## featured article


#### Abstract

Ten process-printed color charts based on the perceptually ordered Munsell system were previously developed. Sixteen cartographers with experience in color map design were mailed copies of the chart and were subsequently interviewed by telephone. The objectives of the interviews were to gather background information on the cartographers' general use of color charts and to examine the perceived usefulness of the Munsell-based charts as aids for map color selection. Approximately half of the interviewees were not satisfied with the color charts they were currently using. Over half of the cartographers had difficulties with differences between printed map and chart colors. As a summary of the interviews, eleven recommendations are made for the design of yellow-magenta-cyan charts of the conventional lithographers' format. Twelve of the cartographers judged the Munsell-based charts as potentially useful aids for map color selection, especially for the design of thematic color progressions. Likewise, the cartographers' solutions to difficulties with the layouts of their conventional charts indicated that a different chart organization, possibly perceptual, would be useful to cartographic designers. Overall, the interviews revealed a surprising diversity of opinions about and requirements of color charts that are used in map design.


Cartographers use color charts (collections of example colors) to aid the color selection and specification process during map design. Within map color schemes, the perceptual dimensions of color (hue, value, and chroma) are used to communicate logical relationships between map features or categories. Therefore, perceptually organized color charts should be useful to cartographic designers for map color selection.

The Munsell (1976) color order system provides a perceptual organization of color that is of potential use to cartographic designers. The development of four-color process printed charts based on the Munsell system is described in a separate article (Brewer 1989). Each Munsell chart presents colors of a constant hue with a systematic vertical change in value and horizontal change in chroma (Figure 1). After developing the ten charts, I interviewed sixteen cartographers with experience in color map design. The objectives of these interviews were to gather background information on the cartographers' general use of color charts and to examine the perceived usefulness of the Munsell-based process charts as aids for map color selection.

A wide variety of color selection aids designed specifically for color printing are available to cartographers. The majority of printed color charts are structured to provide a comprehensive catalog of combinations of overprinted screenings of yellow, magenta, cyan, and black (YMCK) process inks (for example, Allan 1989, Pantone 1984, Kueppers 1982). YMCK charts are commercially available, produced by printers for communication with customers, and produced in-house for specific projects or for frequently-used press-paper-ink combinations. Pantone books (1988-89) that specify ink mixtures (rather than colors produced by screen combinations) are important for the selection of inks other than YMCK that are often used in map production.

Other color charts that demonstrate color order systems have been developed with the goal of objective description of perceived color rather than description of the results of color printing. Such charts are therefore

# Color Chart Use in Map Design 

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not accompanied by printing specifications (for example, YMCK percentages). Example color order systems include: Ostwald (not commercially available), Munsell (from Macbeth, Munsell 1976), Natural Color System (NCS from Swedish Standards Institute 1979), Uniform Color Scales (OSA-UCS from Optical Society of America, Optical Society Committee on Uniform Color Scales 1977), and CIELAB (represented in charts from Colorcurve Systems 1987). These systems are described in Hunt (1987) and Agoston (1987).

## Yellow-Red

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| 3015 | 4020 | 5030 | 6040 | 7050 | 8060 |
| 0040 | 0030 | 0020 | 0010 | 0005 | 0000 |
| 4020 | 5030 | 6040 | 7050 |  |  |
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Process-color screen specifications for chart
Figure 1: Format of the Munsell-based process printed color charts. The complete set of ten charts appears in color in Brewer (1989).

In response to the apparent need for perceptually ordered color selection aids, the ITC designed and produced a printed color chart for cartographers based on the Ostwald system (Brown 1982) and I have produced the set of Munsell-based color charts (Brewer 1989). Although my Mun-sell-based printed charts motivated the interviews on which this paper is based, questions were directed to chart use in general as well as to impressions of the Munsell charts in particular.

INTERVIEW PROCEDURE

The sixteen interviewees were selected because they were known to have experience with color map design. I sought experienced cartographic designers, rather than "naive subjects," to gain information on charts in the context of current mapmaking practices. To avoid biasing the responses toward a particular type of organization or type of experience, roughly equal numbers of people from academia, government agencies, and private firms were interviewed (six, five, and five respectively). The cartographers interviewed are referenced (Appendix), with permission, to give credit for the valuable information they have contributed. Permissions were also granted for use of the interview quotes that appear in this article.

