The Role of Color Saturation in Maps for Children

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Bright, saturated colors are very common on maps for children, especially maps in grade-school textbooks. This is despite the tendency of professional cartographers to use highly saturated colors sparingly in much of their work. This research seeks to determine if highly saturated colors are necessary for children to understand a map's content and if children prefer highly saturated colors. Two hundred forty two fourth and fifth grade students were tested for both performance and preference on land use and time flow maps. Saturation's effect on performance appeared to be largely negligible, however the students, both male and female, strongly preferred the maps that were highly saturated.

Keywords: color, saturation, children's maps

INTRODUCTION

Do children understand maps in the same way that adults do? It has been postulated that they both perceive the map and interpret the data differently than adults (Bartz 1965; Sorrell 1978; Gerber 1984). These alleged differences have led many publishers and cartographers to create maps for children that are different from those for adults. For example the subdued, de-saturated colors and fine line-work in a National Geographic Atlas (Figure 1) contrast with the bright, saturated colors and bold line-work found in elementary textbooks (Figure 2). This paper investigates the effect that color saturation has on both performance and preference in the reading of maps by children.

This research specifically seeks to answer the question *do maps for children need fully saturated, "bright" colors*? Human subjects research was performed to answer the question. Our goal was to provide empirical guidance to both mapping companies and publishing houses on how to choose colors when producing maps for children. Very little research has been directed at children's understanding of color. What research has been done in this area has occurred in the realm of reference map design for children (Bartz 1965; Sorrell 1978). While reference maps are important to children's understanding of geography, it is (as we will show) thematic maps that are predominantly used in scientific and social studies classes. Currently, color choice for thematic maps in textbooks appears to be based on a mix of artistic decision and a belief of what is "childlike," not on any formal study. Thus, most of the maps found in textbooks for children use highly saturated colors, which may or may not be necessary for children's understanding of maps. Although Sorrell's (1978) "rules" for creating children's maps recommend the use of strongly saturated colors—rules that have reached a wide audience via Borden Dent's introductory textbook (Dent 1999)—these guidelines have not been validated with testing, calling into question the widespread their application.

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While the focus of this paper is to report on a map-reading experiment with 242 fourth- and fifth-graders, We will first present (1) a synthesis of

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relevant color research in order to frame this project and show the gaps within that literature this project was designed to fill, and (2) a survey of the maps found in the textbooks of the five major scholastic publishers to characterize how color (and specifically, saturation) is currently used on maps for children.

Cartographic Studies in Color and Color Perception

The study of color on maps has a long history in cartographic research and is one of the most studied aspects of map design (Robinson 1952; Jenks and Knos 1961; Crawford 1971; Kimerling 1980; Olson 1981; Imhof 1982; MacEachren 1995; Dent 1999; Brewer et al. 2003). Robinson's pioneering work "The Look of Maps" (1952), devoted two chapters to color (out of a seven chapter book) and discussed color through the lens of physics, psychology, and cartography. His discussions of how to choose color for a map are still relevant today, as are his claims that color is governed by "sensation, not arithmetic formulae."(Robinson 1952). One of Robinson's students, Jon Kimerling (1980), investigated perceptual aspects of color that generated useful print rules: He found that due to the small reflectance of yellow, only two to three yellow tints could be discerned reliably on a map, in contrast to as many as six shades of black and four to five shades of both magenta and blue.

Imhof (1982) discussed the psychological theories of color, along with the physiological and chemical theories of color and how they relate to cartography in his book "Cartographic Relief Presentation." Imhof also produced a set of empirical rules that he felt were applicable to map design. In putting forth these rules, Imhof stated that "bright or very strong colors have loud, unbearable effects (Imhof 1982)." He further states that bright colors should not be used on large areas of a map. This advice sits in stark contrast to the use of these colors on children's maps.

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Patton and Slocum analyzed the differences between utilitarian use of color (using color to convey information that would not be transmitted if color were removed) and aesthetic use of color (Patton and Slocum 1985). They found that when using color aesthetically, it did not significantly affect reader's ability to recall spatial patterns. However, they cite Mersey (1984) who said that using color for utilitarian purposes does enhance pattern memory in certain cases. Both of these findings are informative as we are testing both the utilitarian and aesthetic aspects of color. Patton and Slocum also indicated that there were no significant differences in performance between males and females during their study.

Brewer's significant body of work on color (Brewer 1989; Brewer 1992; Brewer 1994; Brewer 1996; Brewer 1997a; Brewer et al. 1997; Brewer 1997b; MacEachren et al. 1998; Brewer 2003; Brewer et al 2003) has touched a wide range of topics, including the use of spectral color schemes, guidance for diverging color schemes, the effects of simultaneous contrast on maps, color selection to aid the color-impaired and a tool to select good colors for mapping. Further, Brewer has looked outside of cartography and brought ideas from other fields into our discipline: The ideas of color psychology research from Sivik, Granger, McManus and others (Granger 1955; McManus et al. 1981; Boynton 1989; Sivik and Hard 1994) have been used by Brewer to identify colors that will not be confused and to identify colors that are most readily named (Brewer 1996; Brewer et al. 1997). In particular, McManus et al (1981) found blue was the most preferred color while yellow the least preferred, and noted that preference does not change during the course of an experiment.

Brewer's body of work provides cartographers with a grounded and empirically validated physiological basis for the color use. For example, Brewer et al. (1997) point out that we should select colors that can be readily identified, with hue preference as a secondary design concern, while Olson and Brewer (1997) outline how to avoid problem color schemes for color-impaired individuals and found that the maps aesthetics were not affected by the use of these colors.

Brewer has found more recently that a "smooth trajectory through color space perfected logical relationships but had a negative impact on identification of map polygons (Harrower and Brewer 2003; Brewer et al 2003)". She hypothesized that some "jitter" among the movement through color space would better suit the goals of the map (Brewer et al 2003) because it seems to make the colors more legible to the map reader. Brewer found this jitter effect both in the qualitative and sequential schemes she created for ColorBrewer (Brewer et al 2003). This hypothesis will be worth considering as we attempt to ascertain the reasons for performance variance in the discussion section of this paper.

"The area that has been largely absent from cartographic color research has been the use of qualitative colors."

The area that has been largely absent from cartographic color research has been the use of qualitative colors. Much has been made of diverging and sequential color schemes and their use on maps, but far less mention has been made about the proper use of qualitative colors. Our literature review discovered no research focused on qualitative color schemes. Vast number of maps, such as those of climate zones, land-cover, and political areas, depict nominal data distinctions.

Color Research on Children's Maps

While various aspects of children's mapping have been researched for the past 40 years, it is the work of Bartz (1965) and Sorrell (1978) that have had the greatest impact, with others continuing this work more recently.

Bartz addressed the use of color in hypsometric tinting, legend design, and qualitative versus quantitative differences on maps in her seminal work "Map Design for Children" (Bartz 1965). However, Bartz did not address the problem of choosing appropriate colors for use on children's maps. She pointed out that colors that illustrate qualitative change, such as land cover differences, is easily accepted by children, a point that is highly relevant to the research undertaken here. Bartz focused exclusively on reference mapping and basic map reading tasks in her research rather than the thematic maps that so often appear in children's textbooks today. Bartz (1971) points out that while research on color sounds useful, much of it is "virtually worthless in the real choices that must be made as maps are produced." Given the fact that color research was both difficult and expensive at that time, it was reasonable to spend research time on other questions. However we respectfully disagree with this statement, especially given the current ease of color printing, and posit that color has a real, measurable, and understandable impact on the map-reading preferences and performance of children that can now be studied in depth.

