



THE UNIVERSITY OF
MELBOURNE



GEOM90007
SPATIAL VISUALISATION

LECTURE 4: COLOUR &
PRE-ATTENTIVE
PROCESSING



Image: <http://www.pinsdaddy.com>

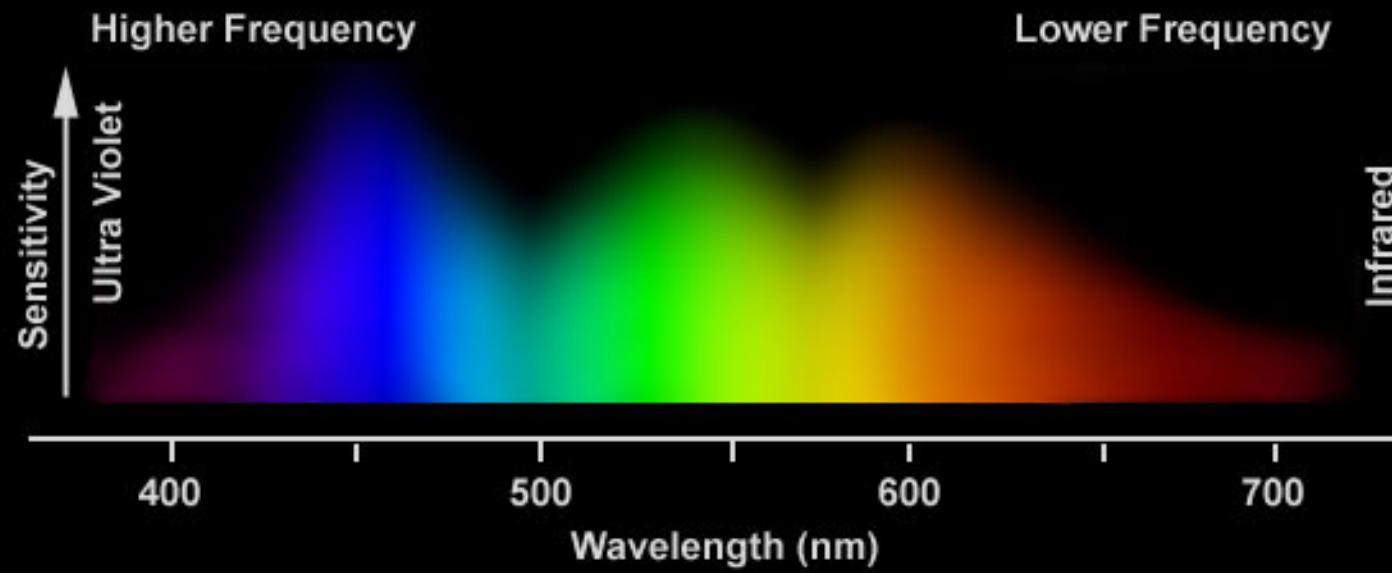


LAST LECTURE

- Neurophysiology
 - The eye, eye-brain system
- Physical impacts for visualisation
 - Acuity
 - Contrast
- Processing
 - Luminance, brightness and lightness

THIS LECTURE

- Colour vision
- Perceptual processing
 - Pre-attentive and attentive
 - Implications for visualisation



Colour

COLOUR USE

- Colour is very important in our daily lives to “break camouflage”
(Ware, 2013)

Find the cherries among the leaves:

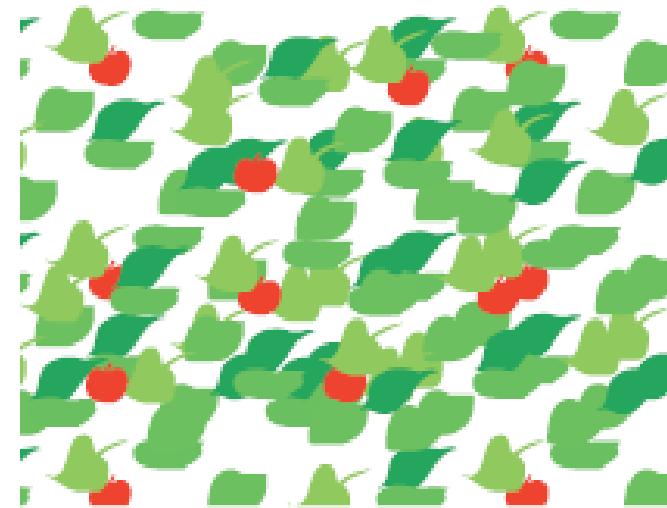
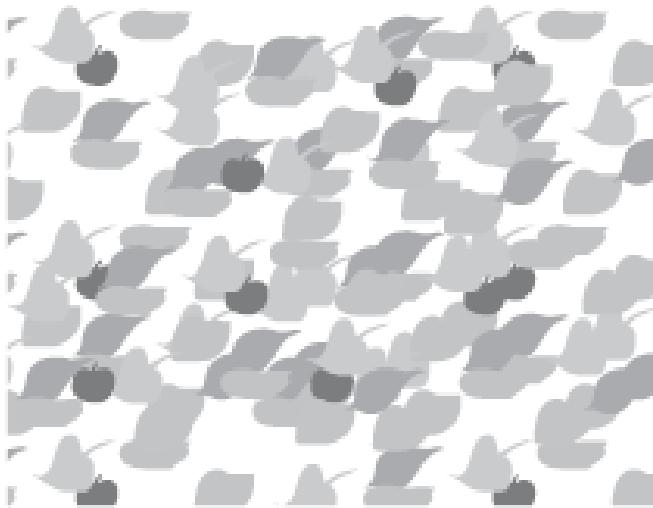


Image: Ware (2013)

COLOUR VISION

- Recall: 3 types of cones L, M, S
 - Three independent channels of information
- Trichromacy (basic theory of colour vision)
- Channels are **mixed** to represent different colours
 - Three-dimensional colour space (LMS)
- Chroma is Greek for colour, monochromatic refers to a single-wavelength
- Colour deficiencies may collapse colour space to two (or one) dimension

COLOUR DEFICIENCIES

- Photoreceptor sensitivity may be varied (may not affect acuity)

1. Anomalous trichromacy (slight, moderate, severe)

One cone has reduced sensitivity

- Protanomaly, reduced sensitivity to long wave lengths (~red)
- Deuteranomaly, reduced sensitivity to medium wave lengths (~green)
- Tritanomaly, reduced sensitivity to short wave lengths (~blue)

2. Dichromacy

One cone type is either absent or not functioning

- Protanopia, no sensitivity to long wave lengths (~red)
- Deutanopia, no sensitivity to medium wave lengths (~green)
- Tritanopia, no sensitivity to short wave lengths (~blue)

3. Monochromacy

Two or more cone types are either absent or not functioning

COLOUR DEFICIENCIES

- Photoreceptor sensitivity may be varied (may not affect acuity)
 1. Anomalous trichromacy (slight, moderate, severe)
One cone has reduced sensitivity

