— PROGRAM ABSTRACTS/ALGORITHMS —

Color-vision demonstrations on an IBM PC/AT with VGA

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The program CVD contains a set of color-vision demonstrations. They include plain color fields with surrounds, cross-context matching, spatial brightness and color contrast transfer, and adaptation. Also available are displays used in flicker photometry, additive color mixing, color order systems, and the diagnosis of color-vision defects. Simulations of experimental setups allow demonstrations of actual experimental methods and effects. Any color field may be modified, and adjustments are simultaneously displayed in a CIE x,y chromaticity diagram. Most demonstrations include a context-dependent, introductory help text with references.

Most introductory texts on color vision contain some pages of demonstrations that make the written material more interesting for the reader. Such printed demonstrations have two major drawbacks: First, they are expensive to print and thus must be limited to taking up only a few pages, and second, they are also limited to the presentation of static pictures. Many color-vision experiments, however, use dynamic effects or require interaction with the observer. So when I was preparing a text on color vision (Irtel, 1991), which was to be usable for an introductory course, I decided to develop a program for presenting color-vision demonstrations on a computer-controlled color monitor. The result was CVD, a program that presents all the demonstrations that are usually found in introductory textbooks on color vision, but which also does much more. It presents experimental techniques that require dynamic displays, such as those in flicker photometry or adaptation. The observer can interactively adjust all color fields shown and simultaneously see the colors' chromaticity coordinates and luminance values, and all of the demonstrations have verbal descriptions and references on line. The program may even be useful for preparing serious experiments. It contains many of the most common types of stimulus displays used in color-vision research and allows a quick check of simple experimental questions.

User Interface

The program is completely mouse-controlled and has two major screens. It always starts with a selection menu,

a list of all available demonstrations. After selection of a demonstration, the second major screen is shown. The left half of the screen contains a CIE x,y chromaticity diagram with a luminance scale at the top. There are also a small submenu and a color-selection field. The right half of the screen shows the demonstration image. The color-selection fields show the active colors of each demonstration.

A single color may be selected from the color-selection field or the demonstration image as the current color and be adjusted in the chromaticity and luminance diagram. The chromaticity diagram also shows the triangle spanned by the screen-phosphor primaries. This triangle marks the range of available chromaticities. The current color is adjusted by moving the mouse pointer with a button down in the chromaticity diagram or the luminance scale. Valid chromaticities are indicated by the mouse pointer's becoming a crosshair. Color adjustments are simultaneously displayed in the demonstration images.

The submenu contains a field for going back to the demonstrations menu, a field for selecting a full-screen display of the demonstration image, a special mode, and a text-selection field. Text selection is context-sensitive and provides some introductory text for the current demonstration, in many cases also including references. The text is available in English and German, the language being chosen by a command-line option. Special display modes are available for dynamic displays such as flicker stimuli or cross-context adjustments.

Demonstrations

The following is an abbreviated list of the demonstrations (there are 40 menu selections). Most of them have been derived from descriptions given by Smith and Pokorny (1986) and Wyszecki (1986).

- A single-color rectangle, with and without surround field for showing color attributes such as brightness, saturation, and hue.
- Two rectangles with surround fields for showing the effects of simultaneous contrast on chromatic and achromatic colors.
- Cross-context matching with the special display modes, showing the context effects by switching off the context fields after matching.
- Contour enhancement and completion in Mach Bands and derived images.
- Assimilation and neon effects with matching for on-line measurements.
- Spatial contrast transfer functions for brightness and color modulation.

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- Adaptation effects such as complementary aftereffect colors, hypersaturation, desaturation, induction by aftereffect colors, and the McCollough effect.
- Brightness matching by direct comparison and flicker photometry.
- Simulations of different methods of additive color mixing: radiance projection, flicker mixing, and spatial mixing.
- Protanopic, deuteranopic, and tritanopic confusion colors.
- Color order systems: a hue circle, a hue line, constant-hue pages, and 1- and 2-dimensional subspaces of 3-dimensional color space.
- Display types from experimental setups: a small test field with surround, a bipartite field with surround, a linear sequence of color fields, regular and irregular multiple-field pages ("Mondrians").

Applications

Within the restrictions of PC-quality color-stimulus generation, the demonstrations provide a good overview of psychophysical color-vision phenomena. It will be hard to find any color-vision effect that cannot be demonstrated with the program. Usually one will find some display that contains the image needed and then be able to tune the image to one's particular needs through interactive color adjustment.

As an example, consider the demonstration of color blindness. Suppose there is a color-blind student in the class, whose type of color blindness is to be diagnosed. The first step would be to test the protanopic, deuteranopic, and tritanopic confusion colors sequentially. Each of the displays shows nine fields in a three by three arrangement. The column colors have the same hue but differ in brightness. The row colors have the same brightness but differ in hue. One asks the subject whether the nine color fields of each of these displays seem to be grouped vertically or horizontally. If the response is "horizontally" for one of the displays, the anomaly is identified. If no display is reported as being grouped horizontally, the second step may be to use a demonstration that shows a 1-dimensional subspace of color space defined by the two endpoints of a line. One of these endpoints is then set to white, and the subject adjusts the other endpoint along each of the phosphor triangle sides in the chromaticity diagram until the point of minimal saturation is found. A color-blind subject should find two complementary points that lie on one of the confusion lines that identify the type of color blindness.

System Requirements and Initialization

The program runs on IBM PC/AT type computers under MS-DOS (Version 3.2 or later) and requires a VGA color graphics adapter, a VGA analog color monitor, and

a mouse pointer with standard driver software installed. Flicker photometry demonstrations will only work properly on 12-MHz ATs with fast enough VGA cards. Approximate gamma correction is implemented via the gamma function $L = E^{2.5}$. The on-screen luminance scale shows relative luminance values. These are percentages of the maximum luminance possible for the current color. The chromaticity diagram shows CIE x,y coordinates graphically, and there also is a numerical display of the current color's x,y chromaticities, its absolute luminance, and its RGB-monitor coordinates. Precise gamma correction and a true luminance scale is possible if the phosphors' x,y chromaticity coordinates are known and exact measurements of the monitor's luminance output are available for each color channel. A README file is distributed with CVD, which describes how to use this information. If the monitor's characteristics are not known, the program can only show approximate luminance values. In such a case, the monitor is assumed to follow the EBU standard for video monitors.

The program has several options. They may be used to select a special gamma table file, the text and message language (English or German), and an initial test image display. The test image is used for proper adjustment of the monitor's brightness and contrast settings. More parameters, such as luminance settings, screen-phosphor coordinates, screen size, and several others may be set in an optional initialization file.

The executable program is available from the SIMTEL 20 public-domain file server WSMR-SIMTEL20.ARMY.MIL via anonymous ftp of the file PD1: <MSDOS.VGA>CVD30.ZIP. To get the file by e-mail in the United States, simply send the single-line message

/PDGET PD1: <MSDOS.VGA>CVD30.ZIP

to LISTSERV@NDSUVM1.BITNET or to LISTSERV@RPIECS.BITNET. In Europe, send the same message to one of the TRICKLE servers like TRICKLE@DB0FUB11.EARN.

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