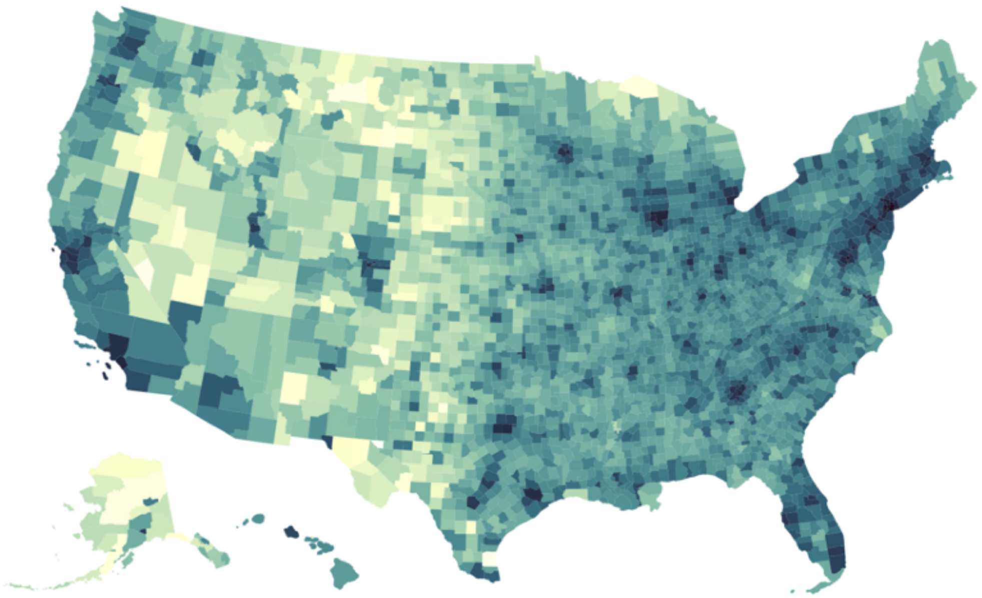
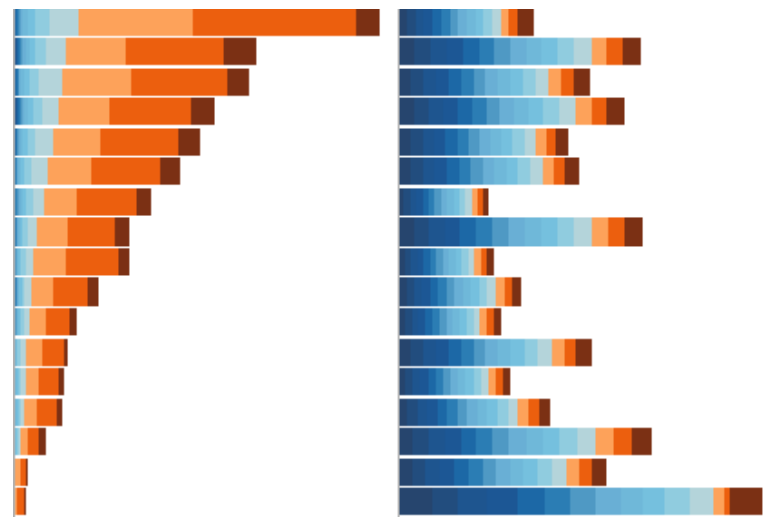
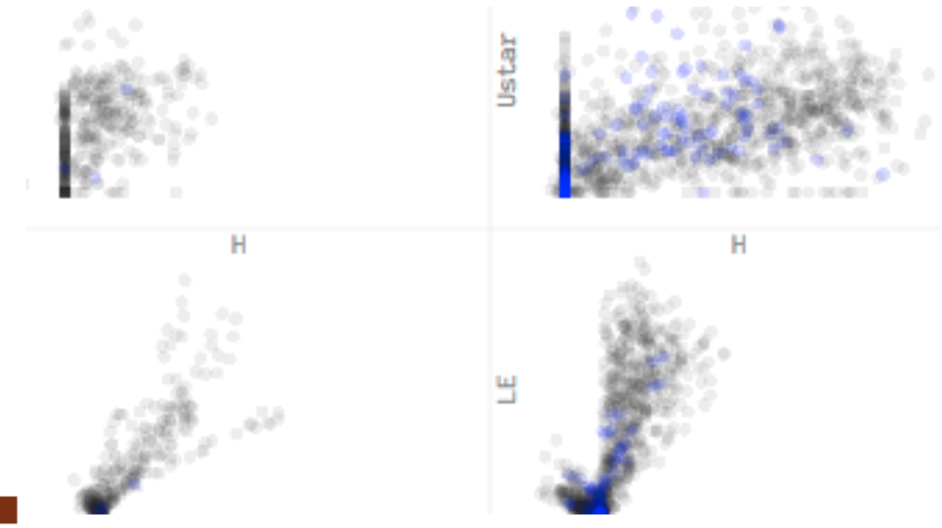






CS526
Computer Graphics II

Khairi Reda | redak@uic.edu
UIC CS

Welcome!

