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ABSTRACT

Value-by-area maps, or cartograms, provide a curiosity-provoking method of depicting geographically related data. The use of cartograms for learning such data involves a learner's familiarity with the region depicted and the distortion of true, earth-centered scale. To examine the effects of region familiarity and region distortion on learning from cartograms, 94 college undergraduates viewed a true-scale map of either a familiar or an unfamiliar region followed by either a cartogram or a data map of the same region. They then drew the true-scale map from memory and matched map data levels on a cued-recall map. Long-term familiarity was observed as an important prerequisite for successful use of cartograms. Cartogram depiction resulted in inaccurate reconstructions and degraded levels of data recall. The results are discussed with respect to a model of map learning and an interference hypothesis. Suggestions are made regarding the use of cartograms. One table and five figures illustrate the study. (Contains 32 references.) (Author/SLD)

The Use of Cartograms in Visualizing Data Associated With Familiar and Unfamiliar Areas

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Abstract

Value-by-area maps, or cartograms, provide a curiosity provoking method of depicting geographically related data. The use of cartograms for learning such data involves a learner's familiarity with the region depicted and the distortion of true, earth-centered scale. To examine the effects of region familiarity and region distortion on learning from cartograms, college undergraduates viewed a true-scale map of either a familiar or an unfamiliar region followed by either a cartogram or a data map of the same region. They then drew the true-scale map from memory, and matched map data-levels on a cued-recall map. Long-term familiarity was observed as an important prerequisite for successful use of cartograms. Cartogram depiction resulted in inaccurate reconstructions and degraded levels of data recall. The results were discussed with respect to a model of map learning, and an interference hypothesis. Suggestions were made regarding the use of cartograms.

Key words: cartogram, data map, true-scale, interference, map reconstruction, mental representation, thematic map.

The Use of Cartograms in Visualizing Data Associated With Familiar and Unfamiliar Areas

Attracting a learner's attention is a primary goal in effectively using instructional materials (Gagne 1985). With visual instructional materials one can attract attention by provoking curiosity in a learner. Thematic maps are curiosity provoking visuals appropriate for instructional topics that involve information relative to some geographic or political administrative areas. One particularly interesting type of thematic map is the value-by-area map, or cartogram, which arouses curiosity with its novelty and incongruity.

In cartograms, political or other administrative boundaries are drawn so they are proportional to some space other than their true geographical space in order to depict data from a theme, like population or income for instance (Dent 1993). Raisz (1934, 292), who developed the first cartograms indicated that their purpose was, " ...for educational uses and for the facilitation of business planning." Tyner (1992) pointed out advantages of cartograms in that they have a strong visual impact and that they attract a reader's attention because they present an unusual view of the world or an area. An additional advantage of using the cartogram method of depicting quantitative data is that no classing or range grading of data is necessary, and thus there is no loss of information through categorization of values represented (Olson 1976). However, one disadvantage is that a map reader's familiarity with a depicted region seems to be necessary in using cartograms to communicate effectively. Dent (1993, 213) stated, "communication with cartograms is difficult, at best because it requires the reader to be familiar with the geographic relations of the mapped space ...." Olson (1976, 372) supported the need for familiarity when she wrote, "Cartograms are usually visually striking and intellectually interesting, at least to those who are familiar with the ordinary map area." Eastman, Nelson, and Shields (1981) concurred that region familiarity is crucial to reading cartograms.

Though familiarity with a region is claimed to be helpful for a map reader to fully appreciate the area distortions of a cartogram, the requirement of familiarity has not, until presently, been tested empirically. Additionally, defining "familiarity" would seem useful since familiarity could indicate at least two general types of acquaintance: (a) "short-term" acquaintance (immediately preceding exposure) or (b) "long-term" acquaintance (prior memorable exposure in a different context). A short-term familiarity with a previously unfamiliar geographic region is logically necessary for a learner to have a basis for comparison of a cartogram's areal distortion (see Dent 1975). However, the crucial question is whether a long-term familiarity with a geographic region is necessary for effective communication using a cartogram. Seeing a correct geographical depiction of an unfamiliar region just prior to, or while viewing a cartogram of that same region (short-term familiarization) may overcome any requirement for long-term familiarity. This may be true since the information communicated by thematic maps need not always be dependent on prior experiences with a region. As Jenks (1973, 27) stated, "... thematic maps are highly intuitive in character since the map model represents an 'unseen' or intangible phenomenon. Additionally, one can conclude that these maps of unseen distributions need not agree with the mental map which may be held in the mind of the map reader."

