The Visual Perception System and Color

The Nature of Color
Color is a perceptual phenomenon. Color is caused by receptors in our eyes that are stimulated by electromagnetic radiation of certain wavelengths. The production of color requires 3 elements: light source, object, and the eye-brain system of viewer. There are some physical dimensions to color, Spectral and Reflected Color. Spectral color refers to color that is emitted as light, we respond to spectral colors of the visible spectrum. Reflected color results from selective absorption of visible radiation.

Spectral Color (Color as Light) Energy emitted from the sun comes in the form of the electromagnetic spectrum; colors come from a small portion of those wavelengths that are spectral hues of light. A hue is a specific color (red, green, blue, etc.) – see figure below. When all the hues are combined together you create 'white light'.

In the textbook, you should read and be able to:

1) Explain Subtractive colors, as well as CMYK

2) Define/explain the color dimensions of Hue, Value and Saturation, and be able to draw the corresponding color space:
3) Explain the Munsel color space (see fig below) – a perceptually determined color space.

4) Label the various parts of the eye, and explain their purpose/function in the visual system. Rods, Cones, Retina, Lens, Pupil,
5) Explain color connotations: color connotations must be taken into account in combination with intended use when designing a map (from Johnson, 2001, Cartographic Perspectives).

<table>
<thead>
<tr>
<th>Hue</th>
<th>Positive Meanings</th>
<th>Negative Meanings</th>
<th>Cartographic or Cultural Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>blood (life); fire (warmth); passion; sentiment; valor; patriotism; revolution; Christ; liberty; strength; excitement; love; busy; action; extroversion; stimulation; loyalty</td>
<td>Blood (spilled); fire (burning); death throes and sublimation; wounds; surging/tearing emotions; passions; war;anity; revolution; martyrdom; danger; the devil; noise; defiant; contrary; hostile strong red: warning</td>
<td>high elevations; important items; communication networks; line symbols (road networks); volcanoes; warm climate; power (i.e., electricity)</td>
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<tr>
<td>Orange</td>
<td>fire/flames; marriage; hospitality; benevolence; celestial fruit; pride and ambition; earthly wisdom; warmth; happiness; busy; harvest; fall; middle life; action</td>
<td>malevolence; Satan strong orange: warning</td>
<td></td>
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<tr>
<td>Yellow</td>
<td>the sun; light; illumination; dissemination and comprehensive generalization; magnanimity; intuition; intellect; supreme wisdom; highest values; divinity; ripening grain; vivacity; kindness; happiness; busy; fertility; joyful; jovial; cheerful; youth; optimism; spring</td>
<td>treachery; cowardice; weakness; noise; dishonesty; hate strong yellow: warning</td>
<td>boundary lines; high elevations; sand; desert; dry climate; power (i.e., electricity)</td>
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<td>Green</td>
<td>vegetation; nature; fertility of the fields; sympathy; adaptability; prosperity; hope; life; immortality; youth; freshness; auspiciousness; recognition of the soul; wisdom; restfulness; country life; rest; peace</td>
<td>death (connecting link between black mineral life and red mineral life); lividity; envy; jealously; disgrace; sinister; opposition; moral degradation; madness; greed; cheapness; ignorance</td>
<td>vegetation (various types); agricultural land (various types); wet lands; tropical climate; young population; recreation areas Islam; Irish</td>
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<tr>
<td>Blue</td>
<td>the sky. light blue: day; calm sea; thinking; religious feeling; devotion; innocence; truth; constancy; justice; charity; cold; restfulness; authority; serenity</td>
<td>doubt; discouragement; depression; melancholy dark blue: night; stormy sea; silence; loneliness</td>
<td>harbors; cold climate; water; air transportation; steel; mountains</td>
</tr>
<tr>
<td>Violet</td>
<td>power; spirituality; royalty;</td>
<td>sublimation; martyrdom;</td>
<td>heath land; Roman</td>
</tr>
<tr>
<td>Love of truth; empire; patience; humility; nostalgia; memories; dignity; richness; elegance</td>
<td>Mourning; regret; penitence; resignation; humility; sorrow; despair; pain</td>
<td>Catholic</td>
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<td>Brown the earth; utility; warmth; country life; cozy; friendly; reassuring</td>
<td>Barrenness; poverty; lonely; dull; depressing</td>
<td>Contours; rock formations; landforms; oil; mud; mountains; wet lands; dry climate; wood products</td>
<td></td>
</tr>
<tr>
<td>White day; innocence; purity; perfection; rectitude; wisdom; truth; quiet; authority; cleanliness; faith</td>
<td>Spectral; ghostly; cold; blank; void; mourning; sickness</td>
<td>Salt; cold climate; glaciers and icebergs</td>
<td></td>
</tr>
<tr>
<td>Gray maturity; discretion; humility; penitence; renunciation; retrospection; quiet; reserved</td>
<td>Neutralization; egoism; depression; inertia; indifference; barrenness; winter; grief; old age; penitence; cold; weakness; lazy; lonely</td>
<td>Clay; iron; natural gas; industrial land use areas; urbanized areas; rocks; mud or sand flats; rainy or moist climate; luke warm climate; roadways; older population; steel</td>
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<tr>
<td>Black mighty; dignified; stark; sophistication; regality (without being pompous) fertilized land; grim determination; night; solemnity; humility; authority; strength</td>
<td>Morbidity; nothingness; despair; night; evil; sin; death; sickness; negation; lonely; mourning; heaviness</td>
<td>Oil; factories; railroads; roadways; Protestant</td>
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</tbody>
</table>