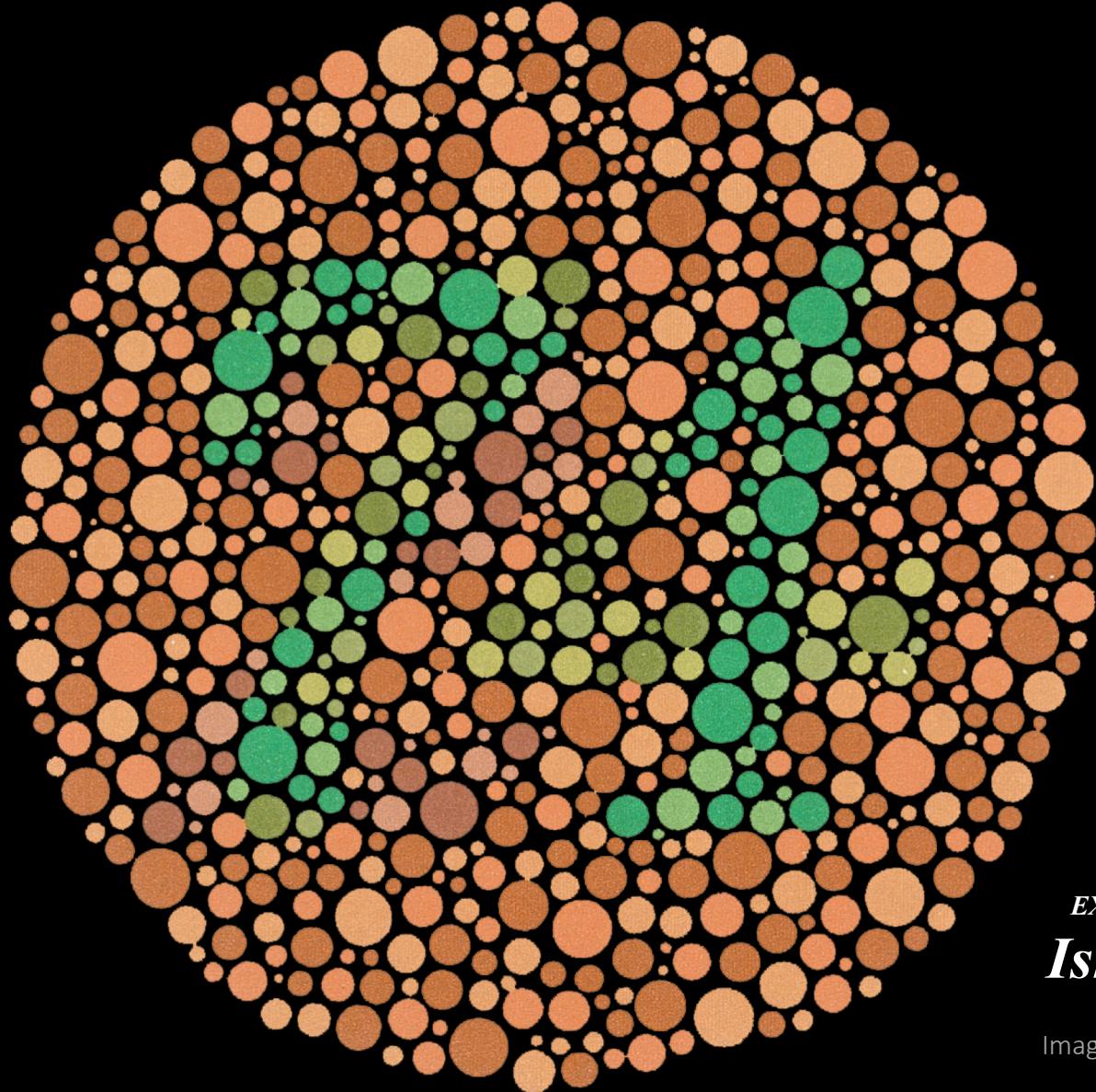
In some geographic areas, the population perceiving red and green the same (protan and deutan) is:

10 - 8% of all men
1 - 0.5% of all women

More information: Birch (2012) Worldwide prevalence of red-green color deficiency, J. Opt. Soc. Am. A, vol. 29, no.3, pp. 313-320

3. Monochromacy

Two or more cone types are either absent or not functioning



*EXTRACT FROM THE
Ishihara Test*

Image: Wikipedia Commons

COLOUR SPACES – FOR VISION

- *CIE*
 - Original created 1931 to link wavelengths and perceived colours
- *sRGB*
 - Standard red-green-blue, additive, cube based, for displaying graphics on and between devices
- *HSV (HLS...)*
 - Hue-saturation-value (lightness), additive, cylindrical, more ‘intuitive’
 - Component definitions on next slide

COLOUR SPACES – NOTES

Hue: An angular measurement (analogous to position around a colour wheel), independent of intensity or lightness

Value: Brightness. A value of 0 represents the absence of light, or black. A maximum value means that the colour is at its brightest

Saturation: Colour intensity. A value of 0 means that the colour is “colourless” (grey); a maximum value means colour at maximum “colourfulness” for hue angle and brightness.

Lightness: Maximum value means colour is white (regardless of the current values of the hue and saturation components).

Mac Developer Library (2005)

- *Avoid confusion*

- CMYK - Cyan, magenta, yellow, black, subtractive for printing
- YUV - Y (luminance) UV (colour), for digital video

COLOUR SPACES – NOTES

Hue: An angular measurement (analogous to position around a colour wheel), independent of intensity or lightness

Value: Bright means that



maximum value

Saturation: maximum v



"s" (grey); a d brightness.

Lightness: M
hue and sat



values of the

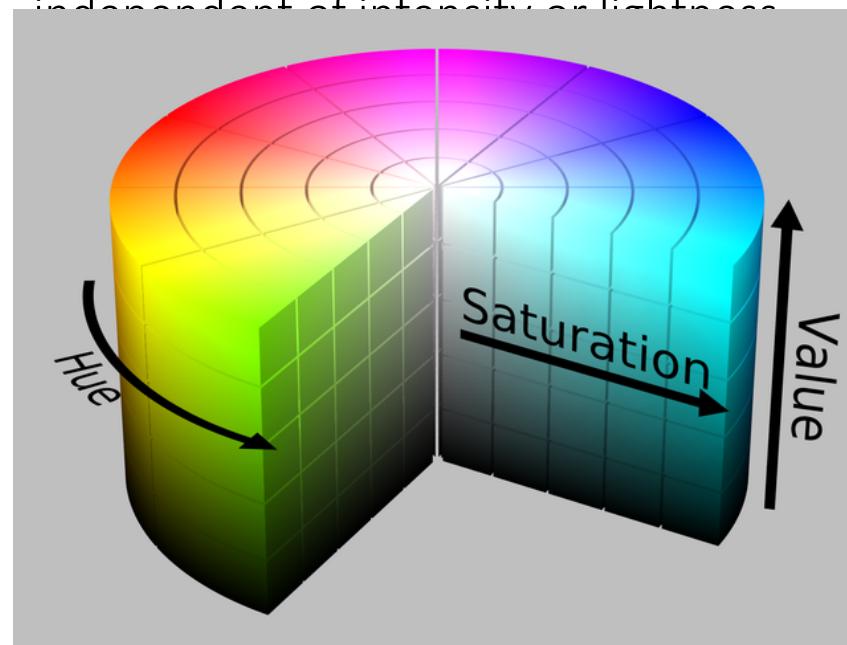
rary (2005)

- *Avoid confusion*

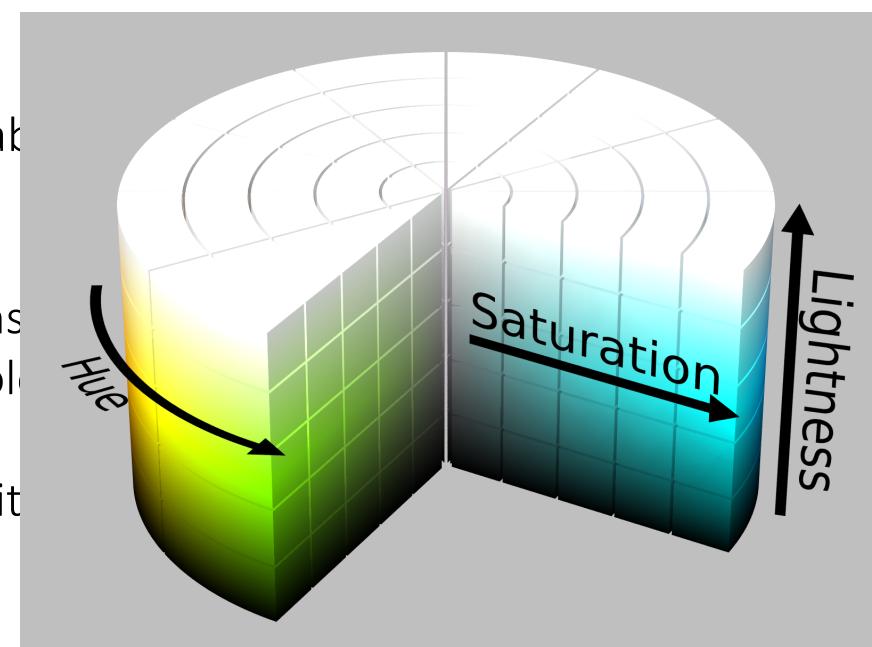
- CMYK - Cyan, magenta, yellow, black, subtractive for printing
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COLOUR SPACES – NOTES

Hue: An angular measurement (analogous to position around a colour wheel), independent of intensity or lightness.



is the ability to distinguish between different colours. It means "colouredness". White is white.