One way to address the familiarity assumption is to simply ask whether a long-term region familiarity is necessary for effective communication with cartograms. To make this question more meaningful for typical map-related learning tasks, we are specifically interested in the degree to which familiarity affects a map reader's ability to make use of cartogram depictions. Realistic uses of cartograms include learning names and general shapes of regions depicted, learning quantities depicted, learning the spatial relationships among the names, shapes, and quantities, and learning names of regions associated with the quantities depicted. Whether these learning tasks can be accomplished without distorting a learner's mental representation of a depicted region's true, earth-centered scale is another crucial question. If using cartograms to accomplish certain learning tasks results in some form of retroactive interference (McGeoch 1932), whereby the more recently learned cartogram reduces and thus distorts recall of the previously learned true-scale representation, this cost associated with cartogram use may outweigh the attention gaining benefits. When alternative map types (data maps, choropleth maps, proportional symbol maps) could be used in accomplishing these same learning tasks, the cost of interference to the learner may become unnecessary. Though interference has traditionally been investigated using verbal material (Postman 1971), here we are interested in the characteristics of interference between two mental representations of maps. In particular we are interested in testing whether exposure to a distorted depiction results in the distortion of a learner's representations of a previously presented, non-distorted depiction. Such distortion would provide evidence for a type of retroactive interference between representations and warrant further investigation of this form of interference.

In order to test the familiarity assumption and the interference hypothesis one would need some way of assessing a learner's mental representation of a familiar or unfamiliar region. Sketch maps have frequently been used for assessing map readers' representations. In fact, Blades (1990) found that sketch map reliability was not affected by self reported familiarity with the region to be sketched. Thus, sketch maps could be a useful tool in eliciting information of one's memory for familiar and unfamiliar cartograms.

The cognitive processes associated with the cartogram learning tasks can be examined by using an existing model of map and text learning (Kulhavy, Lee, & Caterino 1985; Kulhavy, Stock, & Kealy 1994; Kulhavy, Stock, Werner-Bellman, Klein, & Brooks 1993). Although the present study does not examine map and text learning, the model described by Kulhavy, Stock and their associates is appropriate because thematic maps, which include cartograms, make use of both maps and verbal information (region names and theme data). In addition, thematic map studies have corroborated the model's relevant assumptions (Rittschof, Kulhavy, Stock, & Hatcher 1993; Rittschof, Stock, Kulhavy, Verdi, & Doran 1994). The two main assumptions of the model are labeled the "representational assumption" and the "computational assumption." Both of these assumptions have crucial implications for the use of structural and feature information in cartogram-related tasks.

Following Paivio's (1986) dual coding model, the representational assumption states that maps and verbal information are cognitively represented in functionally distinct memory stores. Maps are encoded as images in a non-verbal memory store, and information within these images can be accessed by learners simultaneously. These images contain both feature and structure information. Verbal information is represented in a verbal memory store as linguistic propositions which are accessible, for the most part, sequentially, or one unit at a time. These distinct memory stores can operate independently or they can activate one another through associative connections. For instance, a map's image can be used in working memory to access related verbal information. Additionally, the simultaneous availability of image information gives it a special status above the sequentially available verbal information. This special status has significance with regard to the computational assumption.

The computational assumption states that the capacity of working memory (Miller 1956) directly influences the amount of information that an individual is able to activate at any given time. Images permit a great deal of information to be retrieved and maintained in working memory, relative to the verbal information, because a great deal of structural information is encoded in an image. Structure in a map image allows "chunking" of information which enables a learner to switch attention from location to location on a map image without exceeding the capacity of working memory. Switching attention from unit to unit of verbal information is not as easily done, since between-unit activation must occur with words, rather than the more efficient within-unit activation in images. This computational advantage of images is also discussed by Larkin and Simon (1987) and Winn (1991) with respect to processing information from diagrams.

The feature information in an encoded map image also provides a computational advantage. Feature information includes Bertin's (1983) visual variables of size and shape. Cartogram features, like region shapes, take advantage of the map structure to cue interrelationships among themselves and to cue the associated verbal information like region names. For instance, cartogram region shapes, or features, can answer the question "What is it?" rather than the question "Where is it at?," that is answered by structural information. This distinction between the "what" and the "where" corresponds directly to visual and neurological evidence which indicates that vision and imagery share brain structures for visual-feature (what is it?) information and for spatial-structure (where is it at?) information (Marr 1982; Ungerleider and Mishkin 1982; Levine, Warach, & Farah 1985; Farah, Hammond, Levine, and Calvanio 1988; Tippett 1992).

With these computational and representational assumptions in mind, an analysis of the processes involved in task-specific use of cartograms can be examined. Predictions can then be generated concerning the use of cartograms to accomplish the previously mentioned learning tasks (learning names and general shapes of regions depicted, learning spatial relationships among names, shapes, and relative quantities depicted, and learning names of regions associated with the quantities depicted).

In addition to examining cartograms, the present study makes use of a data map, which is a true-scale map that depicts thematic data using numbers placed within each administrative region, rather than the area distortion of cartograms. If a familiar cartogram, an unfamiliar cartogram, a familiar data map, or an unfamiliar data map were used for the common learning tasks mentioned above, at least six general cognitive processes would be necessary for successful completion of these tasks. These six processes would include (a) encoding the overall mapped region's shape, including its relative dimensions (feature and structural information), (b) encoding each administrative region's shape, including their relative dimensions (feature and structural information), (c) encoding the map's theme or purpose (verbal and feature information), (d) encoding the data-decoding scheme (verbal and feature information), (e) encoding the region names (verbal information), and (f) encoding the spatial relations among names and regions (structural information).