6) List the qualitative conventions for color on maps: blue for water, green for lush vegetation; red = warm and blue = cool in temperatures; hill shading

7) List color preferences:
   • Generally adults tend to favor colors at the shorter wavelengths.
   • Color preferences among North American adults are blue, red, green, violet, orange, and yellow, in that order . . .
   • Women show a slight preference for red over blue and yellow over orange, whereas men slightly prefer blue over red and orange over yellow.
   • Both sexes choose saturated colors over unsaturated colors
   • Colors with longer wavelengths, the red (warm) end of the spectrum, seem to advance in the field of view, thus appearing closer, while colors at the blue, shorter wavelength (cool) end of the spectrum appear to recede.
   • Hues with higher values that are more saturated also advance, while those with lower values or are less saturated recede

8) List the results of the “colors in combination” study described by Dent.

9) Explain the following visual phenomenon:
• **Simultaneous contrast**

  Simultaneous contrast occurs *when the eye spontaneously produces the complementary color of a viewed color*. When a color is surrounded by another color, it begins to appear tinged by the complementary color of surrounding color. Simultaneous contrast adjacent colors will appear lighter when surrounded by a darker color and darker when surrounded by a lighter color.

  ![Simultaneous Contrast](image)

  The medium gray line appears dull against the dull green background but looks brighter against the bright purple.

  Adapted with permission from San Diego Supercomputing Center, 1991

  Note that in the above example, the grey line surrounded by green is tinged with the complimentary color of the green, which is purple. When surrounded by purple, the grey line is tinged with the color green.

  ![Simultaneous Contrast](image)

  The dark gray line barely shows up against the black background but looks strong and dark against white.

  Adapted with permission from San Diego Supercomputing Center, 1991

  Here is another example of simultaneous contrast – note that the grey lines are the same grey.
• **Successive Contrast**
Successive contrast occurs when a given color is viewed in one environment (one color background) and then another (a different color background) in quick succession. Successive contrast can cause problems regarding interpretation of color on a map or in matching a color to its appropriate legend color. This is because the hue appears different with different backgrounds; the eye may be confused if it cannot find the same hue.

![Successive Contrast Images]

Note that the red-brown circles appear strongest against yellow-orange and bright green backgrounds, dullest against purple and blue.

• **Advance/Retreat Colors**
Humans perceive certain colors as advancing, others as retreating. Longer wavelength colors (reds) appear closer to viewer when seen next to colors of shorter wavelengths (blues).
Hue - longer wavelengths advance, shorter wavelengths retreat.
Value - high value (lighter) advances, low value (darker) retreats.
Chroma - deep, highly saturated colors advance, less saturated colors retreat.
10) Describe how color can be used for developing Figure and Ground.

Some websites that provide more visual examples:

http://thevirtualinstructor.com/members/interactive-color-wheel/
Interactive color wheel: be familiar with and be able to explain primary, secondary and tertiary colors, warm colors, cool colors and neutral colors. Note advancing and retreating colors are associated with warm and color colors. There is a discussion of this in the textbook.

http://brainden.com
color illusions:
  Examples of simultaneous color contrast:
    color dogs
    grey vs blue stripes
    lilac chase
Size Illusions:
    Ebbinghaus Illusion

http://colorbrewer2.org
Colors for qualitative vs. quantitative (sequential) data