- *Avoid confusion*
 - CMYK - Cyan, magenta, yellow, black, subtractive for printing
 - YUV - Y (luminance) UV (colour), for digital video



COLOUR

Hue: An angle independent of brightness.

Value: Brightness means that

Saturation maximum

Lightness: hue and saturation

- *Avoid colour blindness*
 - CMYK
 - YUV

HSV space

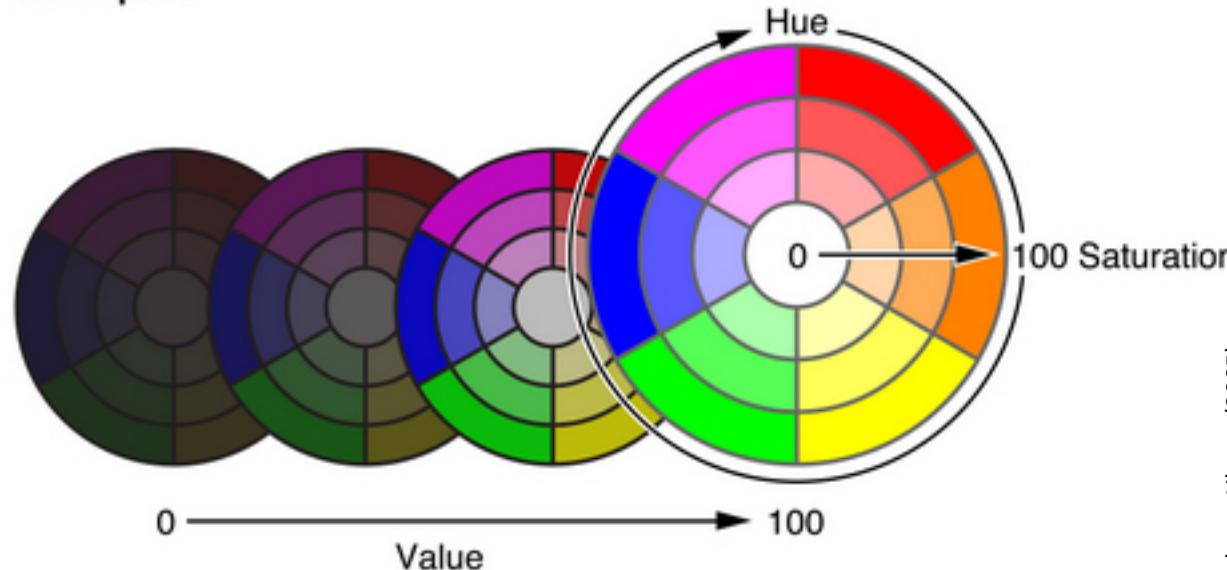
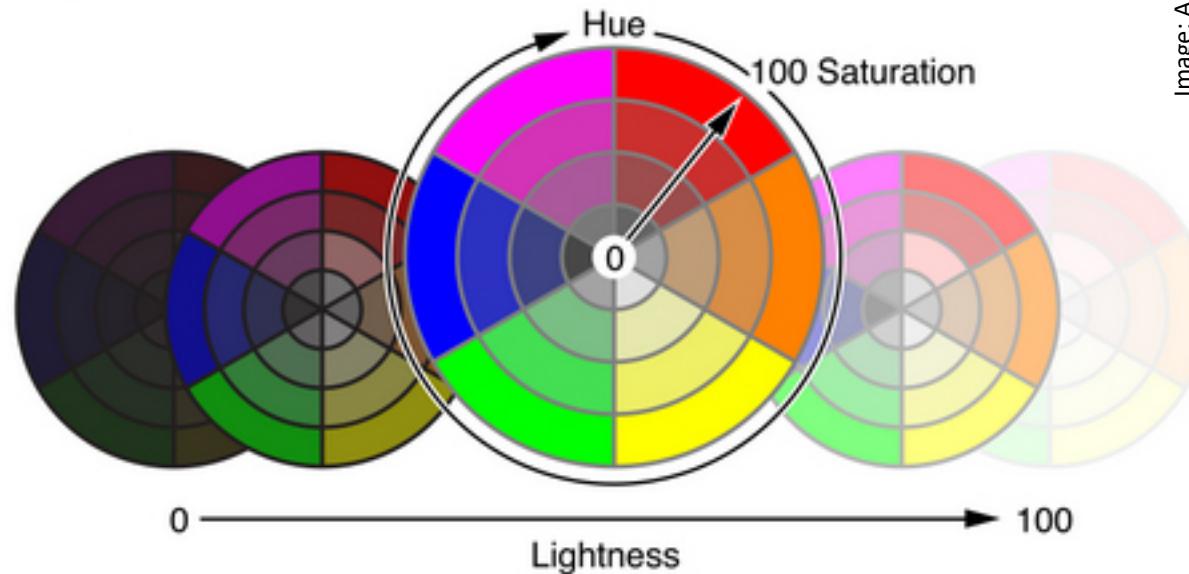


Image: Apple Mac Developer Library (2005)