## Question 1: Number of Color Maps Designed in Two Years

I did not require precise responses to this first question, and the responses are therefore difficult to compare because number of maps and involvement took a variety of forms. Questions arose on how to count atlas maps, series of maps with the same color scheme, revisions, color penplotter maps, two-color maps, student projects, and projects given minimal attention. If questioned, I asked participants to include all maps and count the number of individual maps in atlases and series. Estimates of the number of color maps designed in the last 2 years ranged from 5 to 2500 , and color maps made up 5 to 100 percent of the design work of the cartographers in those 2 years. I was, therefore, satisfied that each person's responses to the remainder of the questions were based on personal experience selecting map colors.

## Question 2: Methods of Printed-Color Specification

The purpose of the second question was to confirm that YMCK process printing was a useful form in which to offer the perceptually organized Munsell-based printed charts. Percentages of the four process inks were used by twelve of the sixteen cartographers for printing maps. Eight used both percentages of process inks and Pantone Matching System (PMS) inks for printing map colors (for simplicity I will use 'PMS' to designate ink colors other than yellow, magenta, and cyan, although these process inks are also included in the Pantone system). Four used only PMS inks and no process printing. Ted Koch noted the difficulty of planning to overprint two PMS colors: "What are you going to get when you combine them? That's really difficult to predict." Two cartographers who used both PMS and process inks usually used process color when the maps were being printed with color photographs, necessitating that the process inks be available on the press. Of the twelve who used process inks, three mentioned occasional substitution of a warmer red for the magenta ink.

## Question 3: Color Charts Available, Their Use, and Use Problems

Responses to this multi-part question revealed that all of the cartographers had access to and used color charts. Of the sixteen participants, fifteen had charts that were acquired pre-printed and three rarely used charts other than those developed within their organization. Three others mentioned custom charts they had produced as color proofs or had printed for specific projects. Most of the charts described were conventional process-printed charts (books or sheets) that were commercially available, supplied by printers, or printed in-house. These showed combinations of screened YMC inks and sometimes included screens of black. Black was usually printed in a constant percentage over individual charts, but the black for one set was on a transparent overlay and another set had three percentages of black printed over quarters of each color sample. One cartographer had a choice of special inks printed with conventional YMC combinations and two had charts printed with warm red replacing magenta. Another chart showed the process combinations on a variety of paper types.

Additionally, Pantone books and strip charts for PMS inks were commonly used and other charts named were the Ostwald-based ITC chart, Color Index charts, Defense Mapping Agency's color book, U.S. Geological Survey charts, restricted palettes for specific jobs, a computer firm's plotted chart, color wheels with process colors on transparent overlays, and two-color charts with screens of black over screens of one PMS ink.

In initial responses to the question on how the cartographers used charts, six of the cartographers said they used color charts to find the

The question of problems with the use of color charts elicited discussion of many interesting difficulties.
specifications for colors they had already decided upon. Nine combined looking for schemes on the charts with looking for pre-selected colors. This approach was often described as having a general idea of the color scheme (working out general relationships or knowing the category of hue desired) and then using the charts to select the final set of colors to be printed. During his interview, Greg Chu said, "I look at charts to give me ideas and see the colors as I'm designing."
Additional specific information on the use of charts surfaced in further comments. Six cartographers cut colors, or parts of colors, from the charts to allow them to align colors in progressions, and two had multiple copies of inexpensive sheet charts to cut up. Two others spoke of folding and overlapping charts to place colors side-by-side or of comparing colors by looking through holes punched in an overlying chart. Three described the use of charts in the iterative process of minimizing the number of percentages of each ink used on a map while maintaining a desirable scheme. This process of refinement reduces the complexity and cost of production and requires much rechecking of colors on charts. Two cartographers discussed the production of a chart showing combinations of a restricted set of percentages. The use of a few common percentages was strongly recommended by Loy (198?) who limited screen percentages to 10, 30, 70, and 100 on his color chart printed for design of the Atlas of Oregon. This approach assists simplification of production and brings colors with shared percentages in closer proximity for ease of comparison (they may be pages apart or widely separated on complete charts). An alternative approach described by one interviewee was to design a palette of ten or twelve colors for a project from which to select colors for individual maps.
The question of problems with the use of color charts elicited discussion of many interesting difficulties. The most common problem, reported by nine cartographers, was that chart colors did not match printed map colors. This problem was ascribed to differences between printers, differences in chart and map paper, and changes in color caused by chart aging. Three explained that chart colors also appear different on maps because the areas covered by the colors differ. Four said that simultaneous contrast with surrounding colors on the chart or map caused differences in color appearance, and two of these cartographers used masks to isolate colors on the chart pages to reduce visual distraction and remove induction from surrounding colors. Descriptions of difficulties were qualified with acknowledgement that charts were not a substitute for experience. Chris Arvetis commented that you "need years and years... to know what it is you are going to get." As charts are used, cartographers learn to anticipate and compensate for deviation from the chart colors and they choose sets of colors with sufficient contrast that differences are maintained with variation in printing.

