Statistics 120
Using Colour

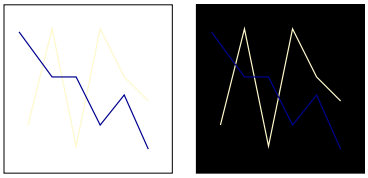
Contrast Reduced

Light and Dark Contrast

- The basic structure of any image is conveyed by the light and dark contrast in the image.
- This information is conveyed by the basic $R+G+B$ channel from the eye to the brain. Additional colour information is conveyed by the $R-G$ and $Y-B$ channels.
- When the $R-G$ and $Y-B$ channels are removed, the structure present in an image is still visible.
- When the light-dark contrast information is removed, the structure of images is much less apparent.

Basic Contrast Rules

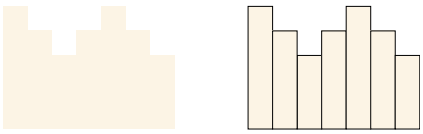
- Draw with dark colours on light backgrounds.
- Draw with light colours on dark backgrounds.



Full Colour Information

Contrast And Boundaries

- Use colours of contrasting lightness to emphasize boundaries between colours of similar lightness.

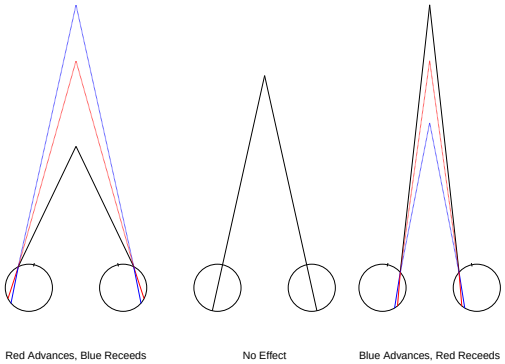


Hue Information Removed

Red and Blue

- Red and Blue are at opposite ends of the visible spectrum.
- They are refracted different amounts by the lens of the eye.
- Most people cannot bring Red and Blue into focus simultaneously.
- Most people see red as being in font of blue, a smaller group see blue in front of red and a few special individuals see them as being at the same distance.

Pseudo-Stereopsis and the Optical Axis



Common Uses For Colour

- Encoding a numerical scale.
- Encoding an ordered scale.
- Differentiating or grouping graphical elements.
- Making dull plots look interesting.

Red and Blue Together

Blue On Red
Hurts Your Head

Red On Blue
Makes You Spew

Purple Is A Mixture Of Red And Blue
It Is Hard To Focus On

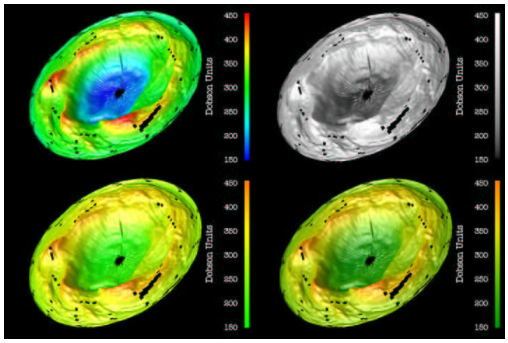
Encoding Numerical Values

- We find it hard to decode numerical values from colour (Cleveland and McGill).
- Research at IBM has shown that luminance is the only effective colour-based way of encoding numercial information.
- The use of a rainbow encoding is common, but misleading. (Hues form a circle, not a straight line).
- Colour can be effective when used in conjunction with light cues.

Blue

- There are relatively few blue cone cells in the fovea.
- It is harder to see fine detail when it is presented in blue.
- Blue is best used as a background colour.
- The blue cone cells have the slowest response to light changes.
- It it hard to see blue objects in motion.

Color-Based Numerical Encodings



All examples use luminance together with colour.

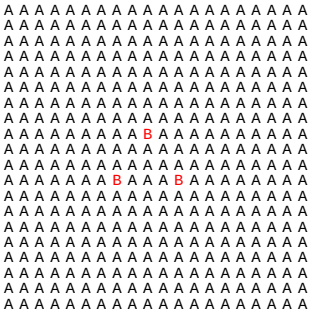
Colour Intensity

- Extended exposure to very bright colours bleaches the light sensitive pigments in the eye's cone cells.
- This makes the eye tired.
- Don't use large areas of saturated colour in displays which need to be studied for extended periods.
- Small amounts of saturated colour are alright because the sacades of the eye means that the colour does not rest for long on the same cone cells.

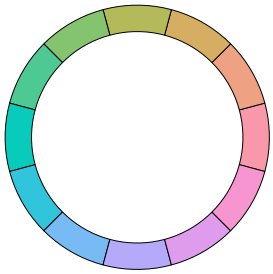
Differentiating or Grouping Graphical Elements

A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A B A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A B A A A B A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A
A A A A A A A A A A A A A A A A A A A A

Differentiating or Grouping Graphical Elements



An CIELUV Colour Wheel

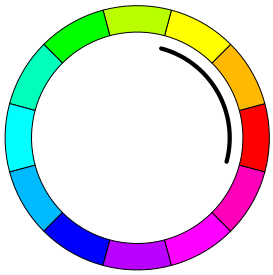


```
hcl(h = seq(0, 330, by = 30), c = 59, l = 75)
```

Choosing Colours

- Humans can distinguish millions of distinct colours.
- The size of this “search space” makes it difficult to find good colour combinations.
- The problem is even tougher because colours change their appearance when displayed together with other colours.
- Choosing colours “randomly” seems to produce very bad results (as does choosing random musical tones).
- Some guidance can be found in the principles of *colour harmony*.