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By comparison, Sorrell's work focused on both preferred map types and color associations in children (Sorrell 1978). Sorrell's survey work established two unsurprising findings. First, he found that children are most interested in thematic maps about interesting subjects (e.g., sports, castles and battles) and reference maps about where they live. They are least interested in maps such as land use or climate, which tend to appear in every fourth- and fifth-grade textbook that we surveyed (next section). Secondly, Sorrell surveyed students about the colors they associate with various landforms. The majority of children appear to make associations such as blue for water, yellow for deserts, and green for forests (which are no doubt, at least in part, culturally proscribed). The lasting messages from Sorrell's work are:

- Children are only aware of the basic spectrum of colors.
- Children appear to reject fully saturated colors – one to two steps below full saturation should be used.
- Children dislike dull and unattractive colors, such as brown.
- Children tend to reject non-colors (e.g., gray).
- The greater the compatibility of the color with the expected, the greater the comprehension. (Sorrell 1978)

Unfortunately, the wording chosen by Sorrell is vague, which makes the suggestions difficult to apply objectively and consistently across maps. In discussing results of our study we will return to some of these suggestions, specifically, the comments about color compatibility and the rejection of fully saturated color.

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More recently the work of Young (1994), Trifonoff (1995), and Michaelidou et al. (2004) has taken up the challenge of critically assessing the creation of children's maps. Young (1994) correctly points out the multitude of problems begetting textbook maps, including "inaccurate and repetitive maps, limited map types, and a scarcity of quantitative data." During the informal textbook survey we conducted below, we witnessed many of these concerns still present ten years after Young's critique.

Trifonoff's (1995) study focused on the use of quantitative data on maps: She argues that students as early as second grade should be exposed to quantitative thematic maps as this skill is within their ability level at that age. These findings are reinforced more recently by Michaelidou et al. (2004) who showed that students in Grade three had the ability to use thematic maps effectively even without prior experience, and stressed that thematic maps need to be used in third through sixth grade studies. Trifonoff (1995) also found during her study that children preferred color on the maps as opposed to grayscale and that they liked bright colors.

Review of Children's Textbooks

The number of publishers working on school textbooks has declined in recent years due to consolidation within the industry, leaving the publishing world with five major players: Scott Foresman, Houghton Mifflin, MacMillan McGraw-Hill, Harcourt and Pearson. These publishers had the majority of textbooks for fourth- and fifth-grade science classes available at the Madison Metropolitan School District's Textbook Library.

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Our informal survey of the popular textbooks yielded insights into the guidelines that publishers feel should be followed when producing maps for this age. Ten Social Studies textbooks were surveyed and they contained a total of 186 maps. These maps were broadly categorized as bright (saturated) or non-bright (de-saturated), similar to the characterizations of Figures 1 and 2. While this was obviously a subjective exercise, it nonetheless gave a general sense of current publishing practices. We found that roughly three quarters of the maps had only bright colors, or were dominated by bright colors.

To confirm these findings, we spoke with professional cartographers who routinely make maps for textbook publishers. These cartographers said it is usually assumed less saturated colors on maps are appropriate for a mature reader and bright colors are appropriate for children's maps. They also commented that the demand for bright colors originates in most cases from the publishers themselves who assume that children will be less interested in subtle color schemes.

Methodology

As an assessment of the use of saturation on children's maps, the objectives of this study are to determine if saturated colors aid children's *performance* in map interpretation, and to discover if children *prefer* saturated colors to de-saturated colors.

The two major research hypotheses are: Children will perform significantly better on maps with saturated colors. Children will prefer the more saturated colors and reject the less de-saturated colors. These hypotheses seem reasonable given (1) Brewer's findings that map readers tend to perform best on the color schemes with high contrasts, (2) Sorrell's suggestions that indicate that children will perform better with brighter colors, and (3) the color choices of the major publishing companies.

To test these hypotheses, two sets of data were gathered in a controlled test environment. Responses, correct or incorrect, to substantive questions were observed, and the children ranked the color schemes according to preference. Collection of both of these data sets will be explained in detail below.

The Maps

"... the objectives of this study are to determine if saturated colors aid children's performance *in map interpretation, and to discover if children* prefer *saturated colors to de-saturated colors."*

Eighteen paper maps were created for use in testing (e.g., Figures 3 and 4). Of these 18, six were land use maps and twelve were time-flow maps. The land cover maps depicted regions of France while the time-flow maps were based on battle maps of the Napoleonic Wars. Land use and time-flow maps were selected because they are the very common in Social Studies textbooks.

France was chosen as the area for the land use maps to reduce the students' familiarity with the base map, but to retain a large geographic footprint similar to what appears in elementary school textbooks. To minimize pre-existing knowledge of the base map further, the geographic area was rotated at various angles for each map. These choices helped eliminate prior knowledge as a performance factor. Fictitious provinces were used and test points were randomly placed on each map to ensure that no memorization occurred during the study. Each test point and province was identified by a letter (A-K). Eleven provinces appear on each land use map. Three test points (A-C) were placed on each map.

The time-flow maps were created using historical battle maps from the Napoleonic Wars as shown in the *Times Atlas of Military History* (Brooks 2000). Two battles from 1806 were selected. The troop movements were traced and simplified. Ancillary data such as rivers and borders were added to the map to simulate common textbook maps. The large-scale nature of these maps required no attempts to reduce familiarity, as the battles are not commonly studied at these grade levels.

Map Color

Both the time-flow map series and the land-use map series featured qualitative, or categorical, color schemes with colors varying primarily by hue rather than by saturation and lightness. The color schemes were designed so that two sets of comparisons would be made. First, differences in performance would be analyzed across color sets, and second, differences in performance would be analyzed for the saturation levels in the color sets.

Six color schemes, broken into two color sets, were represented in total, each appearing on one map in the land use series and two maps in the time-flow series. Figure 5 shows the six color schemes, broken into color (test) sets A and B. Each color scheme is further identified by the saturation level of the scheme. For the remainder of this paper these color schemes will be abbreviated by the set letter and the saturation level (e.g. AH for set A, high saturation). Color sets A and B were both designed following the same procedure. The initial hue, lightness and saturation values were derived from Cindy Brewer's ColorBrewer resource (www.colorbrewer.com) using her qualitative color schemes Set 1 and Dark 1. These two schemes were chosen because both have been perceptually tested and found to be usable by color- impaired map users.

The Survey

The two sets of maps were tested on children from the target age group of nine to eleven years old. The children's school was chosen based on prior contacts and an attempt to produce a representative sample of students. All of the subjects viewed six of the twelve maps and all of the chosen color schemes.

Subjects

Two hundred forty two fourth and fifth graders from the Mount Horeb (Wisconsin) Area School District participated in this study. Participation of the students required consent from parents or guardians. Both the subject and parents were given the opportunity to opt out of the testing both before and during the testing project.

The testing occurred within the school setting and during the course of the normal school day. An entire class was tested at one time with each subject receiving a different series and order of maps than the neighboring child to reduce the likelihood of copying answers. This followed a typical school test environment. No conversations were allowed with other students; rather, each student worked independently. No compensation was provided to the participants.

