CS-5630 / CS-6630 Visualization for Data Science Perception

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Perception

- Identification and interpretation of sensory information From the physical stimulus to recognizing information Shaped by learning, memory, expectation

Cognition

The processing of information, applying knowledge

Hear someone speak: Perception Understand the language and the words: Cognition

Perception vs. Cognition

- Perception
- Eye, optical nerve, visual cortex
- **Basic perception**
- First processing
- (edges, planes)
- Not conscious
- Reflexes

Cognition **Recognizing objects Relations between objects** Conclusion drawing Problem solving Learning, ...



YELLOW PINK WHITE BLUE WHITE BLUE BLUE YELLOW GREEN BLUE GREEN RED

What is There vs. What do we See

Emergence Images. perceptual hysteresis





Looking only at patches doesn't work

http://graphics.stanford.edu/~niloy/research/emergence/emergence_image_siga_09.html





we rely on priors



Pareidolia



Faces in Things @FacesPics · Mar 9

These chairs have seen some terrible things pic.twitter.com/Gjlc9wuP47





Faces in Things @FacesPics · Feb 14 Deep in thought Deep Fryer pic.twitter.com/1Qyqjmslka





Faces in Things @FacesPics · Mar 22 Hey little guy! pic.twitter.com/nt2BgwZeTR





Faces in Things @FacesPics · Mar 10 A terrified pickle pic.twitter.com/Ffph1wzTyv





Take Home Point

Vision is "constructed" top down from the input

"What you see when you see a thing depends on what the thing is. What you see the thing <u>as</u> depends on what you know about what you are seeing."

Zenon Pylyshyn Canadian Cognitive Scientist and Philosopher



The Eye

A CAR WELL AND A SHE SHE



Human Visual System

5-6 mio cones

- color vision
- dense in the center

Fovea: 27 times the density

- responsible for sharp central vision
- only cone cells

~120 mio rods

black/white





Rods - sensitive black and white

Cones - color vision

Ganglion Cells

"Structure of the Mammalian Retina" c.1900 By Santiago Ramon y Cajal



~120 million rods ~5-6 million cones



R 63% - G 31% - B 6%

Wandell, "Foundations of Vision" (left) David R.Williams, Univ. of Rochester (right)

Cone Response



HyperPhysics, Georgia State University

700 nm



C.Ware, "Visual Thinking for Design"

Human Visual System

Vision works as sequence of fixations and saccades

fixations: maintaining gaze on single location (200-600 ms)

saccades: moving between different locations (20-100 ms)

Vision not similar to a camera

More similar to a dynamic and ongoing construction project













Video!



SensoMotoric Instruments presents

Karaoke

Gaze Tracking and User Observation

Human Visual System

No general purpose vision

What we see depends on our goals and expectations

Relative judgments: strong Absolute judgments: weak



Ames Room





Color

Color Basics

Visible part of the electromagnetic spectrum

390-750 nm

Spectral colors

evoked by a single wavelength (monochromatic colors, rainbow colors), e.g., red, orange, yellow, green, blue, and violet

Other colors: unsaturated colors

Mix of multiple wavelengths e.g. purple, magenta, gray scale (achromatic colors) including white





color != wavelength but rather, a combination of wavelengths and energy

relative energy density

400



Color

Color vision is irrelevant to much of normal vision!

- does not help to perceive layout of objects
- how they are moving
- what shape they are
- Color breaks camouflage Tells about material properties (judging quality of food)





Dimensions of Color

Hue Saturation The purity of a color Value (Luminance, Brightness) lightness or darkness of a color high saturation colors have medium values

0 60 120 180 240 300 360



Different Saturation, medium Value



Different Values, low Saturation

http://www.greatreality.com/color/ColorHVC.htm

The role of objects real light is more than a single wavelength:









(jared/flickr/CC-BY-2.0)

We tear into this show with a dark scene from 1665. A young Isaac Newton, hoping to ride out the plague by heading to the country to puzzle over the deep mysteries of the universe, finds himself wondering about light. And vision. He wants to get to the bottom of where color comes from--is it a physical property in the outside world, or something created back inside your eyeball somewhere? James Gleick explains how Newton unlocked the mystery of the rainbow. And, as Victoria Finlay tells us, sucked the poetry out of the heavens.

Jonah Lehrer restores some of the lost magic by way of

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If You're Born In The Sky, What's Your Nationality? An	
Airplane Puzzler	
Cities	
Prello	
Roadways You Can Install Like Throw Rugs	

9-Volt Nirvana

https://www.wnycstudios.org/ story/211178-rip-rainbow/

https://www.wnycstudios.org/ story/rippin-the-rainbow-an-even-<u>newer-one/</u>



What are the primary colors?