This is on (state of the art) topics in Visualization and Computer Graphics

Focus this semester is on **human factors in visualization and VR**

Why study human factors?

- One the main goals of data visualization and VR is to create **visual representations** to aid **people** in **data** analysis, exploration, and communication, and other tasks
- People are an integral part of this process
- Understanding how people see, think, and act upon visual representations is key to designing effective experiences.

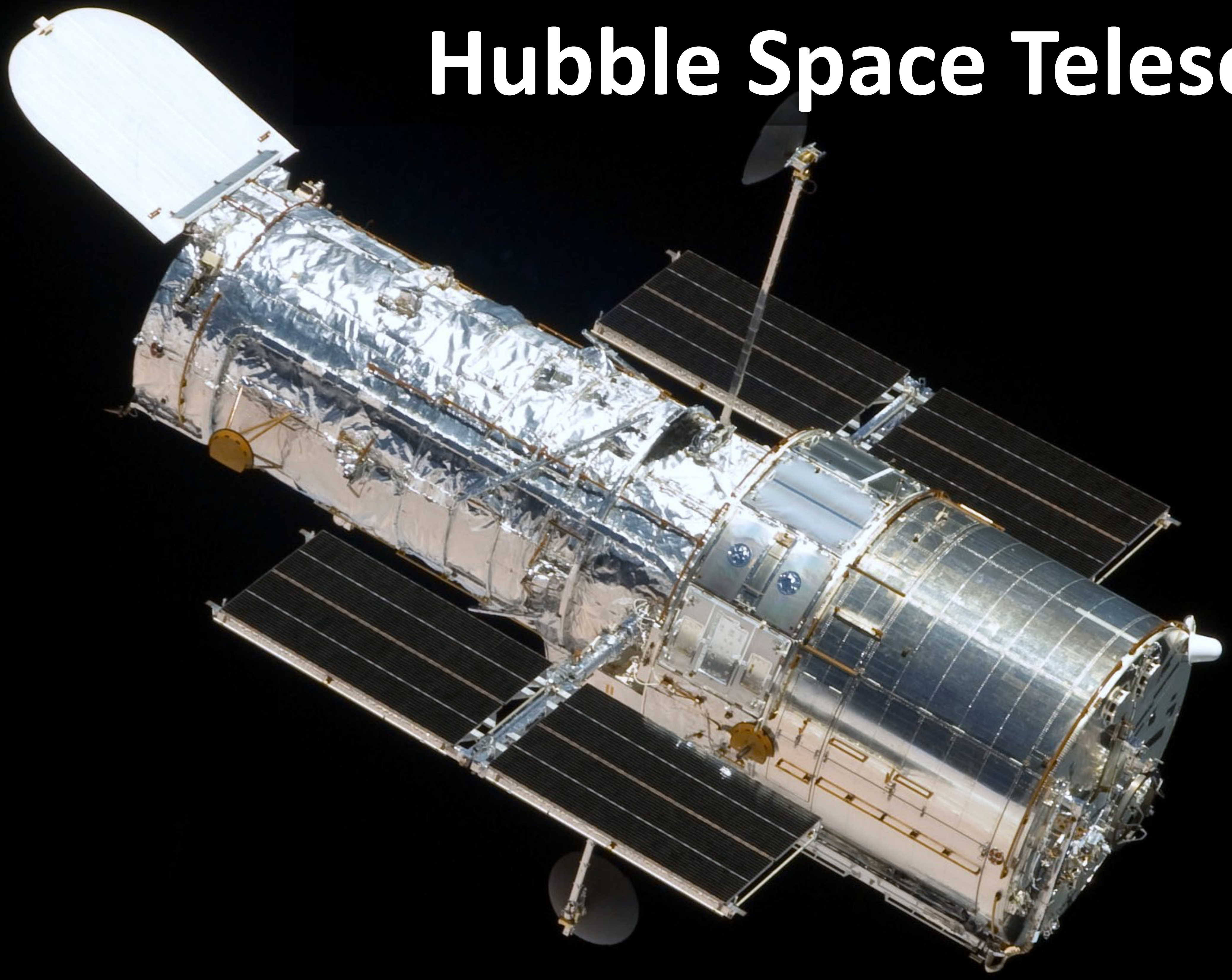
- data
- visual representations
- people
- computers

- **data**
- visual representations
- people
- computers


Healthcare

Financial markets

Scientific instruments: Hubble Space Telescope



The problem

Web,
Books,
Papers,
Scientific data,
News,
Product reviews,
…

Data

How?