Physical layout and the choice of colors on charts were also the subject of comments. Three recommended larger color samples ( $1 \times 1.5$ and $2 \times 2$ inch chips were both suggested). Three wanted moveable chips to lay side-by-side in color progressions. Three said their charts showed too many colors, and one solved the problem by taping out alternating rows and columns to simplify the charts. One preferred a color wheel of process-printed transparencies to avoid the cumbersome task of flipping through chart pages, but another was not satisfied with color wheels because the density of the film layers grayed colors. Two preferred all YMC combinations together on one sheet, but the omission of black screens was seen as a shortcoming of this chart design. Another felt that the subtle but useful differences possible with combinations of low percentages were not well represented in color charts.

In summary, seven of the participants were satisfied and five said they were not satisfied with the color charts they used. Four said they were satisfied, but qualified the statement: there are problems of simultaneous contrast and non-moveable swatches, they could be improved, they are not substitutes for experience, and they all leave something to be desired.

## Questions 4 and 5: Munsell System Familiarity

Fifteen of sixteen interviewees were familiar with the Munsell system but nine had never used it. Four cartographers said they used the system indirectly by working with a mental construct of the Munsell dimensions of color when designing map schemes. One had experience with a computerized slide-production system that used hue, value, and chroma for color designation. Two used the system in teaching about color, and one had used Munsell soil color charts.

## Question 6: Potential Uses of Munsell-Based Printed Charts

The final question of the interviews focused on the Munsell-based printed charts developed in the first stage of the research (Brewer 1989). Twelve of the sixteen cartographers saw potential uses for these charts. Two felt the charts would not be useful for color selection (one used only limited color palettes and the other said there was no difficulty with current charts). The remaining two gave intermediate answers: one was undecided and the other saw very limited potential use (PMS inks were used primarily). These figures must be interpreted with caution because interviewees were well aware that I had developed the charts and there may have been a tendency to provide encouragement with positive remarks. The elaborations on the responses, however, were informative.

The Munsell-based charts were described as useful tools both for color selection and teaching. Seven of the cartographers stated that the Mun-sell-based charts would be useful for selecting choropleth or thematic map progressions. Three suggested that the most useful progressions were found on diagonals, along which color difference steps are greater and both value and chroma change. Two mentioned the charts' value as teaching aids for explaining the dimensions of color, and Onno Brouwer made the general observation that "there really is such a thing as a color illiterate when it comes to choosing colors, and any scheme that can help a person in color choice would be great." One interviewee had already begun using the charts to explain the range of colors that would appear in duotone reliefs; this unexpected instructional use was possible because each chart shows a range of value and chroma for an individual hue.
Problems with use of the Munsell-based charts were also discussed. The charts were not of use to two cartographers because many of the colors were too dark for use on most of the maps they produced. In addition, one uses no more than two inks in colors to avoid registry problems and reduce the number of screen angles used for a color; most of the Munsell-chart colors are composed of three screened inks. The number of screens needed to print progressions of color from the charts was viewed by two as a problem when production costs were a constraint. Black screens are present on all of the Munsell-based charts, but two interviewees did not use screens of black in their map colors because black was reserved for type (late revision of type after compositing was common or black screens interfered with type crispness in gravure printing). On the other hand, one said that the greatest benefit of the charts was the presence of black and six mentioned that they frequently used screens of black to darken or enrich colors.

Interviewees also commented on the format of the chart booklet. Two

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felt that a good range was shown in a small number of color choices. In contrast, one recommended the inclusion of all screen combinations and another felt that too few choices were shown to allow fine-tuning of a color scheme to simplify production. One said that the white space around each chart color had the advantage of reducing contrast effects from surrounding colors. Another suggested that the color squares each be angled to emphasize the sequences along diagonals. Two felt that the hue, value, and chroma designations were unnecessary and two recommended that the process-color percentages be printed or overlaid directly on the colors because checking the separate listing was awkward.