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Training Session

Before beginning the experiment a short training session was conducted. The students were provided with a sample map containing data and questions similar to the actual survey materials. The students were then verbally led through the map, with all of the elements including legend, compass rose, and classification scheme explained. The students answered sample questions together and the answers were discussed to train the students on how to complete the requested tasks. Support was provided during this time by both the researcher and the classroom teacher to ensure that each student was comfortable with both the question type and with reading the maps before beginning the experiment. The large number of participants (n = 242) was expected to create a realistic spread of classroom abilities, and no one subject could overly influence results.

Questions

The questionnaire was created based on observed questions from existing textbooks at fourth- and fifth-grade level. Each subject was asked a series of five questions per map that required "on-the-fly" map interpretation and a written short-answer. The students each had copies of the maps in front of them while they answered the questions. The short answer format was used to reduce the likelihood of "lucky guesses" that occur in multiple choice testing. Each question required the subject to interpret and extract information about the land cover either at a given point or within a given area, from the map. The subjects were instructed not to guess, but instead to leave the question blank if they did not or could not determine the answer.

The subjects also were asked to express their color-scheme preferences at the end of the survey. Each subject was presented with all six of the color schemes using a legend-like set of colored boxes (Figure 5) and asked to rank the schemes from one to six with one being the most preferred scheme and six being the least preferred scheme. This color preference rank information was collected, in part, to determine if any correlation exists between performance and preference.

Students were also asked four demographic questions: age, grade level, gender and if they used eyeglasses for any reason. They also completed a six-question Ishihara test for color vision deficiency.

Results and Analysis

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When analyzing the results, the two basic research questions were expanded as follows:

Does saturation affect the student's performance when answering questions? When answering this question, the possible influence of question type, map type, gender and saturation preference of the participant were explored.

Do children overall prefer highly saturated colors when using a map, or are there gender differences in preference?

ANOVA (analysis of variance) tests were generated that addressed the following questions:

- does map color (hue, brightness and saturation) affect performance on each land use question type?
- does the color scheme affect performance on time-flow maps?
- does the saturation affect performance?
- does gender affect performance at varying levels of saturation?
- does color preference affect performance at varying levels of saturation?

For each test, the performance data were aggregated by percentage. This violates the ANOVA requirement that data are free to vary about the mean. Therefore the data were subjected to the arcsine transformation required of percentage data in an ANOVA test to produce a "normal" sample.

One-way and multiple-way analysis of variance tests were used to answer the research questions. Each test addressed the affect of one or more independent variables (hue-brightness, saturation, gender and preference) on performance (percent score by questions or by individual subject?). The null hypothesis in each case was that the independent variables had no affect on performance.

Before performing any of the statistical tests it was important to determine how to handle answers left blank during the study. ANOVA statistics were run both removing blanks from the analysis, as well as counting blank answers as incorrect. In both cases the statistical significance/non-significance remained the same.

Performance on Substantive Questions

Land use Questions

Five questions were asked about each land use map. Two of the five questions asked the dominant land cover type in a given state area (Regional Questions). The other three asked the land cover type visible underneath a randomly placed test point (Test Point Questions). Table 1 shows the aggregated performance breakdown by color scheme for both types of land use questions. Earlier in this study, it was hypothesized that the lowest saturation color schemes would have the lowest performance numbers. At first glance the performance data for the land use maps does not bear this out. It is the highest saturation schemes that produced the fewest correct answers.

To determine if these differences were significant, two one-way ANOVA tests were run. In both tests, color is the independent variable with six groups (AH, AM, AL, BH, BM, BL). Map reading performance was the dependent variable, with each percent made up of an aggregate of the entire test set answers by student. The null hypothesis in each case was that the mean performance of all six groups would be equal ($N_0 = \mu_{AH} = \mu_{AM} = \mu_{AL} = \mu_{BH} = \mu_{BM} = \mu_{BL}$). The null hypothesis failed to be rejected at the 95% confidence interval for both the regional questions and the test point questions. Based on these results it appears that the effects of saturation on performance are negligible, and the differences observed could have occurred by chance.

Table 1 shows that the questions about points on the map generated lower accuracy than the questions about regions.

For saturation, the null hypothesis expressed that saturation would not affect performance ($N_0 = \mu_H = \mu_M = \mu_L$). For both color schemes we failed to reject the null hypothesis, confirming what the descriptive statistics and the question by question ANOVA showed: saturation does not significantly affect performance. For color, the null hypothesis was the same as for saturation, that hue-brightness did not affect performance ($N_0 = \mu_A = \mu_B$). This null hypothesis was rejected, as the differences in performance were significant between the A and B color schemes. This result indicates that performance differences appeared in the test due to the overall hue-brightness combination more so than because of the saturation level. Table 2 details each of these three test results.

As a result of these ANOVA findings the Tukey's HSD (Honestly Significant difference) post-hoc test was run to determine where the color differences exist. This test indicated that the hue-brightness difference occurs between the A low set and the B high set. However, the overall mean difference between these two sets was small, at about 4.5%, which suggests that performance with color set A low is only slightly better than with set B high.

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Time-Flow Questions

In contrast to the land use maps, the time-flow maps used four types of probes:

- which explorer traveled to the farthest point in one direction?
- what single explorer on the map crossed a river?
- determine the explorer that looped his path.
- determine the explorer that traveled through a village or town shown on the map.

Overall, the flow maps resulted in similar percentages for all saturation levels and color sets (Table 3). This is not unexpected considering that each map contains only three classes thereby reducing the number of colors to interpret, by half, of what is viewed on the land use maps.

An ANOVA test was performed to determine if the flow map performance differences were significant. This ANOVA used the subject percentages for each color scheme. The independent variable was again color while the dependant variable was performance. For the third time we failed to reject the null hypothesis. It can be concluded that for time-flow maps, as for land use maps, color and saturation have negligible effect on performance.

Gender

In total 124 girls (53.3% of the total sample) and 118 boys (46.7%) took part in the study. Gender differences were analyzed both for color and saturation performance differences. To accomplish this, a 2x3x2 ANOVA was designed. In this test the hue-brightness sets (Set A & Set B), saturation levels (High, Medium and Low) and gender were the independent variables f, and performance was the dependent variable. The null hypothesis for the main effect of gender was that the means for each gender would be identical ($N_0 = \mu_G = \mu_B$), i.e., there is no interaction between gender and saturation. The null hypothesis for the interaction effect of color and gender is again that no interaction would occur. Finally, the three-way interaction effect of color, saturation and gender again had a null hypothesis that no interaction would occur. All of the interaction effects failed to reject the null hypothesis, but the gender null hypothesis was rejected, indicating that the mean performance of the girls was significantly higher than the mean performance of the boys across all saturation levels.

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Color Preference

The initial research hypothesis about map preference was that the least saturated color schemes would be the most disliked schemes. This hypothesis appeared initially to be false. When asked, "what is your preferred color scheme" it was the middle saturation schemes that received the fewest votes, with high saturation being the overwhelming favorite. However, when asked about their *least* preferred color scheme, the low saturation one received the most votes (Table 4).

When the favorite choices were aggregated by color and saturation (Figure 6) it became apparent that the basic colors from scheme AH were the preferred hue-sat-brightness combination for a vast majority (57%) of subjects, receiving more votes than the other 5 color schemes combined. A chi-squared test proved that this difference in preference was statistically significant.