While each of these processes would use some unknown amount of the limited computational resources available, there are possible computational advantages to using particular map representation types. One such advantage could be a learner's ability to recognize both names and shapes by accessing his or her long-term store. This advantage could be available to those who saw either of the two familiar maps. A second advantage could be the isomorphic, or true-scale depiction of a region, available to those who saw either of the data maps. A third computational advantage could be the explicitness of symbolic decoding of data, also available from either of the data maps. A fourth computational advantage could be the visual image decoding of data (synchronous rather than sequential access) available from either of the two cartogram depictions. Thus, the map types chosen (familiar data map, unfamiliar data map, familiar cartogram, unfamiliar cartogram) allow comparisons among computational advantages, providing direct tests of the familiarity assumption, the interference hypothesis, and the model of map learning relative to ecologically valid use of cartograms.

To test the assumption of region familiarity, the interference hypothesis, and the assumptions of the model described, subjects viewed a map depicting the true, earth-centered scale of a familiar or unfamiliar region followed by either a data map, or a cartogram of the same region. They were required to reconstruct the region's true-scale on a blank sheet, then label the map's region names and match the theme levels to corresponding administrative areas using an unlabeled map as a cue.

We made five general predictions regarding subjects' reconstructions and map labeling performance. On map reconstructions, predictions regarding map dimensions were identical for both the overall mapped region and each individual administrative region. Based on the familiarity assumption, we first predicted that unfamiliar maps including cartograms would lead to less accurate reconstructions than familiar maps with respect to map dimensions, map labels, and region location. Second, with the requirement to encode a distortion of true-scale, we predicted that seeing cartograms would lead to less accurate reconstructions than seeing tabular data maps, with respect to map dimensions only, due to interference with subjects' original non-distorted representations. Third, even familiar cartograms were expected to lead to a lower reconstruction accuracy than familiar data maps with respect to map dimensions. That is, cartograms were expected to increase distortion in reconstructions while holding familiarity constant, due to interference from their similar but different cartogram representations. Fourth, subjects who saw familiar maps were predicted to perform better on matching thematic data to their corresponding administrative areas than subjects who saw unfamiliar maps. This prediction derives from the computational advantage provided by learners' opportunities to match names, feature shapes, and structure to those already in long-term store, and then to use those names, features, and structure to cue the data. Fifth, subjects who saw cartograms were expected to perform better on matching thematic data levels to their corresponding administrative areas than subjects who saw tabular data maps because of the computational advantage provided by the simultaneously available image structure that they used to decode the data.

Tests of each of these predictions are made by comparing differences in learner's performance levels. Predictions one, two, and three translate to eight specific differences in map reconstruction performance. Predictions four and five translate to seven specific differences in map-cued labeling performance. Each of these comparisons is described in the results.

Method

Design and Subjects

Two levels of geographic region familiarity were crossed with two levels of true geographic area to form four between-subjects groups. The base design was a 2 region familiarity (familiar vs. unfamiliar) x 2 true-scale (distorted vs. not distorted) factorial. The subjects were 94 undergraduates attending a large public university in the southwestern United States who volunteered for participation (N = 23, N = 24, N = 23, and N = 24 for the between-subjects cells). Subjects received course credit for participation in the experiment and were randomly assigned to the four between-subjects groups in the order they appeared for the experiment.

Materials

Maps. Four stimulus maps, each representing one of the between-subjects cells, were used. Cartograms were used to represent distorted geography while numerical data maps were used to represent true, undistorted geography. A cartogram and a numerical data map depicting twelve states in the western portion of the United States of America (familiar region) were constructed, as were a cartogram and a numerical data map depicting twelve counties in the southwestern portion of the state of Oklahoma (unfamiliar region). The Western United States map was printed in black on 21.6 x 27.9 cm white paper. It contained an outline of each of twelve contiguous states including Washington, Idaho, Montana, Oregon, Wyoming, California, Nevada, Utah, Colorado, Arizona, New Mexico, and Texas. Each state was labeled with its respective state name. To the right of the states' outline on the upper portion of the map, a simple compass rose was constructed using two 1.7 cm crossed lines and the cardinal points N, S, E, and W printed directly above, below, right, and left of the crossed lines. Centered at the top of the page was the title "Book Reading In The Western United States." The numerical data map was created by placing numbers directly below each of the state names in the base map, with these numbers depicting fictitious data invented by the author. Each state was given a number identical to two of the other twelve states. Thus, there were four distinct numbers (8, 30, 60, 100) distributed equally among the twelve states. Additionally, a legend was placed to the left of the states outline on the upper portion of the map that read, "Numbers indicate the number of books read annually per capita." Graphic legends were purposely not used on maps in this study to control for legend appearance. In addition, two versions of each map type were constructed by depicting two different arrangements of the data among the states.