- 1. red, green, blue
- 2. red, yellow, blue
- 3. orange, green, violet
- 4. cyan, magenta, yellow
- 5. all of the above

Paint mixing

physical mixing of opaque paints

primary: RYB secondary: OGV subtractive



Ink mixing

- subtractive mix of transparent inks
- primary: CMY secondary: RGB approx. black = C+M+Y true black = C+M+Y+K subtractive



Light mixing

additive mix of colored lights primary: RGB secondary: CMY additive




Anatomy of a CIE Chromaticity Diagram

Gamut

- Set of all colors that can be produced by a device
- Area between the primary colors used can be shown
- Primaries are arbitrary







What is a colormap?

specifies a mapping between color and values

categorical vs ordered

sequential vs diverging

segmented vs continuous

univariate vs bivariate

expressiveness: match colormap to attribute characteristics!





Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

Color for qualitative data

Color labeling (nominal information coding)

recommended: about 6, no more than 10





Color for quantitative data

use value saturation works but not as good don't use hue! Danger: rainbow color map





[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? http://www.research.ibm.com/people/I/lloydt/color/color.HTM]



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]



Rainbow vs. Value Color map



Increment Threshold Experiment: Luminance

15

10

5

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-F





Increment Threshold Experiment: Rainbow Color Scale

15

10

5

-5

Increment





Background Level

To bin or not to bin?

Study: what is faster? What is more accurate?

Example: Elevation

Continuous was faster Binned was often more accurate





Color Blindness 10% of males, 1% of females (probably due to Xchromosomal recessive inheritance) Most common: red-green weakness / blindness altered spectral sensitivity (most common: green shift)



Normal Color Perception

- Reason: lack of medium or long wavelength receptors, or

Deuteranopia (no green receptors) Protanopia (no red receptors)

Color Blindness Tests











Color Blindness





Protanope



Deuteranope No L cones No M cones Red / green deficiencies

Tritanope No S cones Blue / Yellow deficiency





NYT, Feb 12, 2012



Simulate Color Vision Deficiencies



Home CVD Essentia

Coblis — **Color Blindness Simulator**

If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The Color BLIndness Simulator can close this gap for you. Just play around with it and get a feeling of how it is to have a color vision handicap.

As all the calculations are made on your local machine, no images are uploaded to the server. Therefore you can use images as big as you like, there are no restrictions. Be aware, there are some issues for the "Lens feature" on Edge and Internet Explorer. All others should support everything just fine.

So go ahead, choose an image through the upload functionality or just drag and drop your image in the center of our Color BLIndness Simulator. It is also possible to zoom and move your images around using your mouse - try it aut, I hape you like it.

Drag and drop or paste your file in the area below or: Choose File No file chosen

Trichromatic view: Anomalous Trichromacy: Normal

) Red-Weak/Protanomaly Green-Weak/Deuteranomaly Blue-Weak/Tritanomaly

Dichromatic view: Red-Blind/Protanopia

Blue-Blind/Tritanopla

Monochromatic view: Monochromacy/Achromatopsia Green-Blind/Deuteranopia OBlue Cone Monochromacy

Use lens to compare with normal view:
No Lens

Normal Lens

Inverse Lens





http://www.color-blindness.com/coblis-colorblindness-simulator/



Simulate in R



https://github.com/clauswilke/colorblindr

setosa

setosa

versicolor

versicolor

Color / Brightness is Relative!

Simultaneous Brightness Contrast

The perceived brightness of an object is relative to it's background





Cornsweet Illusion



D. Purves and R. B. Lotto

A DESCRIPTION OF

Cornsweet Illusion



D. Purves and R. B. Lotto

A DESCRIPTION OF

Demo http://purveslab.net/see-for-yourself/

purves-lab

Laboratory of Dale Purves, M.D. Center for Cognitive Neuroscience Duke University

MAIN NEWS P	EOPLE RESEARCH	PUBLICATIONS RESOU	RCES SEE FOR YO	DURSELF
Lightness/Brightness	Color	Lines and Angles	Motion	Sound
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		$\stackrel{\checkmark}{\leftrightarrow}$		

Brightness contrast: standard

In viewing this stimulus, people invariably perceive the square on the brighter surround (left) to be darker than the square on the darker surround (right). Click on the "Play" button to convince yourself that the squares are equiluminant or click on the "Move mask" button to manually position the mask over the squares.

- » Read the empirical explanation
- » Download high resolution images







The Dress Meme



black and blue or white and gold?



https://imgur.com/hxJjUQB

https://en.wikipedia.org/wiki/The_dress





INTERACTION OF COLOR



INTERACTION OF COLOR



[Wong 2010]

Design Critique

CAUSES OF UNTIMELY DEATH

Malaria

 \sim

Other neonatal

H PROBLEMS AND

conditions

Malaria—a preventable and treatable diseaseis one of the biggest killers of children.