HLS space



COLOUR SF

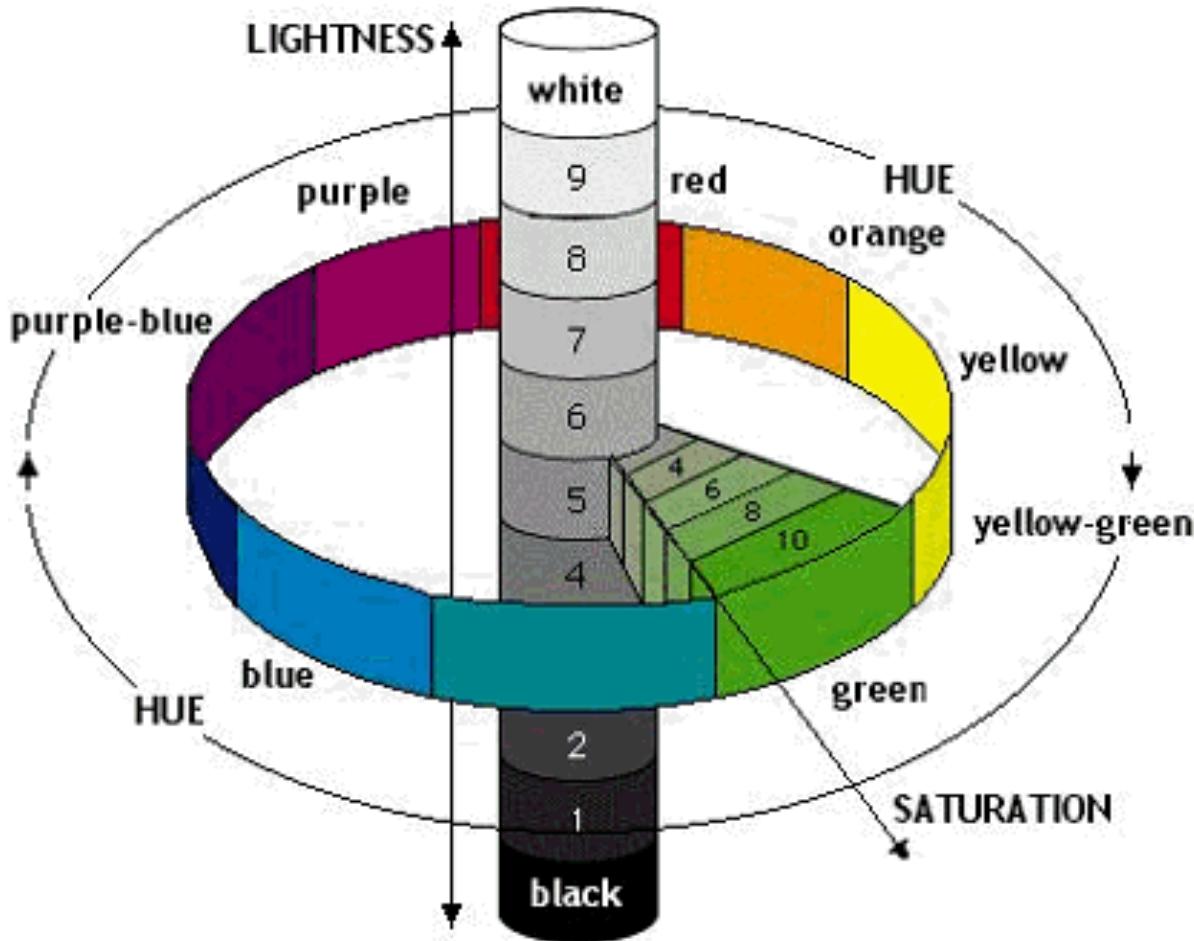
Hue: An angle independent

Value: Bright means that t

Saturation: (maximum va

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- *Avoid cor*
 - CMYK
 - YUV -



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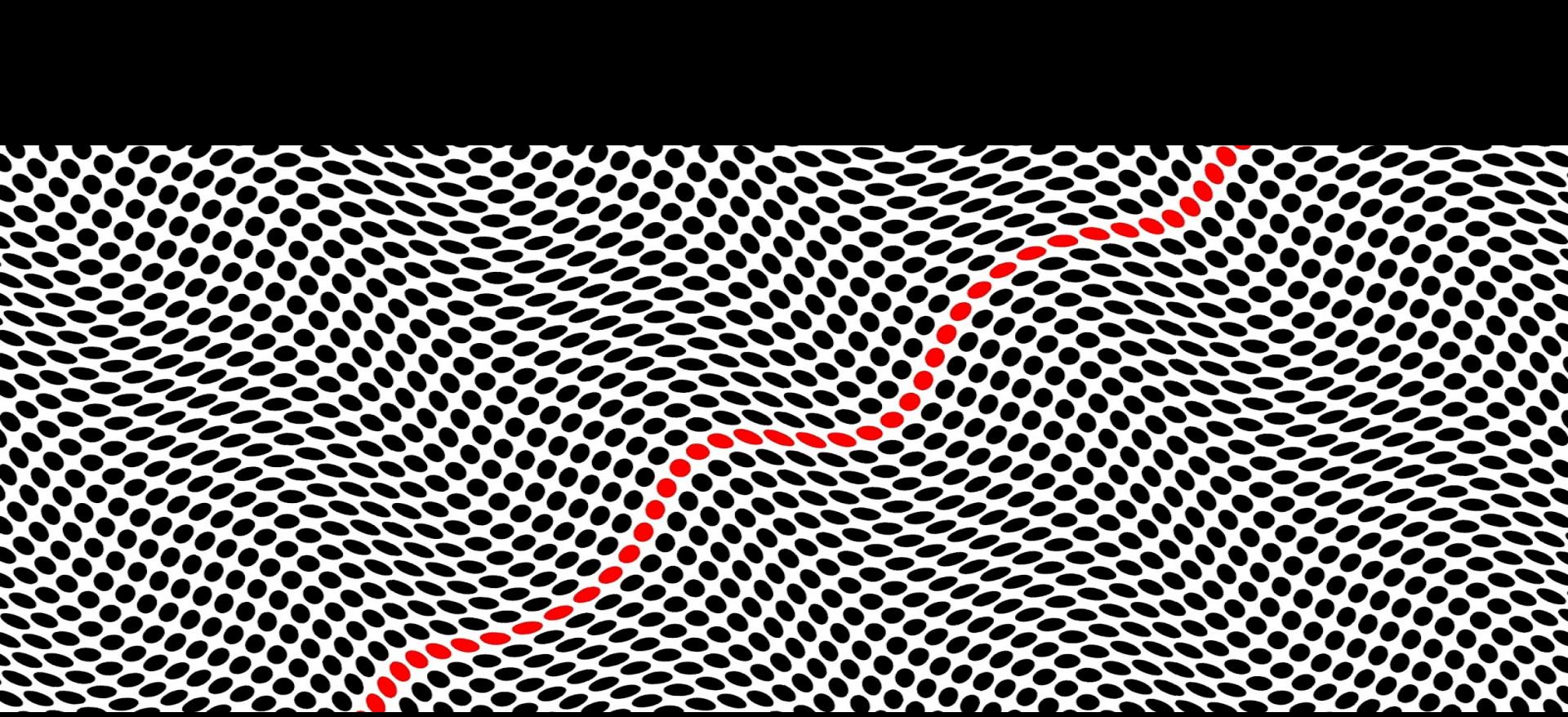
maximum value

ss" (grey); a
nd brightness.

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brary (2005)

inting



Pre-attentive Processing

PERCEPTUAL PROCESSING

- Eyes quickly search the visual field (refer Lecture 2)
 - e.g., saccades
- Pre-attentive stage: subconscious acquisition of information stored into the **iconic buffer** in ~200 -250 msec
- Certain symbol colours and forms “**pop-out**” from their surroundings

PREATTENTIVE (TARGET DETECTION - COLOUR)

What's the frequency of number 6s in the following?

998075424598370916439819832098934703900

a) 908984564897432315019898320459840698112

849879324907090880198274778796908909320

909238091228380140902389890890123059049

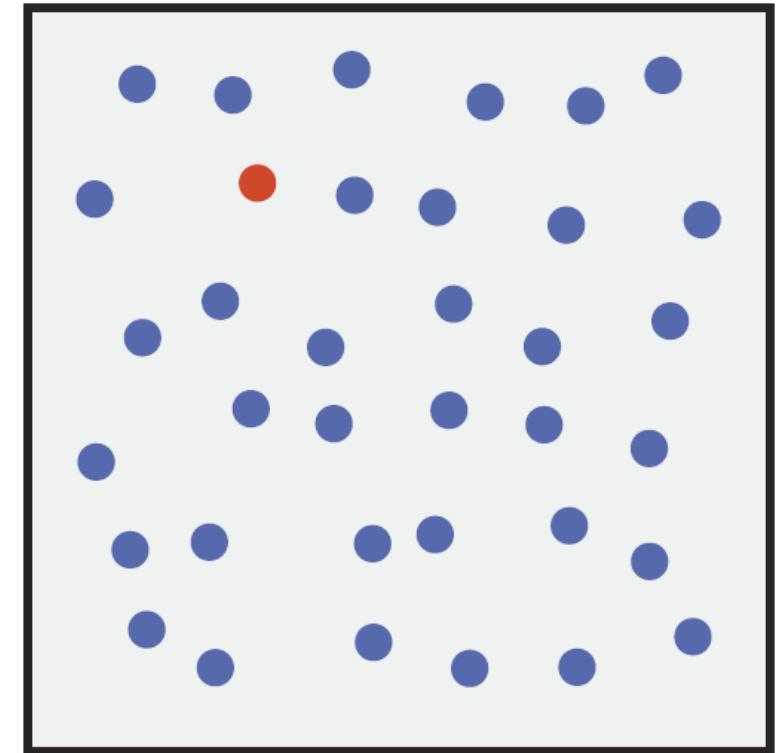
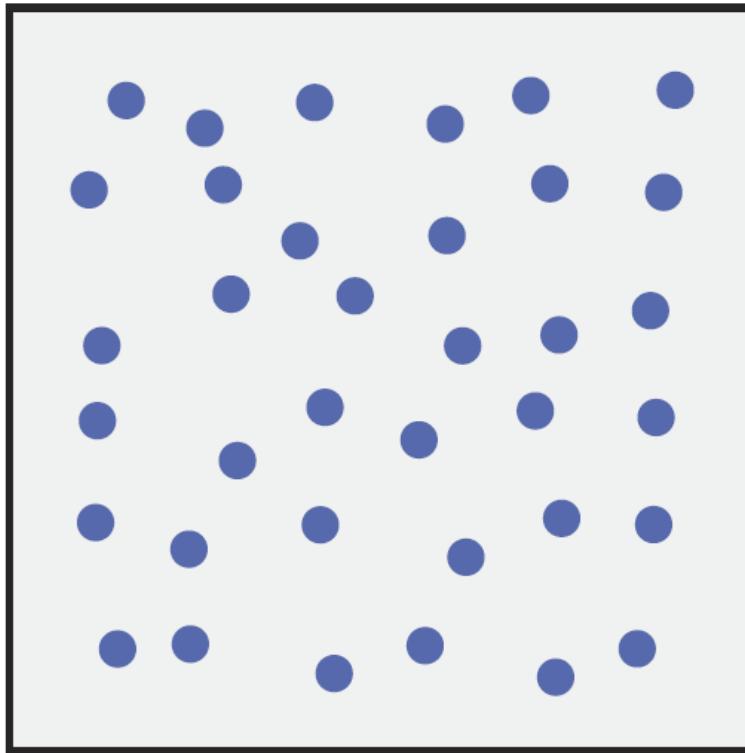
998075424598370916439819832098934703900