The final set of ANOVA tests analyzed whether saturation preference affected performance. In order to assess this it was important to restrict the analysis to within group interaction only, therefore three separate ANOVA tests were run, one for each level of saturation. For each ANOVA test, the null hypothesis was that the performance means for each saturation level would be equal ($N_0 = \mu_H = \mu_M = \mu_L$). The three tests were run for the saturation preference levels of High, Medium and Low. At each level the null hypothesis failed to be rejected, providing evidence that saturation preference has negligible effect on performance at varying saturation levels.

Would gender have any influence on preference? Initially, we thought that there might be some gender difference in terms of preference. But as

Figure 7 illustrates, there is little difference in preference by gender. The major difference is the preference for color schemes AH (Girls 65%-Boys 52%) and BL (Girls 6%-Boys 16%). The BL color schemes difference in preference by gender is not entirely surprising given the similarity in this color scheme to "camouflage," which may have been chosen due to a perceived match with their perception of land cover or just because these colors are "cool". Overall these differences in preference by gender are not very large and fully saturated colors, in particular those derived from basic colors, are overwhelmingly preferred by children of this age and grade level regardless of gender.

Out of 242 students participating, 13 showed signs of color vision impairment, of which 4 appeared to be severe impairment. Of these thirteen students twelve were male and one was female, or roughly 10% of the males were impaired and less than 1% of females. These numbers reflect the current estimates of color vision impairments in the general population (Olson and Brewer 1997).

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<u>*Jitter*</u>

One color element to be considered in explaining the preference for colors from Set A is jitter. Jitter is the variation in brightness across the Munsell color space. Overall, the jitter values were widely varying from roughly 4.5 in the Set A, High Saturation scheme to just about 1 in the Set B, Low Saturation Scheme. However, it was worth noting that the jitter for every saturation level in the B color set was either roughly equal or less than the smallest jitter scheme in the A color set, the AL scheme. Further, an analysis of Figure 8, which shows a graph of the jitter for each color scheme in Munsell color space, supports the formation of the earlier stated hypothesis that more saturated colors will be easier for the subjects to read.

CONCLUSIONS

Both the descriptive and inferential statistics support the conclusion that children do ***not need*** saturated colors on maps but that they ***prefer*** them. Overall this study provides the following conclusions:

- Highly saturated colors, especially the high saturation scheme from set A, were strongly favored over low saturation colors.
- Students performed better on color set A than color set B.
- Saturation had minimal impact on performance.
- Saturation had a big impact on preference.

While lack of performance difference was surprising, the clear preference for highly saturated colors seems to confirm the practice of using such colors on the majority of children's maps by textbook publishers. Both girls and boys preferred highly saturated colors and disliked the most de-saturated colors. While this appears to be counter to the previously stated opinion of Sorrell (Sorrell 1978) that children reject fully saturated colors in favor of those one to two steps down, in fact, it does not. The saturation level of the high sets were by no means as saturated as possible, and may have more closely resembled the "one to two steps below full saturation" that Sorrell describes.

"While lack of performance difference was surprising, the clear preference for highly saturated colors seems to confirm the practice of using such colors on the majority of children's maps by textbook publishers."

Revisiting Sorrell's suggestions, it is possible to compare the results of this study:

- Children are only aware of (and hence prefer) the basic spectrum of colors – *this appears to be upheld by the preference for the basic colors in color set AH, as well as the previous research by McManus et al. (1981).*
- Children dislike dull and unattractive colors, such as brown – *Low preference for the AL, AM, BL and BM schemes appear to support this state-*

ment .We applied Sorrell's choice of the word "dull" to equate in our study to the color sets at the medium and low saturation level, making no evaluation of the "attractiveness" of each scheme.

This preference for fully saturated colors harkens back to the research about color naming which shows that more basic colors enter the vocabulary earlier and highly saturated colors tend to be more "basic" (McManus et al. 1981; Boynton 1989; Whitfield and Wiltshire 1990; Sivik and Hard 1994). McManus et al. (1981) indicate that high chroma is preferred to low chroma during their study, thus, considering the use of crayon colors on television and in classrooms and clothing further reinforces the preference findings in this study.

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One other question to be raised about our preference findings is whether children are conditioned to prefer saturated, bright colors. It is possible that children prefer these colors because they are more commonly exposed to them on maps. These are the colors that children have come to expect on maps; therefore they assume that these are the colors that should be on those maps. This experiment was described to the students as being a study of colors used on textbook maps, and that description may have skewed the student's viewpoints to believe that bright colors were the "right" ones. If children were exposed to the less saturated colors more often in their textbooks, these preference findings might change dramatically.

The other significant performance difference was by gender. Across the entire test girls performed better than boys, even though within each group the differences were not statistically significant. This result does not indicate that saturation was the influencing factor, but instead the result is likely caused by well-known differences in development that occur at this age between boys and girls (and that are beyond the scope of this study), which is counter to the research findings of Patton and Slocum on gender.

"For performance reasons, there appears to be no need to present children's maps using fully saturated colors."

For performance reasons, there appears to be no need to present children's maps using fully saturated colors. Saturation's lack of influence on performance should give pause to cartographers and publishers who produce maps for children. While they may prefer the brighter, more saturated colors, it is by no means *necessary* to use such bright colors. In fact, performance proved to be marginally, but statistically non-significantly, better on the reduced saturation schemes. More important than the saturation values of the chosen colors is the overall hue-saturation-brightness combinations chosen and the ease of differentiating between all of the colors on a map. The fact that color set A resulted in better performance than color set B suggests that with set A it is simply easier to discern differences within the map than on color set B (regardless of saturation level). This ease of use may also play into the findings on preference; essentially the easier the map is to use the more it will be liked. Careful choice of hue is vital to ensure the colors are distinguishable and easy to use.