A value-by-area map, or cartogram, was created by transforming the sizes of each state outline from the base map to correspond with the fictitious data used for the numerical data map. That is, each state shape was shrunk or expanded in proportion to its relative data value, while retaining the basic shapes of each state (see Dent 1972 1975). The re-sized state outlines were then connected at their edges such that the overall shape of the region was approximated, thereby maintaining most of the states' contiguity. A legend was placed to the left of the states outline on the upper portion of the map that read, "State areas are distorted in proportion to the number of books read annually per capita" (see Figure 1).

Insert Figure 1 about here

Two unfamiliar maps were created that were identical to the tabular data map and the cartogram described, except that they depicted southwestern Oklahoma and twelve counties, instead of twelve states. The counties included Harmon, Jackson, Tillman, Cotton, Greer, Kiowa, Comanche, Beckham, Washita, Caddo, Roger Mills, and Custer. In addition the title was "Book Reading In Southwestern Oklahoma Counties." Southwestern Oklahoma was chosen as the unfamiliar map because (a) it is not a commonly depicted map, (b) it is somewhat similar, but not obviously similar to the overall shape of the Western United States, (c) the county shapes are similar to the western states' shapes in simplicity, but not shape, and (d) the county names are similar to the western states' names in simplicity (see Figure 2).

Insert Figure 2 about here

In addition, one map depicting the true-scale of southwestern Oklahoma and one map depicting the true-scale of the western United States were developed from the base maps. These maps did not depict any data except for the region names, and the titles "Southwestern Oklahoma Counties," and "The Western United States," respectively. They were developed for presentation prior to the experimental maps described above to expose all subjects to the true-scale of the region they were to study and reconstruct.

Unlabeled maps for each of the two regions were created for a recall task. The familiar base maps were used with the state or county names replaced by horizontal lines for subjects to fill in with the appropriate name and level. The levels, "Very High," "High," "Moderate," and "Low," respectively, were printed below the compass rose to provide subjects with a consistent theme level labeling scheme that corresponded with the instructions they received.

A one page instruction was created on 21.6 x 27.9 cm white paper to familiarize subjects with reading a chart listing and the various type of maps. A square region outlined in black was divided into four quarters and represented as a numerical data map, a cartogram, a proportional symbol map, and a choropleth map. The chart and the four map types were each depicted on the page and represented equivalent data for each of the corresponding four regions. Centered, at the top of the page, were the words, "These five representations each depict the same data using different techniques. Each technique is described to the right of each representation. In the materials that you study, you will see one of these types of representations." The chart and the four map representations were placed in the order stated above from top to bottom of the page, evenly spaced, on the left side of the page. On the right side of the page, from top to bottom, were corresponding short descriptions of the technique used. For instance, to the right of the chart read, "Quantities are listed verbally by area name. Larger numbers represent larger quantities. Smaller numbers represent smaller quantities." The purposes of familiarizing all subjects with the representations was to control for exposure to the representation techniques and to eliminate the need for graphic legends on the maps, thus controlling for legend appearance.

Procedure

The subjects participated in classroom-size groups. As subjects entered the room, they were each handed a packet of materials from a randomly shuffled stack that contained an equal number of packets from each of the four between-subjects conditions. Subjects were seated several feet apart from one another to prevent distractions and peeking. Subjects were instructed to open envelope number one from their packet, take out the materials and begin reading the general instructions silently while the experimenter read them aloud. After procedural questions were answered subjects were told to turn to the second page and read the first set of specific instructions. They were instructed that they could use the maps to help them learn information that would be presented later. Subjects were given 3 minutes to study the lesson, 1 minute to study the true-scale map and 3 minutes to study the experimental map. Following the lesson and maps presentation, subjects returned the materials back into envelope number one and set it aside. Subjects then opened envelope number two from their packet, removed the materials, and read the instructions on the first page. The instructions stated that they would have 5 minutes to draw everything they remember about the entire map in its true and correct proportions. They were further instructed as follows:

"If the regions on the second map you studied were not in true geographic proportions, draw them as you remember the correct proportional size is. Remember: Draw each region you remember in its correct size proportional to the entire map." After 5 minutes of drawing, subjects returned their materials to envelope number two and set it aside. Subjects were then told to open envelope number three from their packet, remove the materials and read the instructions. After seeing a generic demonstration of the map fill-in task described in their instructions, subjects were given 3 minutes to fill in the blanks on the attached map with the name of the region and either "Very High, High, Moderate, or Low," according to the quantities indicated on the map they viewed.

After the fill-in task, subjects were asked to open envelope number four from their packet, remove the materials and read the instructions. Subjects were given 4 minutes to answer a set of post-experimental questions which included inquiry of their familiarity with the western United States and southwestern Oklahoma.

Results

Map Reconstruction

Dependent measures of representation accuracy were taken from subjects' map reconstructions. The reconstructions were measured for distortion and bias averages of each administrative region (states or counties) drawn, and of the reconstruction as a whole. Distortion was computed by taking the average of the absolute values of each region's reconstructed height divided by the region's reconstructed width minus the actual height to width ratio of that region (Σ[|height/width - actual height/actual width|]/regions drawn). Bias was computed by taking the average of each region's reconstructed height divided by the region's reconstructed width minus the actual height to width ratio of that region (Σ[height/width - actual height/actual width]/regions drawn). Distortion and bias measures for the reconstruction as a whole were co puted using the height and width of the entire map drawn, and the height and width of the actual map. The distortion indices expressed the average amount of difference between the height to width ratios of the reconstructed maps and the actual map, without regard to the direction of that difference. The bias indices served to further characterize any observed distortion by expressing the direction of the difference between the height to width ratios of the reconstructed map and the actual map. Both bias and distortion provided objective measurements of reconstructions, relative to the original map images.