b) 908984564897432315019898320459840698112

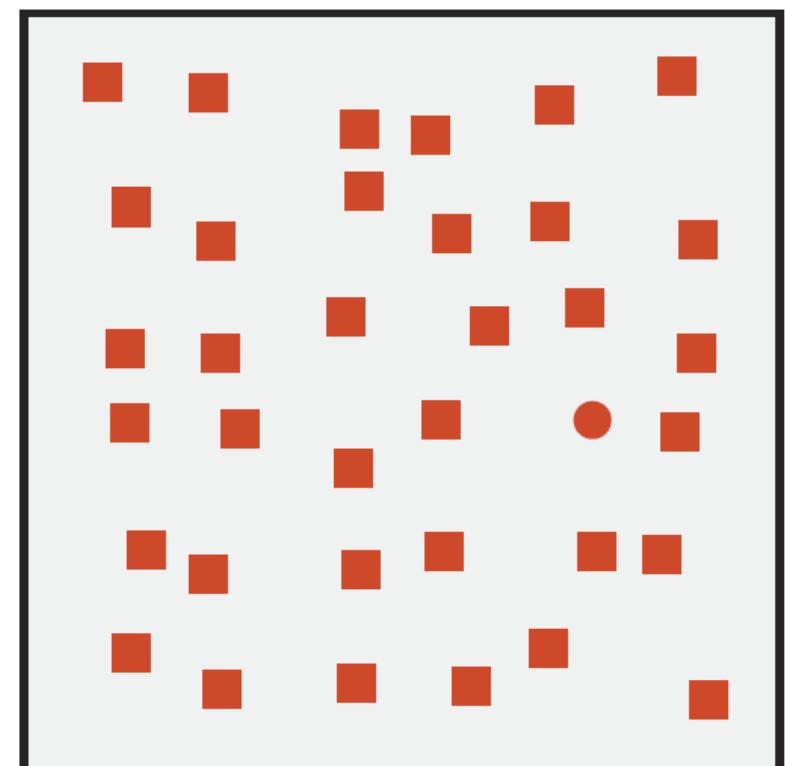
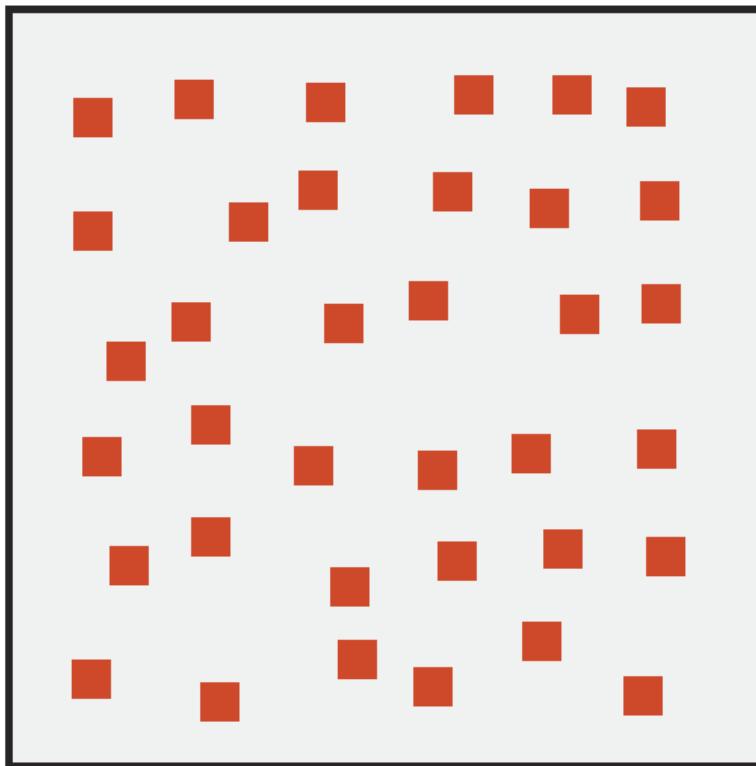
849879324907090880198274778796908909320

909238091228380140902389890890123059049

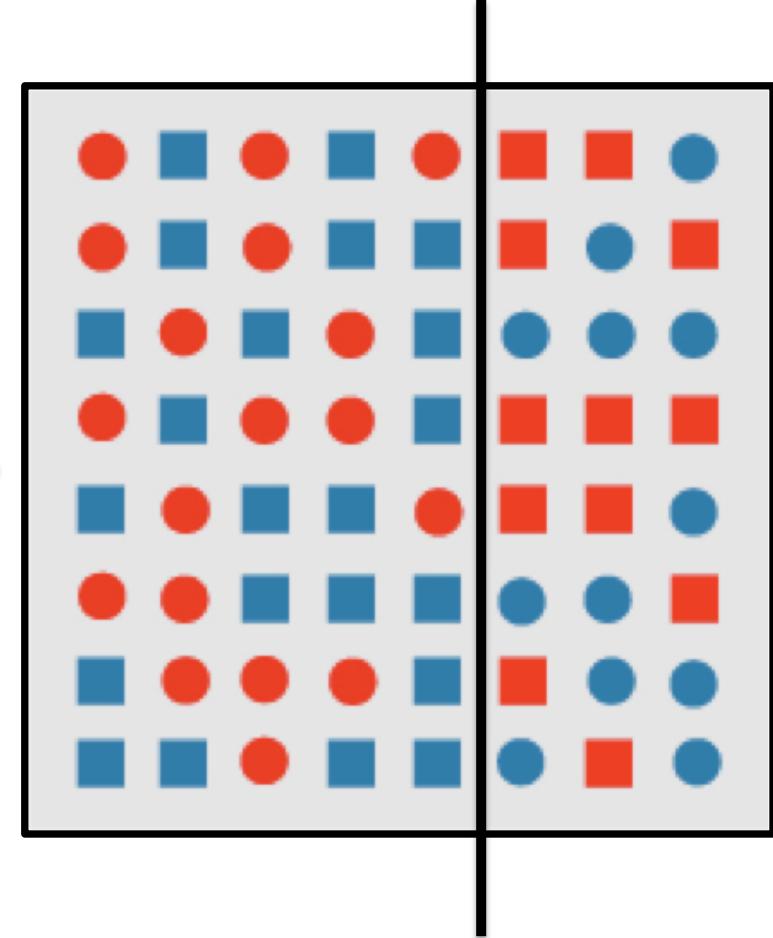
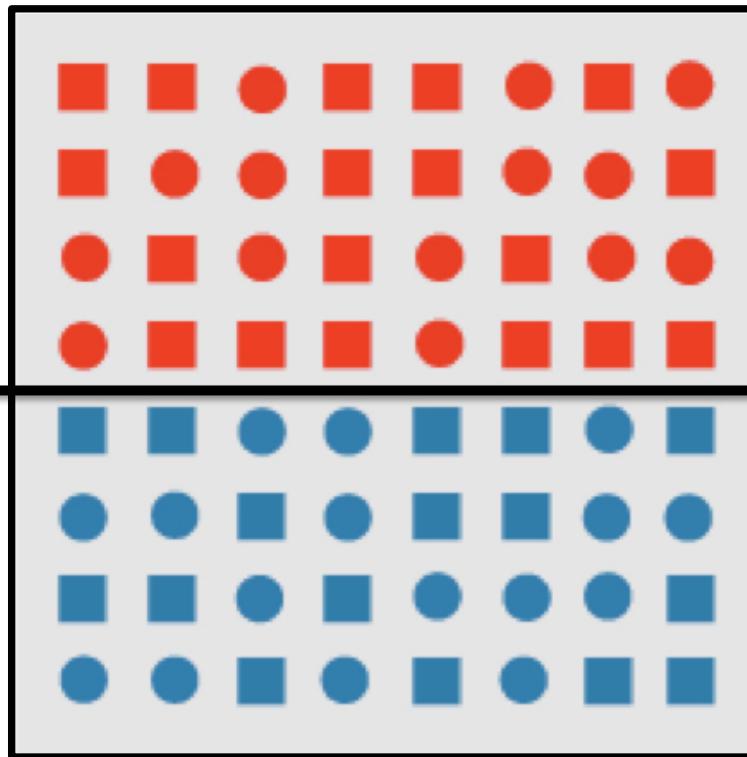
PREATTENTIVE (TARGET DETECTION – HUE)