COMMENTS AND CONCLUSIONS

Cartographers use color charts in many different ways. The wide variety of maps produced, resources available, and personal preferences created a range of chart-use problems and desired chart qualities that would be impossible to satisfy in the design of a single chart. Based on the interviews, the following recommendations are made for the design of conventional process charts for cartographers:

1) provide large color samples
2) include space between color samples to limit simultaneous contrast
3) use percentages that are available in production work
4) print percentage specifications directly on or adjacent to each sample
5) provide a greater selection of low percentages than high percentages
6) overprint screens of black on a subset of charts
7) substitute a warmer red for magenta on a subset of charts
8) price charts affordably (allows purchase of extra copies to cut apart)
9) punch holes in samples to ease color comparison
10) show colors on different paper types
11) print with the press and inks with which the maps are printed

A conflicting preference exists between the desire to have all percentage combinations represented and the desire to limit the charts to combinations of a subset of percentages. Charts produced for cartographers by Allan Cartography and Pikes Peak Lithographing (Allan 1989) fulfill all of the above requirements with the exception of points 9 (holes for overlay) and 11 (if Pikes Peak does not print the map). Their charts have the conventional format and are printed with a $0,5,10,20,40,70,100$ subset of screen percentages.
Approximately half of those interviewed were not satisfied with their charts and, given the problems discussed, I expect that almost all would welcome alternative chart organizations and automated color selection tools. Most chart-use problems discussed in the interviews focused on printing and physical format rather than specific organization of the chart colors. Cartographers did, however, mention moving colors around, folding, overlapping, cutting out colors, punching holes, creating limited palettes, and masking colors. Patricia Caldwell Lindgren described the awkward process of color selection: "When you are working with three or four variables or more . . . you have to either flip through a lot of pages or turn a lot of things or something. It's all just a cumbersome process. If you could sit at some sort of terminal and spec it out, . . . that would be helpful." These practical problems with chart use indicate that different color selection tools, possibly perceptually organized, should be useful to cartographic designers.
Overall, twelve cartographic designers judged the Munsell-based process-printed charts as potentially useful aids for map color selection, especially for the design of thematic color progressions. However, the

Munsell-based charts also had new problems inhibiting their use and shared some of the problems of other charts. As on existing charts, colors often will not match those of future printings and color samples are small and not moveable. The perceptual organization of the Munsell-based charts does not lend itself to looking for a color given a specific screen percentage combination and this was viewed as a disadvantage. Conventional charts, however, already provide a well organized catalog of screen combinations useful for refining percentage selection, and the Munsellbased charts are not intended to replace these charts. The Munsell-based charts are also not intended to obviate the need for color selection experience, though their use as teaching tools may aid in the acquisition of experience.

The nature of map production constraints is changing as automated production becomes more readily available to cartographic designers (Mattson 1989). Screens in one-percent increments are commonly available in digital map design, although limited precision at the press remains an important constraint. Labor for production of composite negatives need not be determined by the number of screens that map schemes require when composites are produced digitally. These developments free the cartographic designer to refine both logical relationships within and the attractiveness of their map color schemes. The flexibility of automated screening will allow perceptually ordered color-selection aids to be useful to a wide range of cartographic designers. Automation of printed-map production will not, however, immediately eliminate the need for printed color charts because of the persisting complexity of equating the appearance of emitted color on a CRT and reflected color from a printed map.

The interviews revealed a surprising diversity of opinions about and practical requirements of color charts. This diversity provides a rich source for future research on both printed color charts and CRT-displayed aids for map-color selection. The perceived usefulness of the Munsellbased charts was dependent on the type of design challenge cartographers faced. Are different color chart organizations better suited to different design problems? The importance of experience in chart use and color selection was acknowledged, but how does chart organization inhibit or facilitate learning about effective color selection and gaining that critical experience? How will cartographers use charts in the automated production environment and what new tools will be most effective for map color selection? Color selection may be better aided by tools such as comprehensive sets of appropriate color schemes or limited palettes and programs that accurately convert hue, value, and chroma combinations into process color specifications. Alternative chart organizations may assist cartographic designers in exploring effective and innovative color combinations. As Barbara Petchenik offered during her interview, "The real question is how do you think of a basic color scheme?"

I would like to thank Judy Olson for her guidance throughout this research.

Agoston, G. A. (1987) Color Theory and Its Application in Art and Design. 2nd edition, New York: Springer-Verlag.