00

INFEC

Starvation

Matemaldise

SIDS

War casualties account for just 0.05 percent of total life-years lost annually.

Natural disasters are by far the fastest-growing contributor to the death toll.

ANNUAL % CHANGE (2005 TO 2010)

INFECTIOUS DISEASES/BIRTH PROBLEMS INJURIES NONCOMMUNICABLE DISEASES



Ulcers

Preterm

birth

Cinhosis

HNIADS

encephalopathy

Neonetal

infections





Graph of the Year?

"I love this graph because it shows that while the number of people dying from communicable diseases is still far too high, those numbers continue to come down. [...] But there remains much to do to cut down the deaths in that yellow block even more dramatically. We have the solutions. But we need to keep up the support where they're being deployed [...]"

-Bill Gates

CAUSES OF UNTIMELY DEATH

Malaria—a preventable

and treatable disease-

of children.

SS

is one of the biggest killers

ON

Starvation



Malaria

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Cinhosis

HIMIADS

INFECTIOUS DISEASES/BIRTH PROBLEMS INJURIES NONCOMMUNICABLE DISEASES

-3%







Some causes of death contribute disproportionately to years of life lost because of their effect on the young. For example, malaria, while not huge in the number of deaths, is much more significant in the number of years that are lost.

Two interesting changes reside in "Injuries other than accidents and self-harm." War, which accounted for only 0.05% of years of life lost, decreased since 2005 by 31.5% in years of life lost per 100,000 people. Natural disasters, which accounted for 0.65% of years of life lost, increased by 217% in years of life lost per 100,000.

Communicable, maternal, neonatal, and nutritional disorders (the gray bars) are often easier to prevent through healthcare than other causes of death. This reveals itself in the graph above by the fact that all of these disorders have decreased during this five year period.

The five forms of cancer that cause the most deaths are trachea/bronchus/lung (2.9%), stomach (1.4%), liver (1.4%), colon/rectum (1.4%), and breast (0.8%).

All cardiovascular and circulatory diseases combined account for 30% of deaths.

<u>Redesign</u> by **Perceptual Edge**



Popout

Popout

Properties detected by the low-level visual system

very rapid - 200-250 milliseconds

very accurate

processed in parallel

happens before focused attention -> "pre"attentive attention is very important for cognition Independent of the number of distractors! Opposite: sequential search (processed serially)

Difference in Hue





Difference in Curvature / Form






orientation





hue

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closure



size



Not Valid for Combinations

Conjunction Targets – no unique visual property target: red, circle distractor objects have both properties



Some Preattentive Properties





Tasks

target detection

detect the presence or absence of a target

boundary detection

detect a texture boundary between two groups of elements, where all of the elements in each group have a common visual property

region tracking

track one or more elements with a unique visual feature as they move in time and space

counting and estimation

users count or estimate the number of elements with a unique visual feature.

Tasks

Number Estimation



Boundary Detection





Hierarchy of Preattentive Features







Examples online!

Theories of Preattentive Processing Not known for sure how it works Several theories:

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

Preattentive Processing in Vis

Can be used to draw attention to areas of interest Can be used to express similarity/group memberships Visual features must be carefully designed Conjunctions must be avoided

Examples are "Cues" (Focus and Context technique)

Change Blindness

Change Blindness

- Details of an image cannot be remembered across separate scenes
 - except in areas with focused attention
- Interruption (e.g. a blink, eye saccade or blank screen) amplifies this effect
- Not failure of vision system
- failure due to inappropriate attentional guidance





Ron Rensink 2002



Ron Rensink 2002



Ron Rensink 2002



Change Blindness

Various theories about causes

- Overwriting: Information that was not abstracted is lost
- First Impression: Only initial view is abstracted
- Nothing is Stored: Only abstract concepts are committed to memory
- Everything is Stored, Nothing is Compared: We compare only when we are forced to
- Feature Combination: scenes are combined as long as they make sense

Influencing factors

- attention
- expectation (knowing something will change)
- semantic importance of changed object
- low level object properties overlooked more easily







Attention Blindness



Transport for London







Take Home Points

- To find meaning in what we see **we must selectively pay attention** to what is important
- Low-level vision is driven by object features rather than a conscious effort where to look (e.g., pre-attentive processing)
- Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

Gestalt Principles

Wertheimer, 1923, and recent extensions

Gestalt Principles

Patterns that transcend the visual stimuli that produced them

- The whole is something else than the sum of its parts. Kurt Koffka







Andy Rutledge, "Gestalt Principles of Perception"









4 columns

https://twitter.com/pablostanley/status/974303621092225024



Proximity

Grouping/linking by placing entities in close proximity





Similarity







Andy Rutledge, "Gestalt Principles of Perception"



1 group







No focus

Focal Point
Similarity

Co-modulation of a channel color, shape, size, value, orientation, texture, ... Adding a glyph, label, frame, background



Color

Shape



Value

Glyph

Color – Perception Issues (1/2) Popout properties: Very good for 1-2 simultaneous, serial

search for more





Color – Perception Issues (2/2)

Slower in a cluttered environment

Size of colored object relevant.