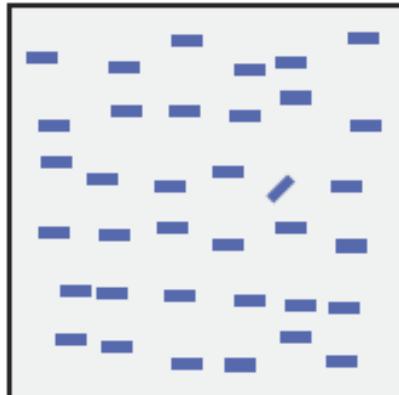
PREATTENTIVE (TARGET DETECTION - CURVATURE)



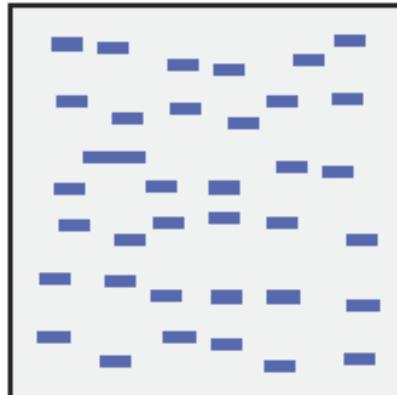
PREATTENTIVE (BOUNDARY DETECTION – CONJUNCTION OF HUE AND CURVATURE)



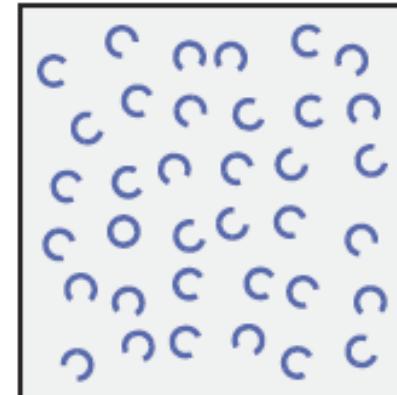
PREATTENTIVE (MORE EXAMPLES)



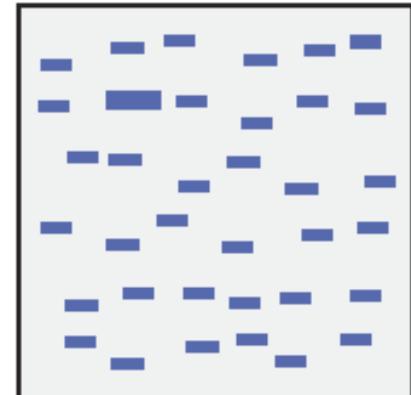
orientation



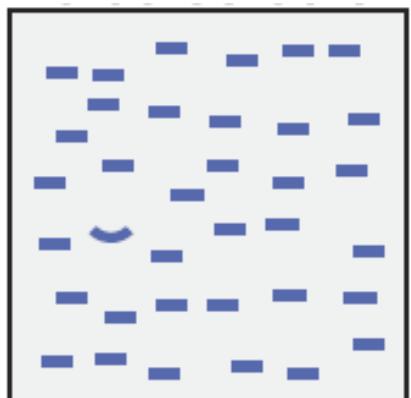
length



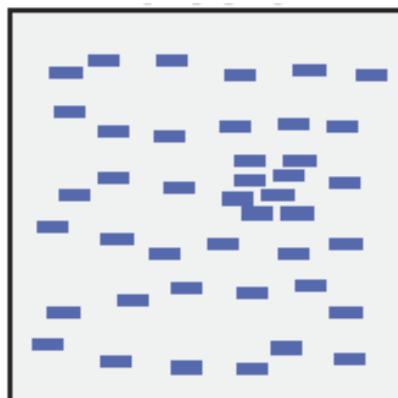
closure



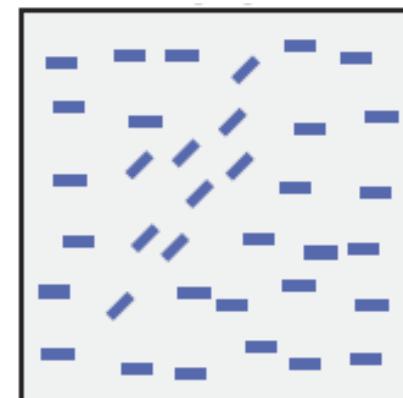
size



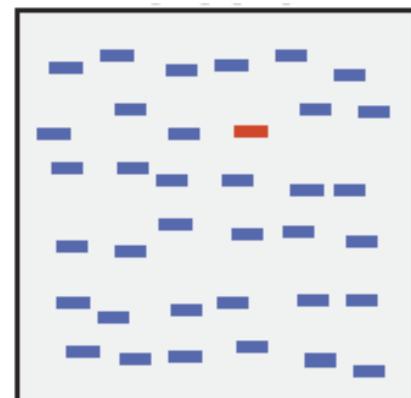
curvature



density



number



hue

PREATTENTIVE CATEGORIES

Form

- Line orientation
- Line length
- Line width
- Line collinearity
- Size
- Curvature
- Spatial grouping
- Blur
- Added marks
- Numerosity