Four judges scored all the data from this experiment and a fifth judge re-scored the data from ten of the subjects. Reliability of map reconstruction scores was determined by using a Pearson correlation coefficient of the height and width measurements. Both the height and the width correlations were .99.

Table 1 shows the means and standard deviations for bias and distortion for each treatment group. Single degree of freedom planned contrasts were used to examine three meaningful differences in both bias and distortion among the four stimulus map conditions. Contrasts involved the four groups from the 2 (Familiar, Unfamiliar) x 2 (Cartogram, Data Map) factorial. All statistical tests were evaluated at the $p < .05$ level of confidence.

Insert Table 1 about here

The first set of contrasts compared the familiar map groups with the unfamiliar map groups. There was greater distortion in the reconstructions of the unfamiliar map groups when each administrative region was measured, $F(1,90) = 7.79$, $MSe = .05$, but no significant difference in bias. For distortion in the entire map region without regard to each administrative area, there were no significant differences, but the unfamiliar map groups' reconstructions had a negative bias that differed from those of the familiar map group which had a positive bias, $F(1,95) = 30.26$, $MSe = .07$. As predicted, distortion results indicated that unfamiliar maps were not as accurately reconstructed from memory as familiar maps were. Specifically, the twelve regions drawn of the unfamiliar map were, on the average, more distorted than those of the familiar map, but the direction of that difference for each region did not differ between the unfamiliar map reconstructions and the familiar map reconstructions. Conversely, for the entire mapped region the direction of difference between familiar and unfamiliar map reconstructions was opposite, but the average distortion of the entire region did not differ between unfamiliar and familiar reconstructions, contrary to the predication.

The second set of contrasts compared the data map groups with the cartogram groups. Contrary to prediction, the distortion of each region did not differ between reconstructions of cartogram groups and those of data map groups. However, for distortion in the entire reconstructed map, there was greater distortion in reconstructions by the cartogram groups, $F(1,95) = 6.03$, $MSe = .05$, as predicted. For bias in all regions and bias in the entire map there were no significant differences.

The third set of contrasts compared the familiar data map group with the familiar cartogram group. Similar to the findings with the second contrast set there was no significant difference for distortion in each region, but for distortion in the entire map there was greater distortion in the familiar cartogram group reconstructions, $F(1,95) = 5.10$, $MSe = .05$, as predicted. For bias in the entire map, the familiar data map and the familiar cartogram group reconstructions were both in positive directions and were significantly different, $F(1,95) = 4.42$, $MSe = .07$. Figure 3 illustrates the differences observed distortion.

Insert Figure 3 about here

Although the three sets of contrasts did not yield significant differences for distortion of both individual regions and the map region as a whole, there were predicted differences in either one or the other for each of the contrast sets. Thus, the distortions in the reconstructions by cartogram groups were not of the same nature as the distortions observed in the reconstructions by unfamiliar map groups. Cartogram depictions and unfamiliarity influenced subjects' representations in slightly different ways. Unfamiliarity led to distortions of administrative areas, while cartograms led to distortions in the entire region only. Even among familiar map reconstructions only, the reconstructions by the cartogram group had greater distortion in the entire region than was found in reconstructions by the data map group.

Also examined on the map reconstructions were the number of regions drawn that were correctly labeled, and the number of correctly labeled regions that were correctly placed on the map, relative to the other regions. Inter-rater reliability on these measures was computed as a proportion of scores from the separate judges. Reliability was .97 for correctly labeled regions, and .96 for correctly placed regions. Figure 4 shows the means and standard deviations for correct labeling and correct placement.

The same contrasts described above for familiar and unfamiliar groups, and for cartogram and data map groups were used to analyze these measures. For the first contrast set, more regions were correctly labeled by the familiar map groups than by the unfamiliar map groups (*F*(1,95) = 49.7, *MS*e = 9.28), as predicted.

Insert Figure 4 about here

Also as predicted, more regions were correctly placed on the reconstruction by the familiar map groups than by the unfamiliar map groups, *F*(1,95) = 82.28, *MS*e = 8.69. For the second contrast set, there were no significant differences between the cartogram groups and the data map groups on these measures for regions labeled or regions placed, as expected. For the third contrast set (familiar data map group compared with the familiar cartogram group) there were also no significant differences for correct labeling or cor ect placement as expected.