First Daptist Church in di America, lounded 1905, present building accupied in 1776, is the oldest Daptist compression in America



Providence in the mid-nineteenth century \mathcal{D}







Similarity

Modulate everything else Blurring, darkening, desaturating, etc.



Blur



Darkening

Modulating Everything Else: Recommendation, Example

Don't use unless the sole objective is to guide attention toward one (set of) items



[Zhai et al., 1997]



A Little Experiment...



Proximity

Color



Size

Shape

Connectedness and Common Region Connected items with a line or curve Surround items with a outline, surface, volume





Common Region

Enclosure / Common Region

Similarity

Connection

Enclosure





Bang Wong, "Gestalt Principles, I", Nature Methods

Connectedness / Enclosure





Bang Wong, "Gestalt Principles, I", Nature Methods



Scattered elements



Connectedness Varieties

Bubble Sets Line Sets Kelp Diagrams



Image by [Dinkla et al., 2011] Technique by [Collins et al.,2009]

[Alper et al., 2011] [Dinkla et al., 2012]

Continuity



Continuity





Continuity Principle

Scattered elements

Continuity Things: smooth & continuous

Closure / Completion

Symmetry

Things: symmetric

Population Pyramid

Figure / Ground

M.C. Escher: Sky and Water I 1938 woodcut

Applications in Uis

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First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

The area which is now Providence was first settled in June 1636 by Roger Williams, and was one of the original Thirteen Colonies of the United States.^[10] Although the west bank of the Providence River was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Iribe of the Wampanoag Nation led by Massasoit Ousamequin.^[11] Williams secured permission to settle from the Pokanoket and gave the city its present name.^[12] Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from Massachusetts.^[13] Providence's growth would be slow during the next quarter-century —the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.^[13]

In the mid-1770s, the British government levied taxes that impeded Providence's maritime, fishing and agricultural industries, the mainstay of the city's economy. One example was the Sugar Act,

> which was a tax levied against Providence's distilleries that adversely affected its trade in rum and slaves. These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious Gaspée Affair of 1772.^[13]

> Though during the Revolutionary War the city escaped enemy occupation, the capture of nearby Newport disrupted industry and kept the population on alert. Troops were quartered for various campaigns and Brown University's University Hall was used as a barracks and military hospital.^[13]

> After departing from Newport, French troops sent by King Louis XVI and commanded by the Comte de Rochambeau passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by General George Washington in a decisive march that ended with the defeat of General Cornwallis in the Siege of Yorktown at Yorktown, Virginia and the Eattle of the Chesapeake.

> Following the war, Providence was the country's ninthlargest city.^{b[][13]} with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country_including Brown & Sharpe

First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

Providence in the mid-nineteenth century 5

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Providence in the mid-nineteenth century 50

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Though during the Revolutionary Way the city escaped enemy occupation, the capture of nearby Newport disrupted industry and kept the population on alert. Troops were quartered for various campaigns and Brown University's University Hall was used as a barracks and military hospital.^[13]

After departing from Newport, French troops sent by King Louis XVI and commanded by the Comte de Rochambeau passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by General George Washington in a decisive march that ended with the defeat of General Cornwallis in the Siege of Yorktown at Yorktown, Virginia and the Battle of the Chesapeake.

Following the war, Providence was the country's ninthlargest city.^{b[>][13]} with **]**[614 people. The economy shifted from maritime endeavors to manufacturing. particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country including Brown & Sharpe

What is the problem?

First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

Providence in the mid-nineteenth century 🗗

The area which is now Providence was first settled in June 1636 by Roger Williams, and was one of the original Thirteen Colonies of the United States.^[10] Although the west bank of the Providence River was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.^[11] Williams secured permission to settle from the Pokanoket and gave the city its present name.^[12] Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from Massachusetts.^[13] Providence's growth would be slow during the next quarter-century —the subsuming of its territory into surrounding towns, difficulty of tarming the land, and differing of local traditions and land conflicts all slowed development.^[13]

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Context-Preserving Visual Links

Takeaways

- Knowing about Perception is important for Vis and UI design
 - How to choose your colors
 - How to show relationships
 - How to draw attention
 - How to minimize risk of overlooking