Colour

- Hue
- Intensity

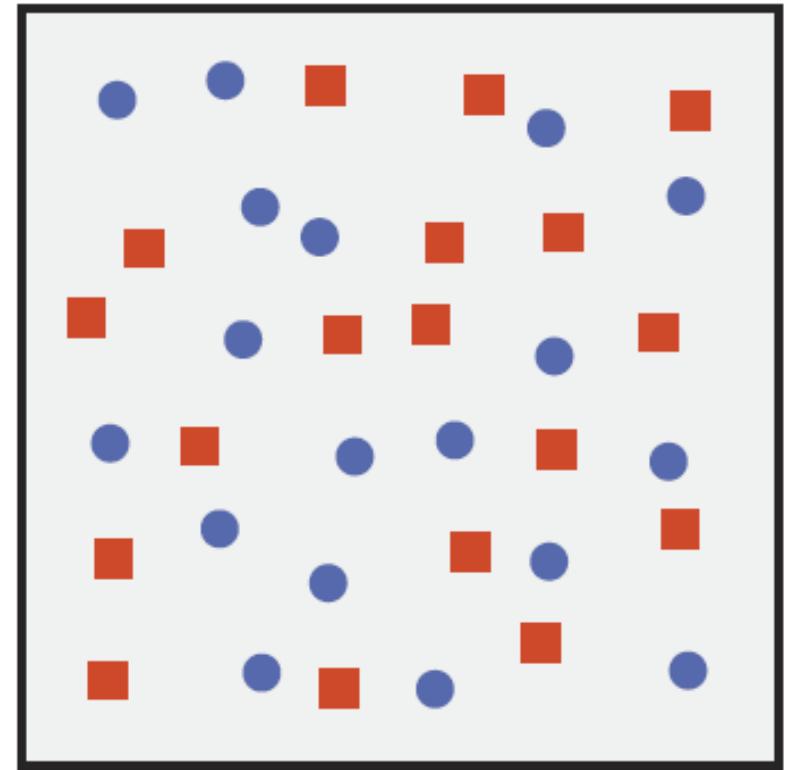
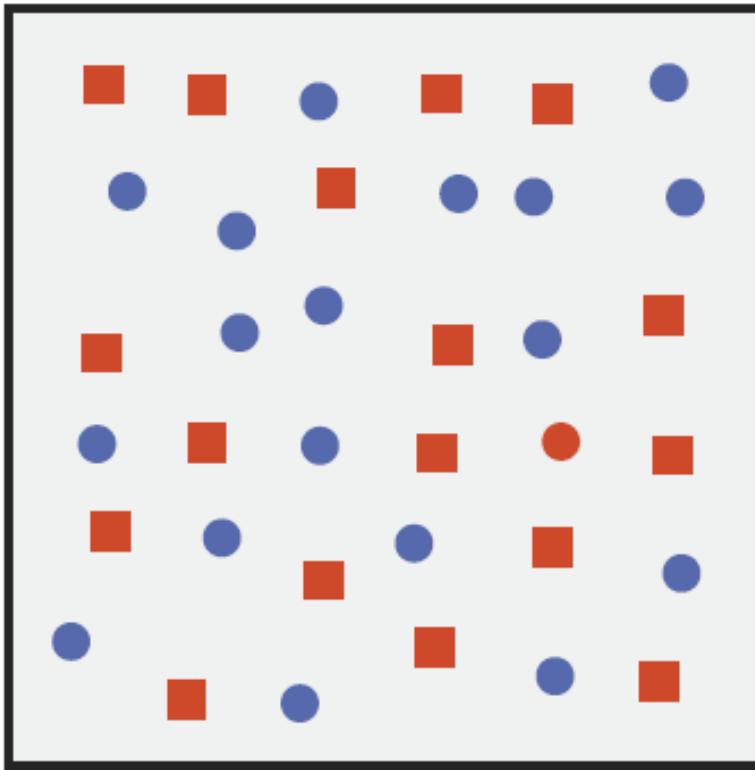
Motion

- Flicker
- Direction and velocity of motion

Spatial Position

- 2D (x,y) position
- Stereoscopic depth

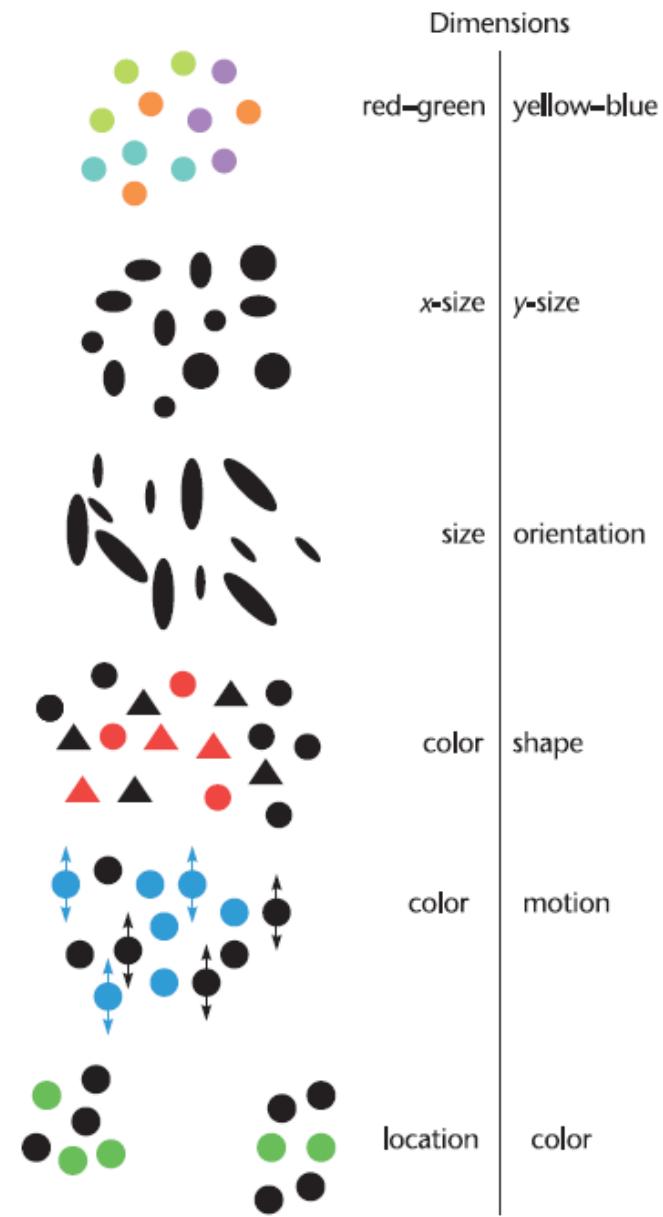
PREATTENTIVE (CONJUNCTIONS)



Finding the red circle may be slow due to serial searching (post-attentive)

GLYPHS

- Commonly used to represent discrete map data
- Data attributes can be mapped to preattentive categories (e.g., form, colour, position)
- Multidimensional Whisker Plot
 - Each data attribute is represented using a line



Images: Ware (2013)

GLYPHS

- Cor

disc



Calm

- Dat

map



5 knots

cate



10 knots

pos



15 knots

- Mu

o



20 knots



50 knots



75 knots



Dimensions

red-green

yellow-blue

South east wind
at 75 knots



Image:
Pilar and Ware (2013)