In sum, seeing a cartogram resulted in less accurate reconstructions than seeing a data map, even when the region depicted was familiar. These inaccuracies were observed as distortion of the relative dimensions of the entire map area reconstructions, but not as errors in labeling or location. In addition, unfamiliarity with the region depicted resulted in less accurate reconstructions. Specifically, distortion was observed in administrative regions reconstructed while bias differences were observed in the entire map reconstructions for unfamiliar areas. Examination of these differences in bias revealed that unfamiliar representations led to underestimation of height to width ratios as compared to familiar representation reconstructions. The number of regions correctly labeled and placed was also less accurate in unfamiliar reconstructions, but map type did not lead to differences in labeling and placement. Overall, five of eight predicted differences were observed in map reconstructions, though among the four sets of contrasts where differences were expected, all four of them revealed some type of predicted inaccuracy in map reconstructions.

<u>Map Labeling</u>

To examine map data recall, a map outline was labeled by subjects with each region name and the corresponding level of data depicted in each region on the stimulus map. Maps were scored for the number of correctly labeled region names and the number of correctly labeled data levels. Inter-rater reliability was .99 for region names and .92 for data levels.

Figure 5 shows the means and standard deviations for regions and data levels correctly labeled. Single degree-of-freedom planned contrasts, identical to those used previously, were used to examine differences among stimulus map conditions for region names and data levels labeled.

Insert Figure 5 about here

For the first set of contrasts, three predicted differences were observed. More region names were correctly labeled by familiar map groups than by unfamiliar map groups $F(1,95) = 198.35$, <u>MSe</u> =

4.31. More data levels were correctly labeled by familiar map groups than by unfamiliar map groups, $F(1,95) = 31.28$, $MSe = 8.32$. More correct region names and data levels were jointly recalled by familiar map groups than by unfamiliar map groups, $F(1,95) = 98.97$, $MSe = 6.61$.

For the second set of contrasts, differences observed were opposite of those predicted. More data levels were correctly labeled by data map groups than by cartogram groups, $F(1,95) = 11.93$, $MSe = 8.32$. More correct region names and data levels were jointly recalled by data map groups than by cartogram groups, $F(1,95) = 6.35$, $MSe = 6.61$. As expected, there was no significant difference for region names labeled on the second contrast set.

For the third set of contrasts, two differences were observed that were contrary to predictions. More data levels were correctly labeled by the familiar data map group than by the familiar cartogram, $F(1,95) = 11.93$, $MSe = 8.32$. More correct region names and data levels were jointly recalled by the familiar data map group than by the familiar cartogram group, $F(1,95) = 14.16$, $MSe = 6.61$. As expected, there was no significant difference for region names labeled on the third contrast set.

In sum, for theme data associated with geographic regions, unfamiliarity and cartogram depiction both degraded data recall. Thus, cartograms did not facilitate data recall in the manner expected. Likewise, unfamiliar region name recall was degraded but region name recall was unaffected by map type. Overall, the three of seven predicted differences and one unpredicted difference were observed in the map labeling task.

Post-Experimental Question

Self reports of familiarity with the regions depicted were taken to examine the validity of the 'region familiarity' variable. Subjects rated both the western United States region and the southwestern Oklahoma region on a four point scale as either a) very familiar, b) somewhat familiar, c) vaguely familiar, or d) unfamiliar. For the western United States region, 33.3% responded "very familiar," 49.5% responded "somewhat familiar", 15.2% responded "vaguely familiar," and 2.0% responded "unfamiliar." For the southwest Oklahoma region, 0% responded "very familiar," 3.0% responded "somewhat familiar," 3.0% responded "vaguely familiar," and 93.9% responded "unfamiliar." Based on this data, the western United States was predominantly familiar to the present subject sample, and southwestern Oklahoma was predominantly unfamiliar to the present subject sample.

Discussion

We have gained several new insights regarding the use of cartograms and the effects of region familiarity. Of the five general predictions made, evidence was observed in favor of four of them. First, the familiarity assumption regarding cartogram use was corroborated by the data from this study. That is, without a long-term familiarity with a depicted region, the cartogram was shown to be an inefficient communication and learning tool. Even when a short-term familiarity with a region was provided, the previously unfamiliar cartogram led to relatively high distortion in map reconstructions, and relatively low recall levels for location and region names.

Second, ignoring region familiarity, the cartogram did lead to greater distortion in learner's reconstructions, suggesting retroactive interference with their original true-scale representations of the depicted region. Conceivably, learners' representations of the cartogram were being used in conjunction with their incomplete true-scale representation to create the new distorted representation depicted by the sketch maps. The interference from the cartogram representation might be influencing learners to mentally fuse portions of their cartogram representation with the poorly defined portions of their true-scale representation. Continued investigation into this hypothesis could determine whether the apparent interference between two images found here is due to interference between visual imagery and visual perception found in previous studies (Perky 1910; Segal & Fusella 1970, Craver-Lemley and Reeves 1987). Nevertheless, one of the possibly unavoidable costs associated with any cartogram use was shown to be their potential for interfering with and subsequently distorting learners' true-scale representations.

