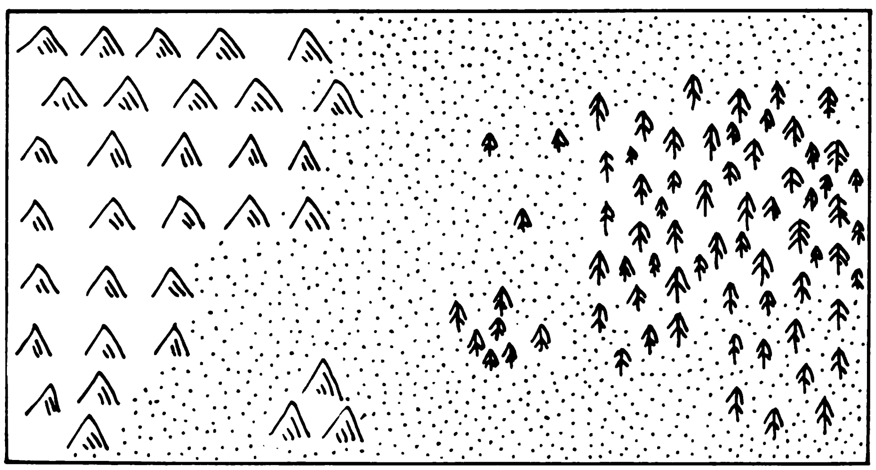
ORAL TESTING INSTRUCTIONS AND DEMONSTRATION MAPS

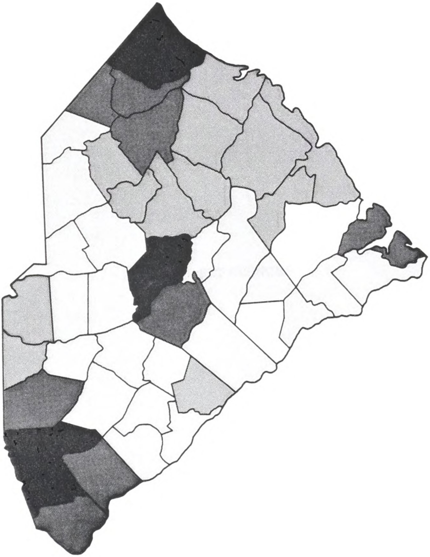
The test you will be taking here today is a map reading test. Part of the test requires you to draw regions on maps. I am sure that most of you can define the word region - it is simply an area of similar characteristics. For example, on this map I see three different kinds of regions - mountains, desert and scrubland. I can draw boundary lines separating the three regions like this. Now my regions may contain some minor areas with different characteristics, but they are not visually significant enough to stand alone as regions themselves. I am just drawing general regional patterns, and I am not concerned with detail.

Another example of region-drawing can be shown on this map which illustrates the distribution of snowfall in Michigan's lower peninsula. I see several general areas of high, medium and low density. Once again I am generalizing and looking at overall patterns of density.

If I asked you to look at this map of South Carolina and draw regions of high, medium and low density, each of you would probably see regions a little differently. For instance, I see several general areas of high, medium and low density. This is a subjective process, and there is no right or wrong way of doing this.

Now each of you has a booklet containing a map on which you will be drawing regions. I would prefer that you use a pen, so if you do not have one, I have plenty of extras up here. There is no time limit. Make sure that you read the instructions carefully, and you may now begin. When you are finished, please bring the materials to the front of the room.





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