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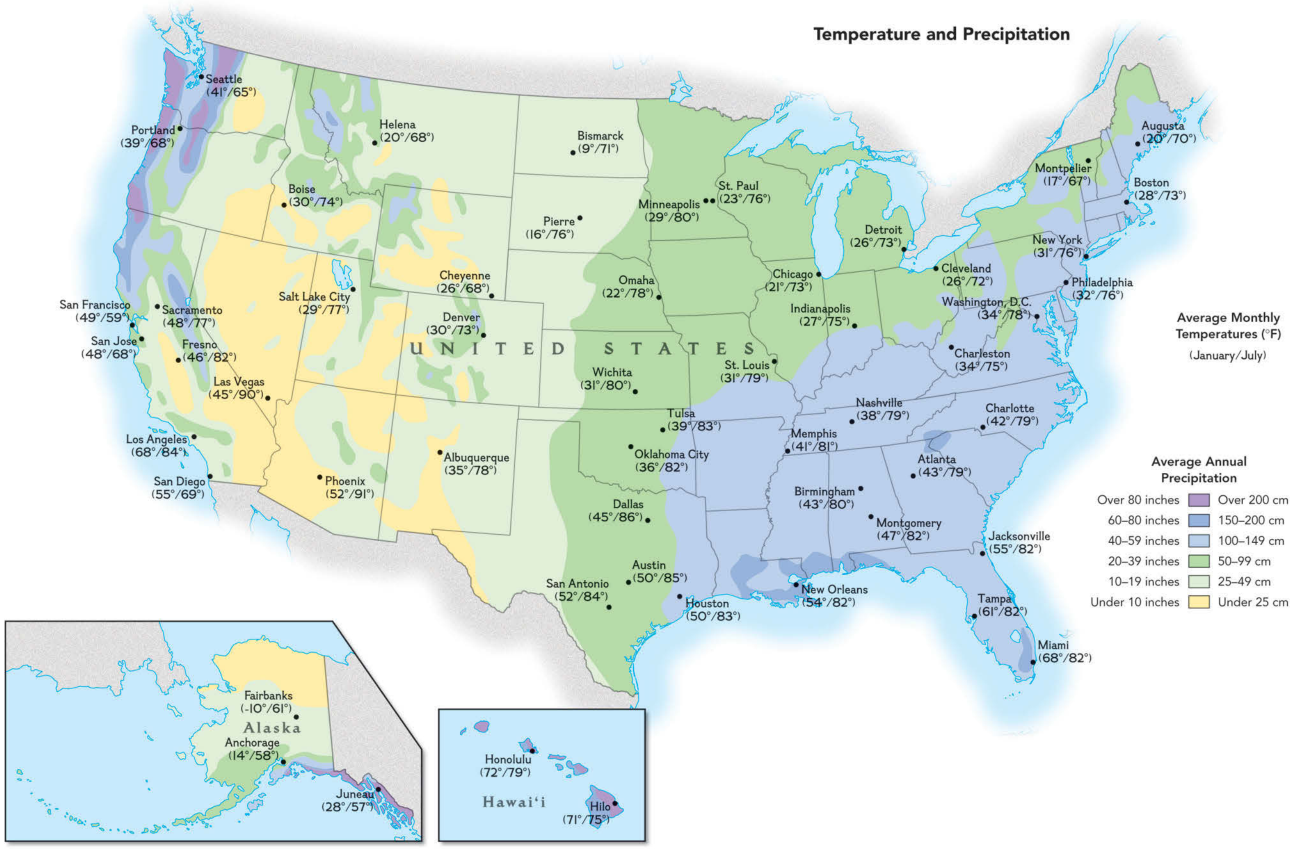


Figure 1. U.S. Temperature and Precipitation Map ©National Geographic (Shown at Reduced Scale).

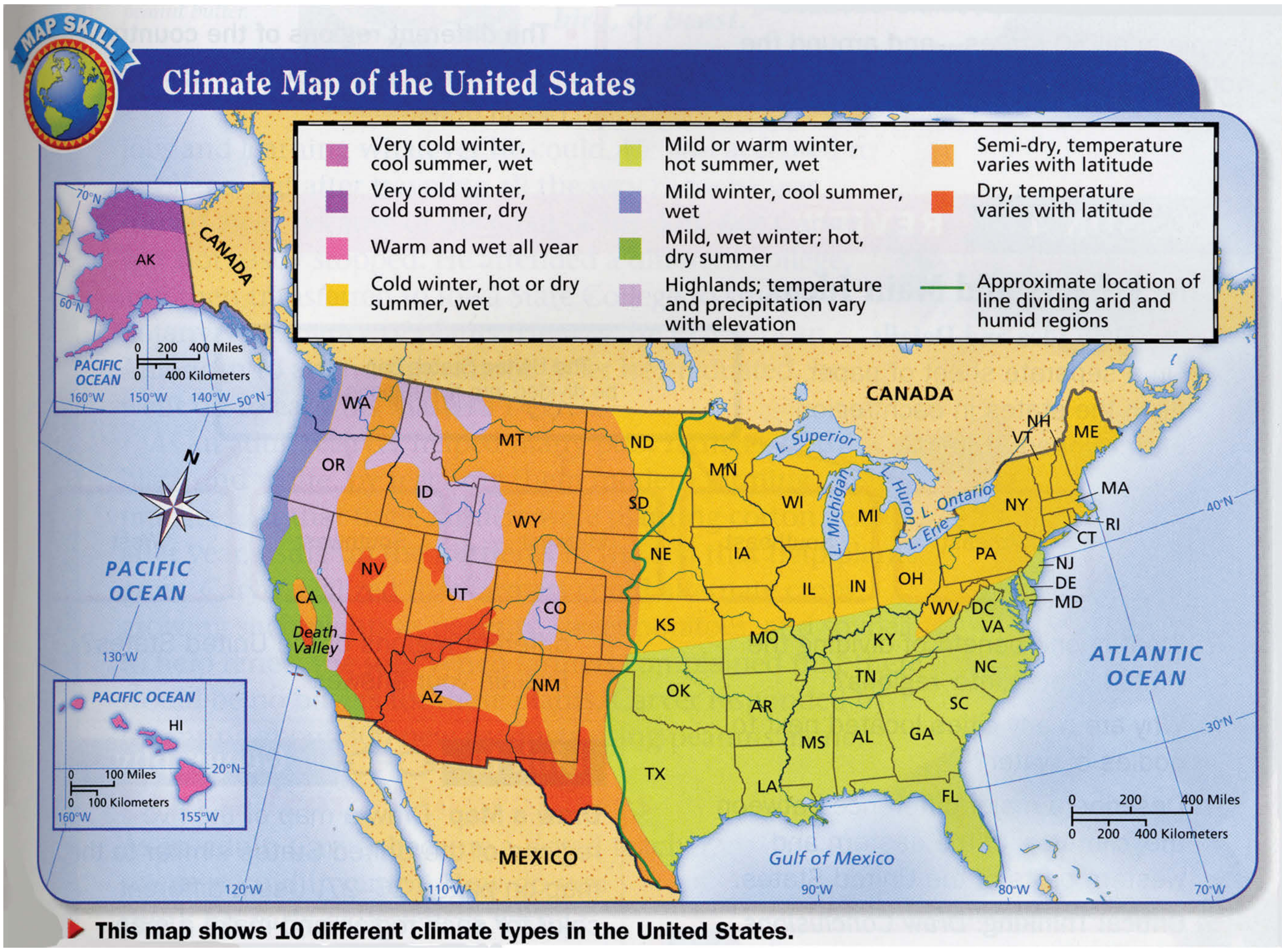


Figure 2. U.S. Climate Map ©Geonova Publishing.

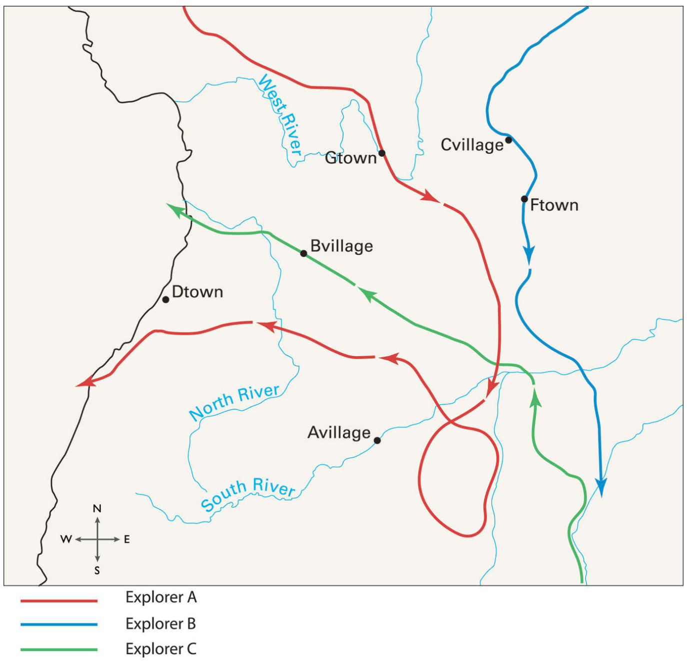


Figure 3. Example of the time-flow map used in this study.