Third, this interference hypothesis was put to a stronger test by comparing reconstructions of familiar cartograms with those of familiar data maps. Cartogram interference was again evidenced by distortion which paralleled the distortion observed when using familiar and unfamiliar map groups together. In addition, the direction of bias observed in familiar map reconstructions (positive bias) and unfamiliar map reconstructions (negative bias) of the entire region were consistent with the direction of bias measured within the familiar and unfamiliar stimulus maps themselves. This consistency between stimulus maps and map reconstructions supports the notion that distortion within subjects' reconstructions was due to the area distortions of the cartogram they viewed. It should be noted, however that the lack of difference in recall levels for region names between cartograms and data maps suggests that any interference from cartogram representations did not include verbal interference.

Fourth, familiar maps did lead to superior performance on matching data levels with administrative regions. This outcome indicated the computational advantage of having map features and map structure in learner's long-term memory representations prior to studying particular maps of a region. The availability of a coherent structural and feature framework provided an increased opportunity for data to be cued relative to its appropriate spatial location. The observed feature and structural advantage corroborates the Kulhavy-Stock model and highlights the versatility of this model for analyzing map-related phenomenon.

Finally, cartograms did not provide an advantage over data maps for matching data levels with administrative regions. The simultaneous availability of the spatially depicted data in a cartogram image was not sufficient to provide an advantage over the data map depiction. Apparently this additional use of spatial structure to depict data did not facilitate recall beyond the facilitation provided by the structure within the geography of either map. Thus, the known cueing advantage of structural coherency in map images (Kulhavy, Stock, Verdi, Rittschof, &

Savenye 1993) did not exist for the recall of thematic data, when that data was depicted by the structure itself. In fact, the relative simplicity of the maps used may have allowed sufficient processing resources to encode all or most of the numerical data from the data map. Presumably, the explicit nature of the data map benefited learners more than the efficient structural representation of data in these twelve-region maps. Alternately, the true-scale representations may have been interfering with the cartogram representations (proactive interference) such that the recall of the cartogram data levels was hindered. Requiring subjects to reconstruct their cartogram representations in a similar study would shed light on this possibility. In either case, any advantage of spatial depiction used in cartograms might only exist for complex regions with greater than twelve administrative regions, though this too remains to be tested.

Conclusion

In many fields of science, visualization of data is crucial to learning, problem solving, inferring, correlating, and understanding change. Cartograms are valuable visualization and learning tools that through advances in computer mapping and graphics technologies have become more accessible to educators and scientists than ever before. Like other tools the value of the cartogram depends upon the appropriateness of its use. The present study explored issues that are tied to the cartogram's appropriate use. These issues of appropriateness are particularly important because with the increasing accessibility of visualization and learning tools like the cartogram comes the potential misuse of such tools. To help prevent such misuse we suggest several implications of the present study for cartographers and educators.

1. Use cartograms only when learners have a long-term familiarity with the region depicted.
2. A short-term (immediately preceding) familiarity with a depicted region may not be a sufficient basis for the use of a cartogram.
3. For simple mapped areas containing about twelve administrative regions, the cartogram may not be the ideal choice among thematic map types when remembering thematic data is important.
4. Any use of cartograms may lead to at least temporary distortion of learners' representations of a geographic region. So, when cartograms are used, instructors should emphasize the true, earth-centered scale of the region depicted to prevent misunderstandings.
5. Cartograms do not appear to cause any degradation in the recall of region names depicted.

While these implications rule out the use of cartograms in many situations, there are numerous applications where cartograms can and should be used appropriately. An examination of empirical data from the present study and forthcoming studies will help clarify our understanding and suggest the appropriate use of cartograms and other thematic maps.

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Table Caption

Table 1. Means and Standard Deviations for Bias and Distortion in Map Reconstructions.

Stimulus Map		Each Region Bias	Each Region Dist.	Entire Region Bias	Entire Region Dist.
Familiar Data Map	M	.04	.27	.03	.09
	SD	.11	.07	.13	.09
Familiar Cartogram	M	.06	.30	.18	.24
	SD	.16	.10	.43	.40
Unfamiliar Data Map	M	.15	.39	-.11	.17
	SD	.33	.23	.19	.13
Unfamiliar Cartogram	M	.04	.44	-.25	.25
	SD	.29	.36	.19	.18

Figure Captions

Figure 1. A familiar cartogram used in one of the four experimental conditions.

Figure 2. An unfamiliar data map used in one of the four experimental conditions.

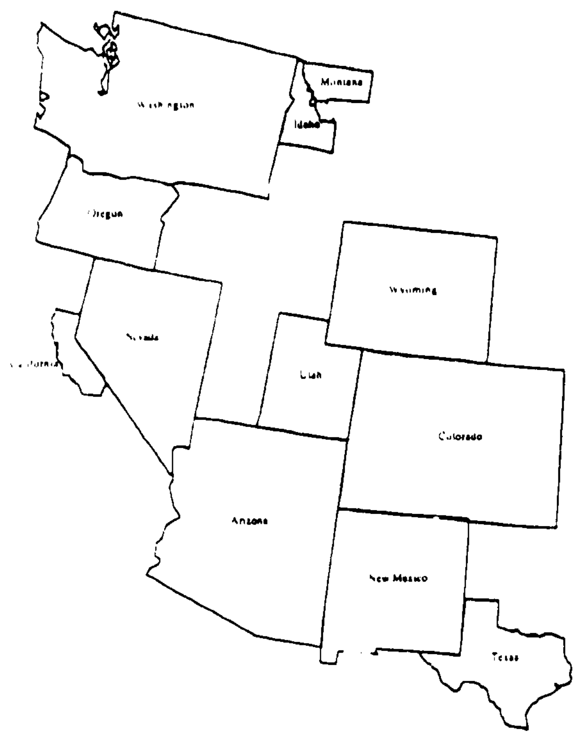
Figure 3. Means (and standard deviations) for distortion on map reconstructions in the overall mapped region and in each administrative region within the map.