Allan, S. (1989) Map Production Color Book. Medford, Oregon: Allan Cartography.
Brewer, C. A. (1989) The development of process-printed Munsell charts for selecting map colors. The American Cartographer, 16:4, pp. 269-278.
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## ACKNOWLEDGEMENT

## REFERENCES

Unpublished Masters Thesis, Department of Geography, Michigan State University, East Lansing, Michigan.

Brown, A. (1982) A new ITC colour chart based on the Ostwald colour system. The ITC Journal, 2, pp. 109-118.

Colorcurve Systems (1987) Colorcurve. Minneapolis: Colorcurve Systems Inc.
Hunt, R. W. G. (1987) Measuring Colour. New York: Wiley-Interscience.
Kueppers, H. (1982) Color Atlas: A Practical Guide to Color Mixing. Woodbury, New York: Barron's Educational Series.

Loy, W. G. (198?) Colorful Yet Simple: The Color Chart of the Atlas of Oregon. Unpublished Circular, Department of Geography, University of Oregon, Eugene, Oregon.

Mattson, M. (1989) Desktop mapping at Temple University. Cartographic Perspectives, 3, pp. 3-12.

Munsell, A. H. (1976) Munsell Book of Color. Baltimore: Munsell Color, Macbeth.
Optical Society Committee on Uniform Color Scales (1977) Uniform Color Scales. Washington D.C.: Optical Society of America.

Pantone (1984) Process Color Selector. Moonachie, New Jersey: Pantone Inc.
$\qquad$ (1988-89) Color Formula Guide. Moonachie, New Jersey; Pantone Inc.
Swedish Standards Institution (1979) Natural Colour System Atlas. Swedish Standard SS 01 91 02, Stockholm: Swedish Standards Institution.

## APPENDIX

Names of the interview participants and their professional associations at the time of the interviews in 1985:

## ACADEMIC

Onno Brouwer, Associate Director, Cartography Laboratory, Department of Geography, University of Wisconsin-Madison
Henry Castner, Professor, Department of Geography, Queen's University
Gregory Chu, Director, Carfography Laboratory, Department of Geography, University of Minnesota
Richard Groop, Associate Professor, Department of Geography, Michigan State University
A. Jon Kimerling, Associate Professor, Department of Geography, Oregon State Uriversity

Joseph Wiedel. Associate Professor, Department of Geography, University of Maryland
GOVERNMENT
Frederick Broome, Chief, Mapping Operations Branch, Geography Division, U.S. Bureau of the Census Ted Koch, Mapping Technologist, Mapping Services Bureau, New York State Department of Transportation Carolyn Weiss, Senior Research and Development Officer, Geocartographics Subdivision, Statistics Canada James Wray, Research Geographer (retired), National Mapping Division, U.S. Geological Survey, and Consultaint, TRADCOMP Charts
A graphic designer at a government agency (name withheld by request)

## PRIVATE

Chris Arvetis, Vice President and Creative Director, Rand McNally
Herb Heidt, President, Mapworks
Patricia Caldwell Lindgren, President, Caldwell and Associates
Barbars Petchenik, Senior Sales Representative, Cartographic Services, R.R. Donnelley be Sons Company Alfred Zebarth, Assistant Supervisor, Cartographic Division, National Geographic Society

## La Utilización de Cartas de Colores en el Diseño Cartográfico

Extracto

Diez cartas de colores de proceso de impresa, basado en el sistema de ordén perceptual Munsell, fueron desarrollado. Se despacharon copias de estas cartas a diez y seis cartógrafos con practica en el diseño de mapas coloreados, y subsiguientemente fueron entrevistados por telefono. El objetivo de las entrevistas fue para obtener una historial de el uso percibido de la carta base Munsell para asistir en la selección de colores. Sobre un mediano de los entrevistados no estában satisfechos con la carta de color que usaban corrientemente. El otro grupo, tuvo dificultad con la diferenciación de los colores entre los mapas impresos y los colores de la carta. Sumariamente, once cartógrafos recomendaron el diseño de una carta para los colores amarillo, azul, y rojo en un formato convencional litográfico. Doce cartógrafos votaron por la carta base Munsell como un auxiliar útil en la selección de colores, especialmente en el diseño temático de la progresion de colores. Igualmente, estos cartógrafos indicaron que las dificultades que tuvieron con el modelo convencional pudiera se corregido por una reorganización de la carta, posiblemente perceptual, que seria mas útil para los diseño cartográficos. Sobretodo, las entrevista revelaron una diversidad de opiniones sobre los requerimientos para el uso de las cartas de colores en el diseño cartográfico.