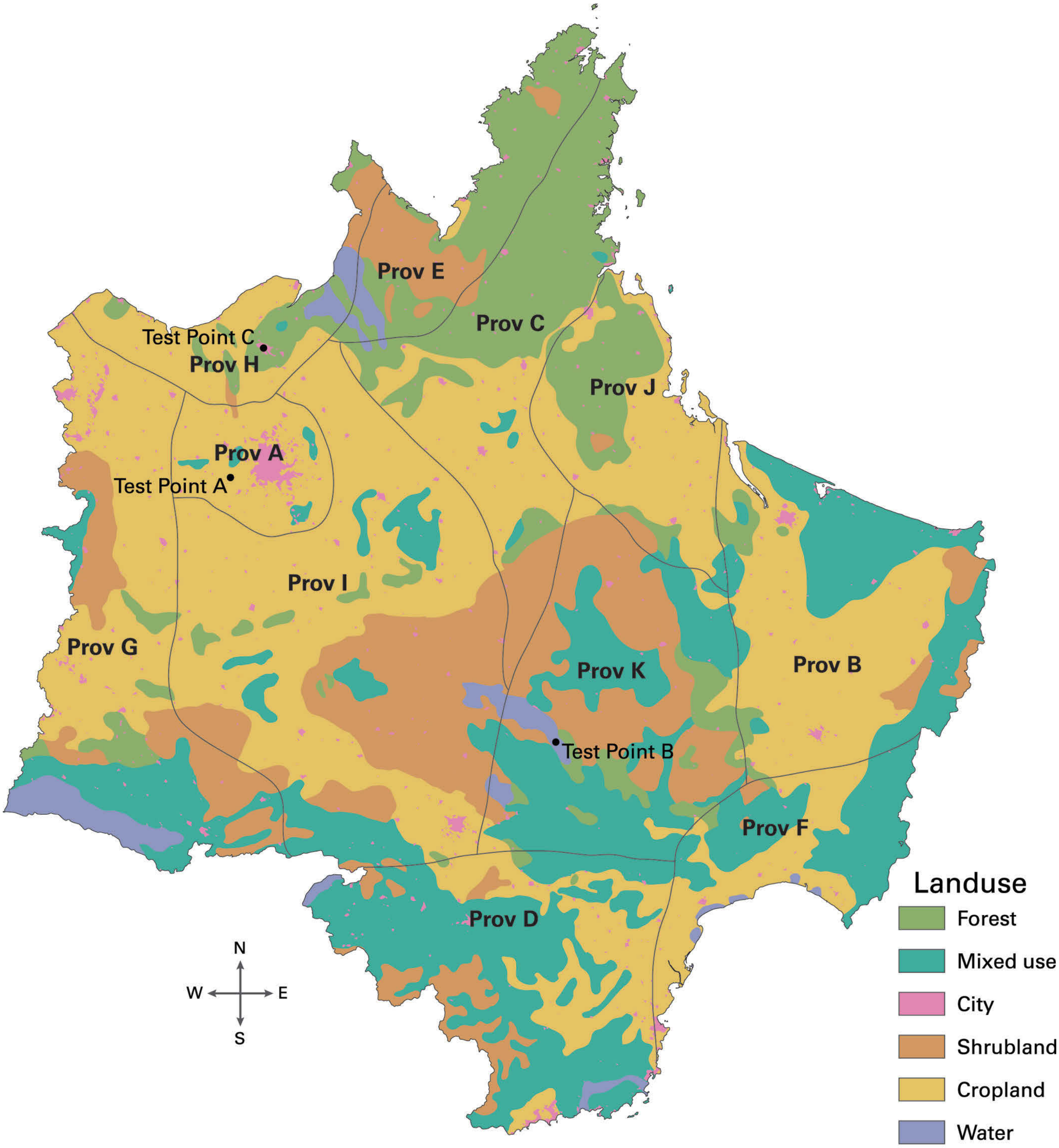


Figure 4. Example of the land use map used in the study.

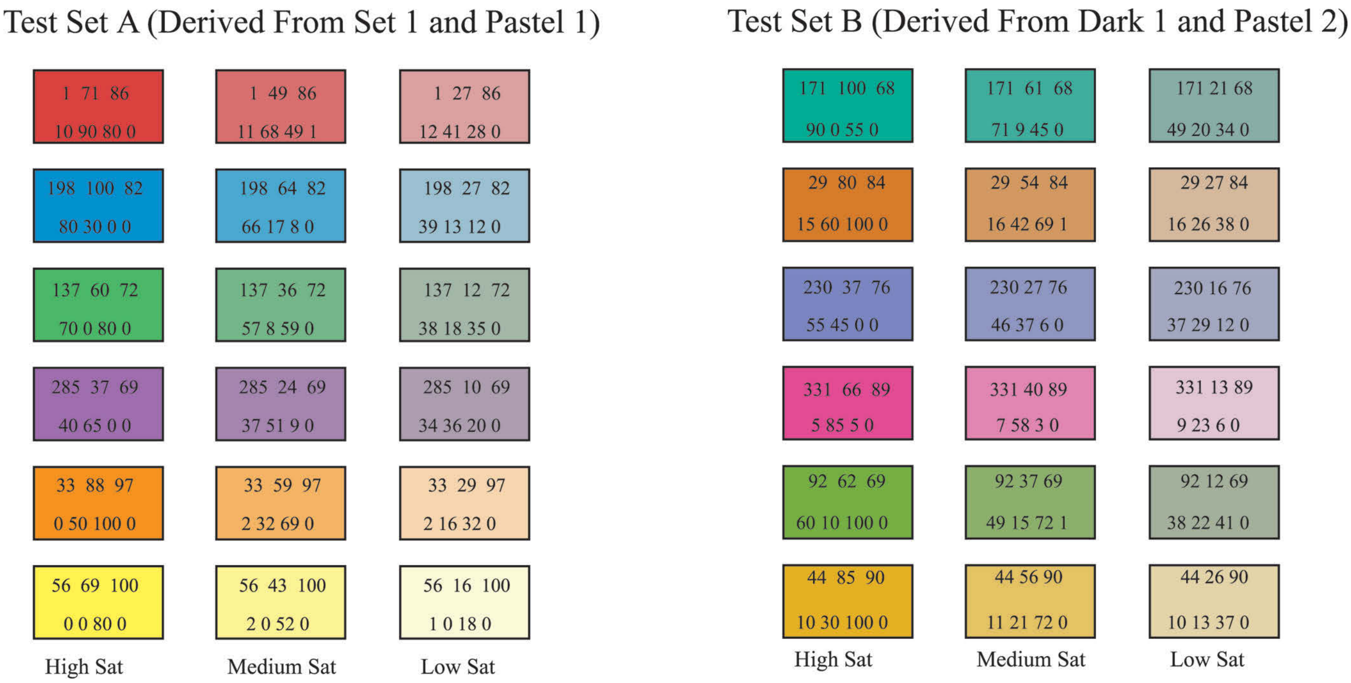


Figure 5. Tested Color Schemes (with HSB and CMYK values listed), derived from www.colorbrewer.org.