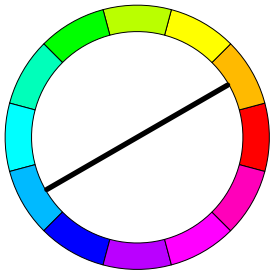
Analogous Colours



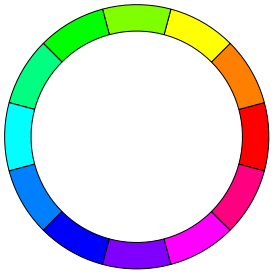
Colour Harmony Advice From Artists

- Books on the graphic arts offer some advice on how to choose “good” combinations of colours. Some suggestions are to use:
  - Analogous colours.
  - Complementary colours.
  - Triads.
  - Tetrads.
- These are typically described in terms of *colour wheels*.

Complementary Colours

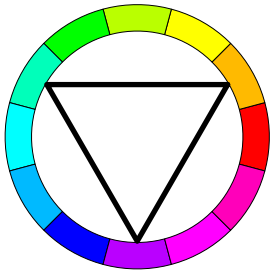


An HSV Colour Wheel

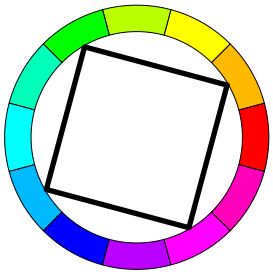


```
hsv(h = 0:11/12, s = 1, v = 1)
```

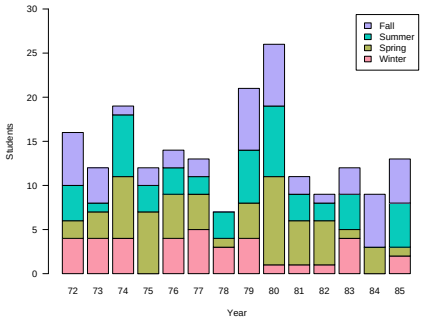
Colour Triad



Colour Tetrad



CIELUV Colours - Tetrad



`hcl(h = c(0,90,180,270), c = 59, l = 75)`

Choosing Colours From Colour Wheels

Generating `n` equally spaced hues using `hsv`.

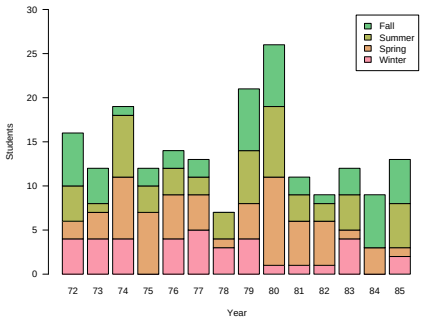
```
> hsv(h = seq(0, 1, length = n + 1)[1:n],
      s = 1, v = 1)
```

Generating `n` equally spaced hues using `hcl`.

```
> hcl(h = seq(0, 360, length = n + 1)[1:n],
      c = 59, l = 75)
```

Note that `hcl` is not a built-in part of R (yet). It is contained in a library called `colorspace` which is installed in the University labs and available from the class web site.

CIELUV Colours - Analagous

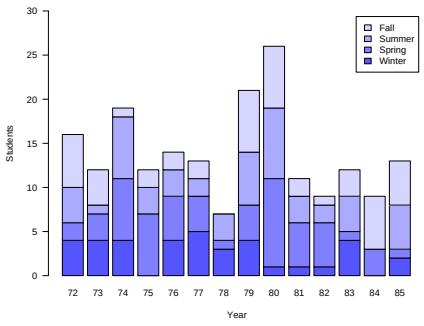


`hcl(h = c(0,45,90,135), c = 59, l = 75)`

Computer Science Graduations

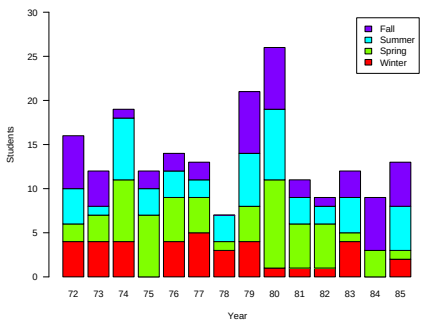
Year	Winter	Spring	Summer	Fall
72	4	2	4	6
73	4	3	1	4
74	4	7	7	1
75	0	7	3	2
76	4	5	3	2
77	5	4	2	2
78	3	1	3	0
79	4	4	6	7
80	1	10	8	7
81	1	5	3	2
82	1	5	2	1
83	4	1	4	3
84	0	3	0	6
85	2	1	5	5

Monchrome HSV Colours



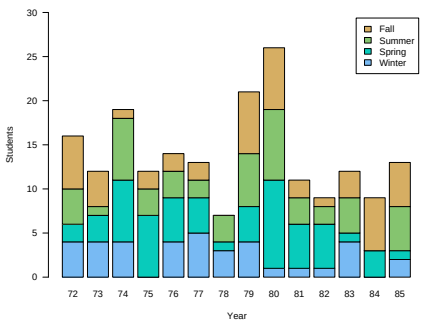
`hsv(h=2/3, s=4:1/6)`

HSV Colours - Tetrad



`hsv(seq(0,1,length=5)[1:4])`

Metaphorical Colours



`hcl(h = c(240,180,120,60), c = 59, l = 75)`