Figure 4. Means (and standard deviations) of region names labeled and correct relative placement of regions on map reconstructions.

Figure 5. Means (and standard deviations) for region names and data levels recalled on map labeling task.

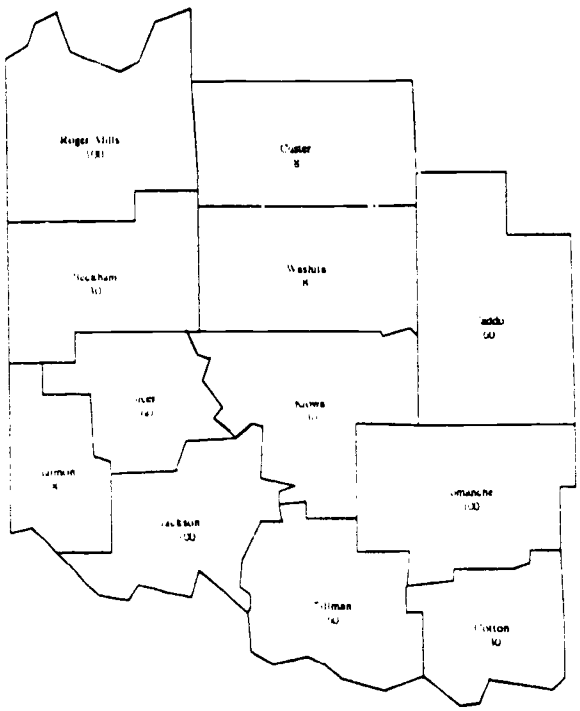
Book Reading In The Western United States

State areas are distorted in proportion to the number of books read annually per capita

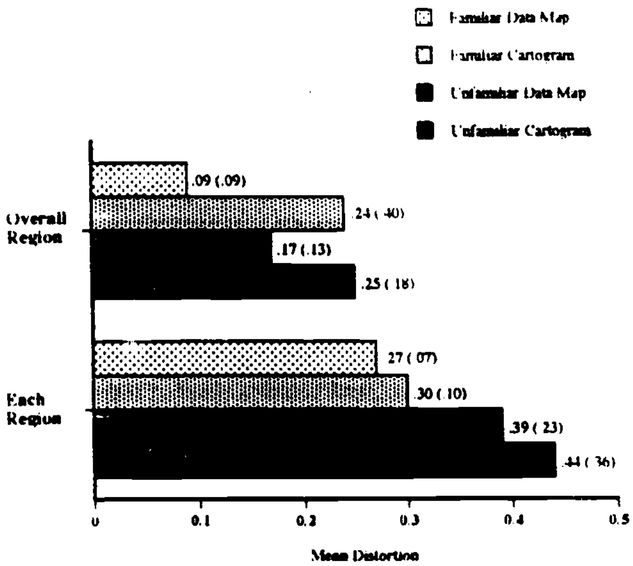


Book Reading In Southwestern Oklahoma Counties

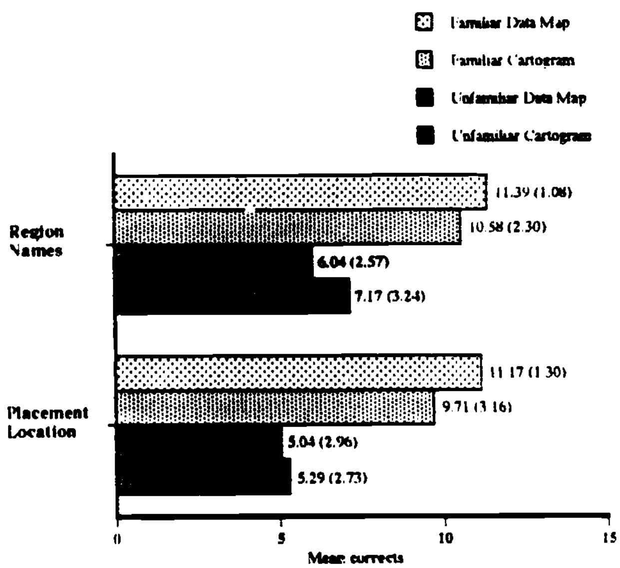
Numbers indicate the number of books read annually per capita



Distortion in Map Reconstructions



Reconstruction Labeling and Placement



Map-Cued Labeling of Names and Data