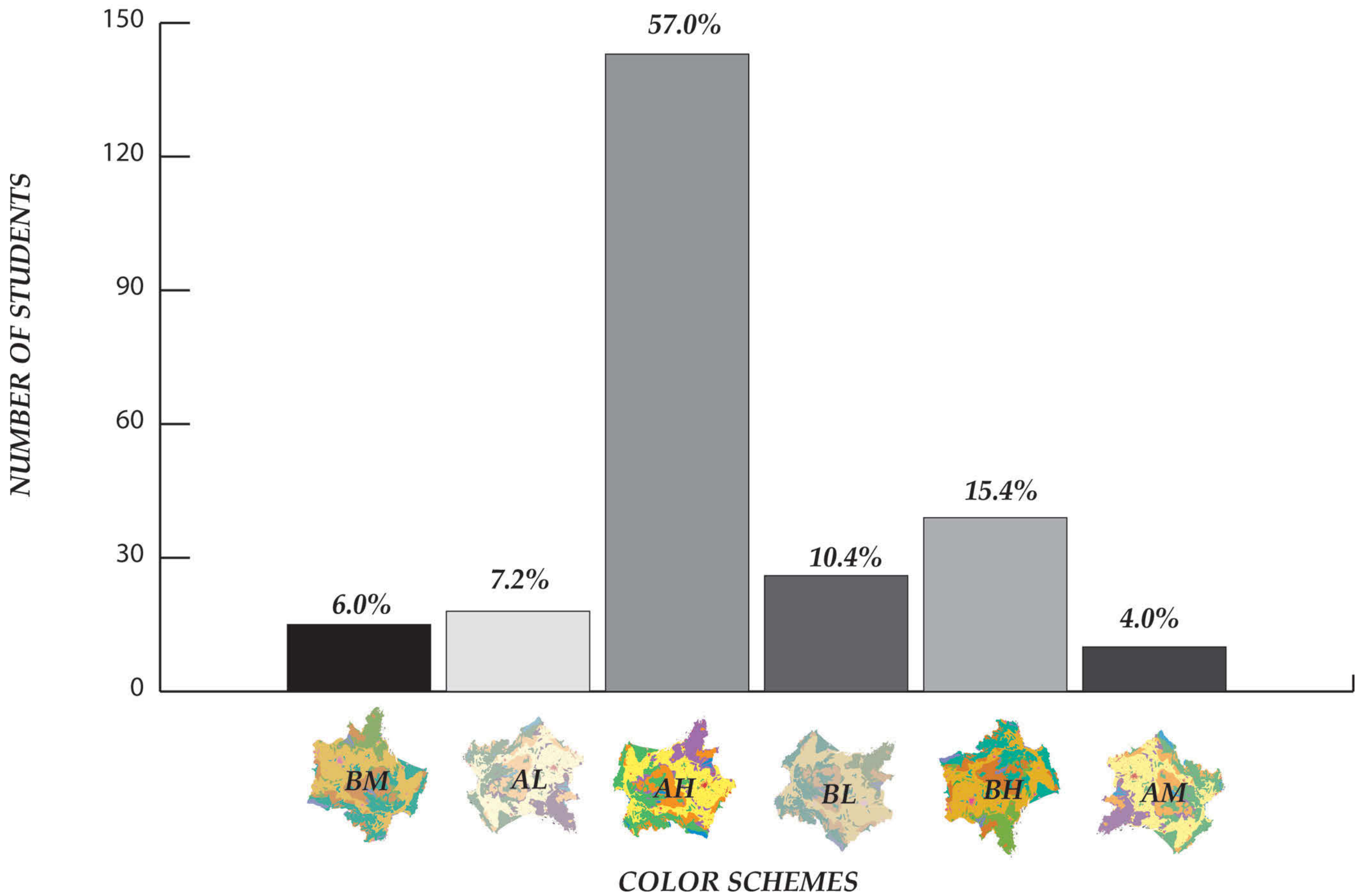


Figure 6. Preference by color scheme.

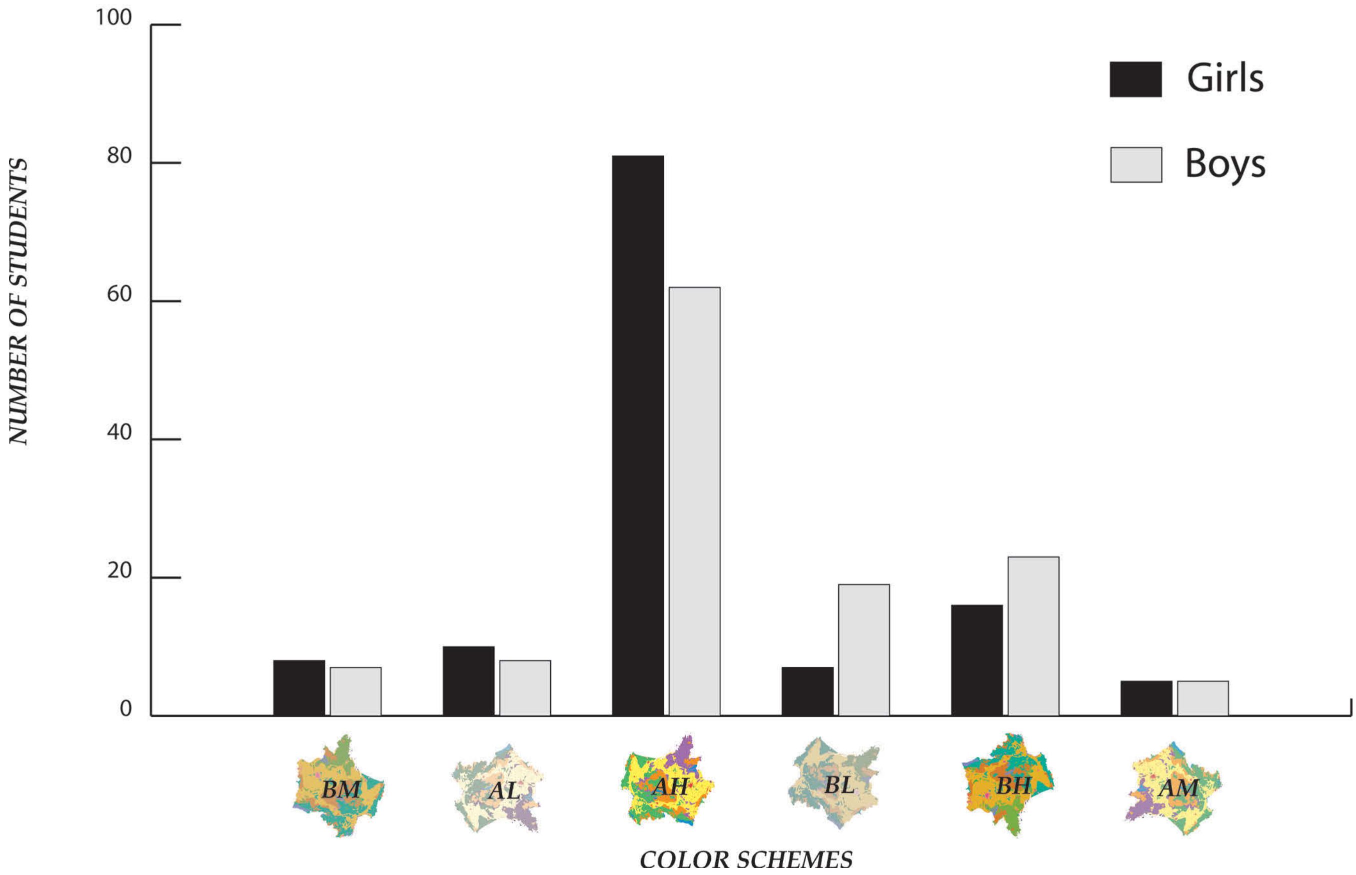


Figure 7. Color scheme preference by gender.