location

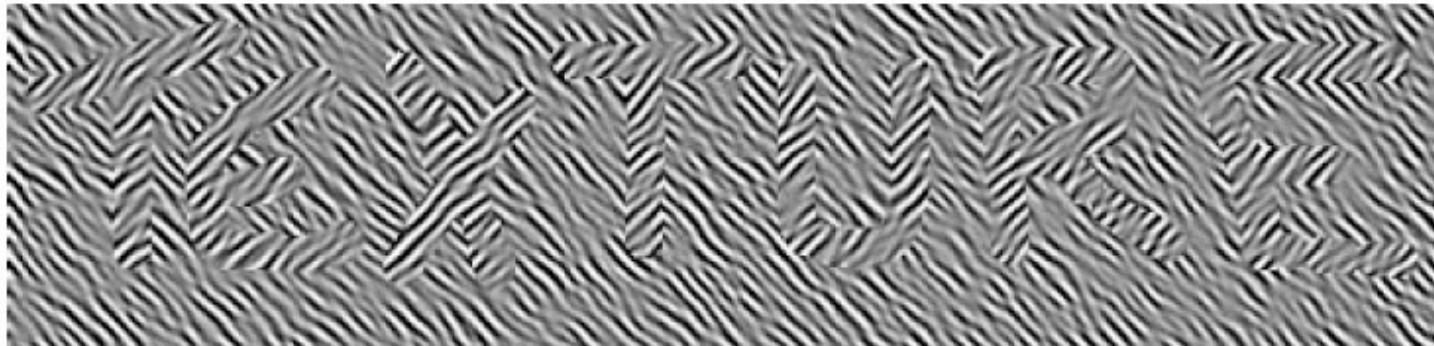
color



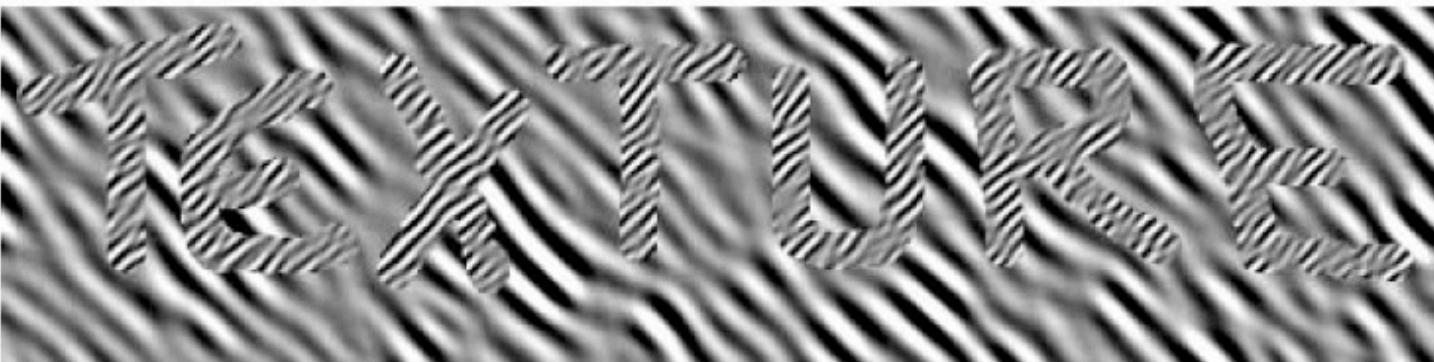
TEXTURE

- Textons are fundamental micro-structures in images, considered as the atoms of pre-attentive human visual perception (Julesz, 1981)
- Can be modelled using a mathematical Gabor function to create texture
- With hue added, textons have four variables:
 1. Size
 2. Contrast
 3. Orientation
 4. Hue
- Commonly used to represent continuous map data varying over space

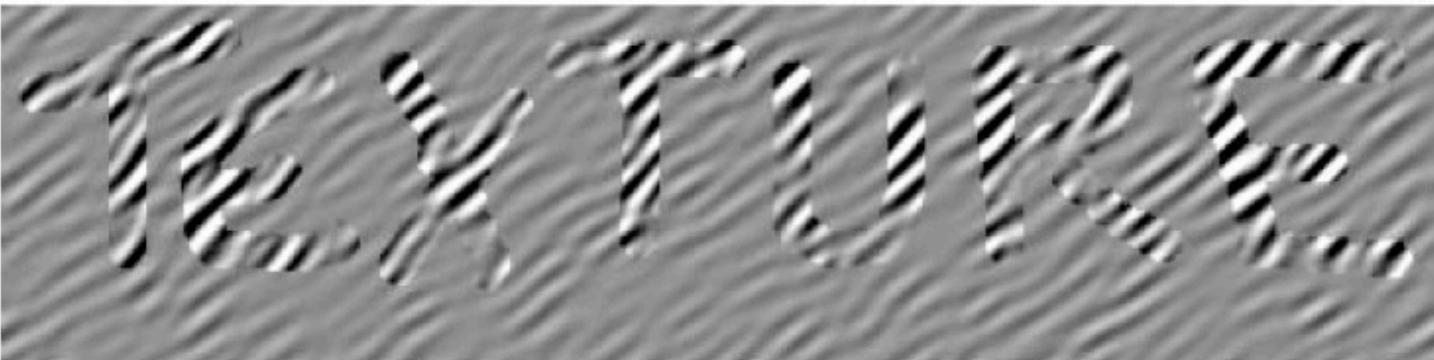
TEXTURE



Only orientation changed



Orientation and scale changed



Only contrast changes

WHY PREATTENTIVE PROCESSING IS IMPORTANT?

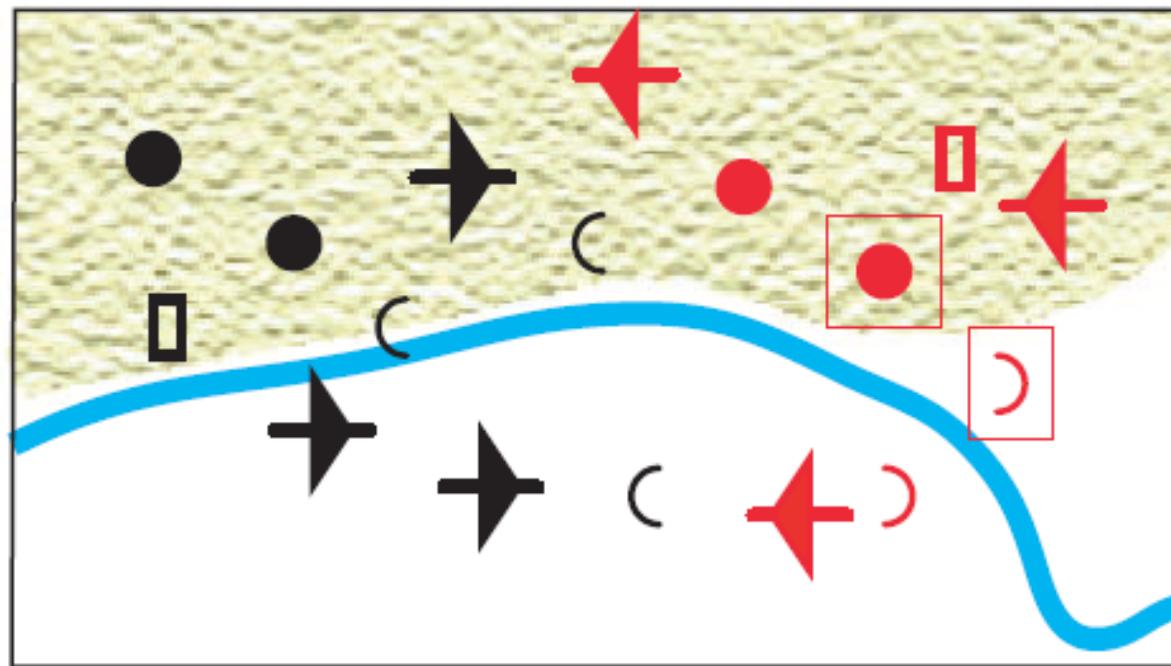
When displaying information, it is often useful to be able to show things “at a glance”

If you want users to be able to instantaneously identify features being of type ‘A’, it should be differentiated from all other marks in a pre-attentive way.

(Ware, 2013)

Remember: Conjunctions can be complex requiring serial processing (post-attentive stage), which takes time

DESIGNING A SYMBOL SET



Aircraft 
Infantry 
Building 
Tank 

Suspected 
Hostile 
Friendly 

PERCEPTUAL PROPERTIES – IMPLICATION FOR VISUALISATION

- **Colour**
 - Allows: perceptual balance, distinguishability, flexibility
- **Texture**
 - Allows: Single feature to comprise various perceptual dimensions
- **Motion**
 - Allows: Direction and velocity of motion
 - Challenges: Wagon wheel effect ([see reading links](#))
- **Memory**
 - Allows: Pre-attentive processing to quickly process information
 - Challenges: Short term memory (limited capacity requiring chunking), long term memory (requiring complex coding)
 - Interruption and change blindness ([see reading links](#))

NEXT LECTURE:

- Data graphics 1

READING (LINKS):

Pre-attentive examples:

<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>

Gestalt laws (pattern perception):

1. <https://www.siggraph.org/education/materials/HyperVis/vision/percorg.htm>
2. <https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/gestalt-principles-of-form-perception>

Wagon wheel effect (motion):

http://en.wikipedia.org/wiki/Wagon-wheel_effect

Change blindness (interruption and memory):

1. <http://www.cogsci.uci.edu/~ddhoff/cb.html>
2. <http://7e.biopsychology.com/av18.02.html>