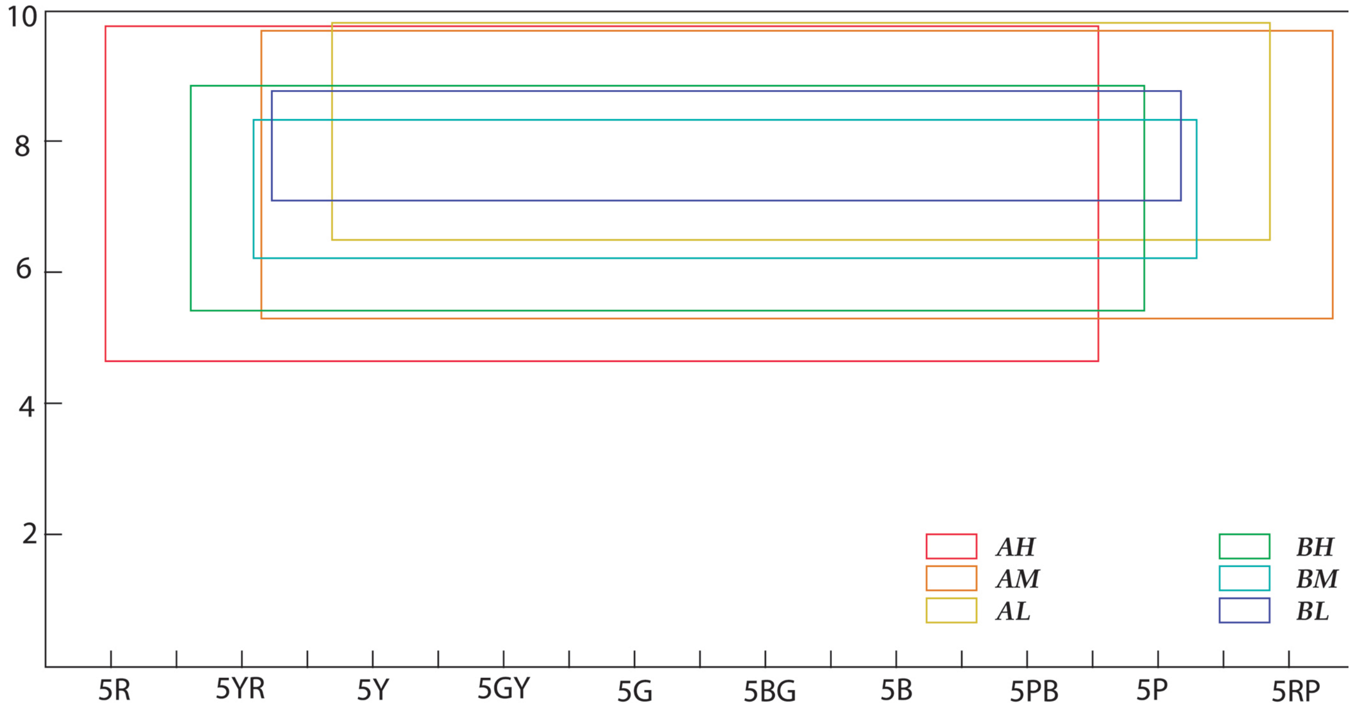


Figure 8. Graph of jitter for the six tested color schemes.

Question Type	Color Scheme AH	Color Scheme AM	Color Scheme AL	Color Scheme BH	Color Scheme BM	Color Scheme BL
Region Question (1,4) mean=88.6%	89.8% (n=322)	89.3% (n=318)	92.7% (n=328)	86.2% (n=318)	90.2% (n=328)	83.2% (n=322)
Point Question (2,3,5) mean = 76.35%	76.4% (n=483)	80.1% (n=477)	82.3% (n=497)	71.3% (n=477)	75.0% (n=492)	73.0% (n=483)
Total Performance	82.5%	84.7%	87.5%	78.8%	82.6%	78.1%

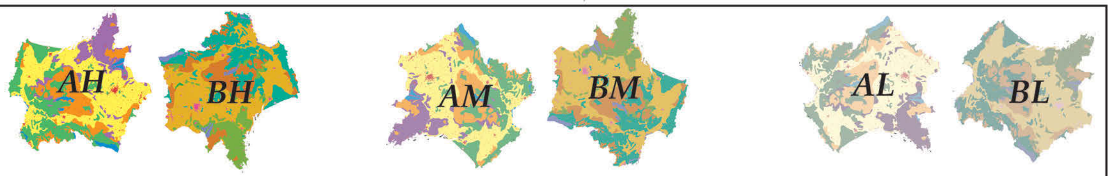
Table 1. Land use Performance (%Correct) by Color Scheme.

Source	Sum of Squares	df	Mean Squares	F ratio	Sig.
Saturation	910.82	2	455.41	0.9	0.39
Color	5157.92	1	5157.92	10.7	0.0011*
Sat*Color	1584.35	2	792.18	1.6	0.20
Error	470492.84	972	484.05		
*p<0.05					

Table 2. Saturation, Hue, and Brightness versus Performance ANOVA.

Question Type	Flow Map	AH Color Scheme AH	AM Color Scheme AM	AL Color Scheme AL	BH Color Scheme BH	BM Color Scheme BM	BL Color Scheme BL	Means
Direction Question	1	69.8% (n=43)	82.5% (n=40)	79.5% (n=44)	88.4% (n=40)	85.3% (n=44)	50.0% (n=43)	75.9%
	2	89.5% (n=37)	88.4% (n=43)	88.2% (n=34)	82.5% (n=43)	75.0% (n=34)	90.7% (n=37)	85.7%
River Question	1	83.7% (n=43)	92.5% (n=40)	88.6% (n=44)	97.7% (n=40)	91.2% (n=44)	73.7% (n=43)	87.9%
	2	89.5% (n=37)	79.1% (n=43)	82.4% (n=34)	80.0% (n=43)	86.4% (n=34)	88.4% (n=37)	84.3%
Loop Question	1	48.8% (n=43)	85.0% (n=40)	79.5% (n=44)	88.4% (n=40)	85.3% (n=44)	50.0% (n=43)	72.8%
	2	81.6% (n=37)	58.1% (n=43)	52.9% (n=34)	65.0% (n=43)	50.0% (n=34)	88.4% (n=37)	66.0%
City Question	1	57.0% (n=86)	88.8% (n=80)	79.5% (n=88)	93.0% (n=80)	88.2% (n=88)	57.9% (n=86)	77.4%
	2	82.9% (n=74)	62.8% (n=86)	54.4% (n=78)	73.8% (n=86)	64.8% (n=78)	89.5% (n=74)	71.4%
Total Mean Performance		73.35%	79.65%	75.63%	84.18%	78.64%	77.99%	

Table 3. Time Flow Map Performance (%Correct) by Color Scheme and Question Type.



	High Saturation	Medium Saturation	Low Saturation
Most Preferred	182	25	44
Least Preferred	37	51	164

Table 4. High and Low Preference by Saturation Level.