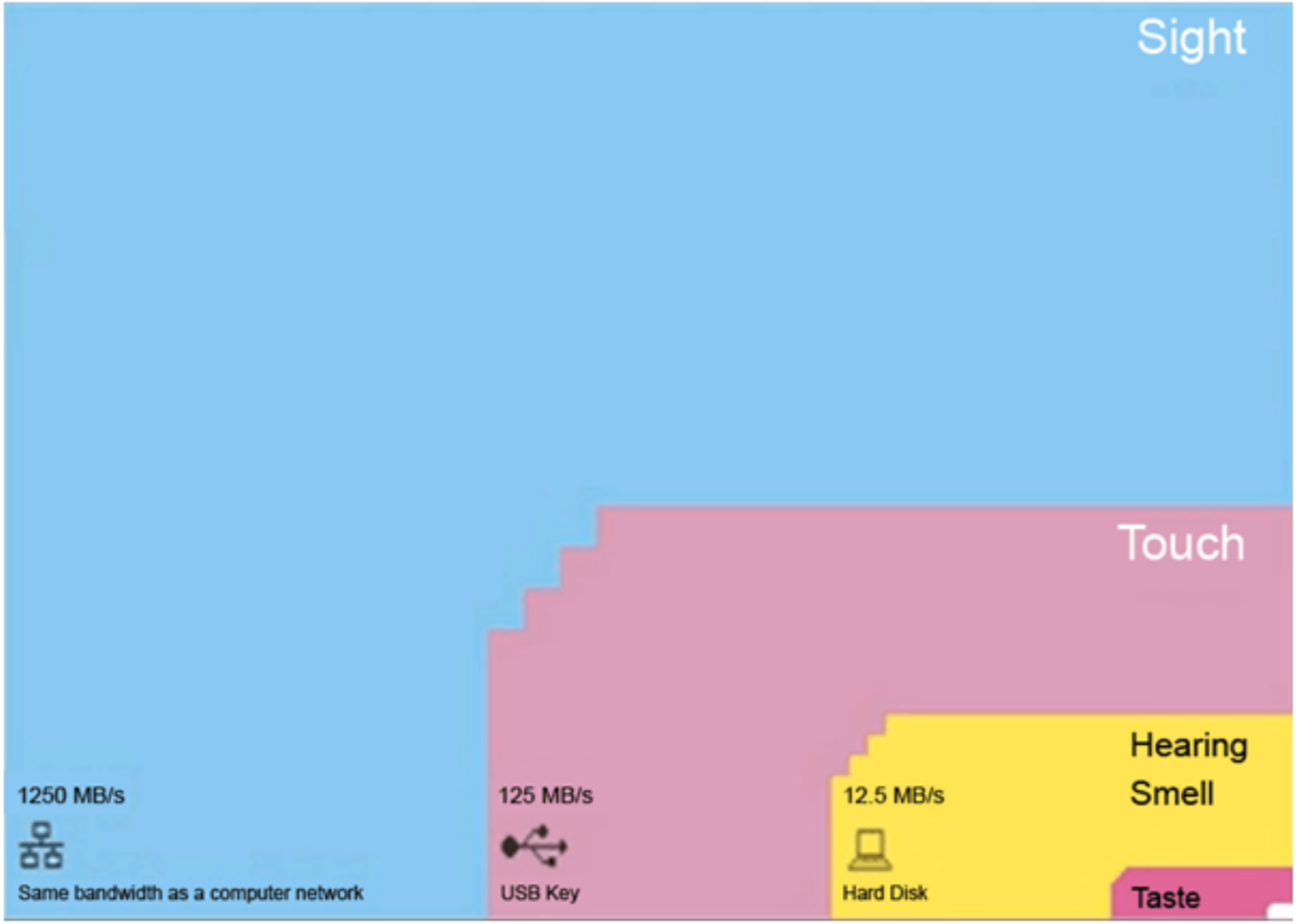
Sight,
Hearing,
Touch,
Smell,
Taste,
Telepathy?

Based on a slide by John Stasko / Chris North

Why use **vision** to analyze information?

1. Vision is the highest bandwidth channel into our brain

Sensory bandwidth



T. Norretranders, The User Illusion: Cutting Consciousness Down to Size, 1999

How much we are actively aware of

Why use **vision** to analyze information?

1. Vision is the highest bandwidth channel into our brain

2. Cognition is limited. Visual perception beats cognition

345OIJDFG98C90U5ET09VBKK23490XIVBCIBJ0345T09U
2G84GDF09U34590IDFK90345I-09345K90FU90DF90JDF
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Based on a slide by John Stasko

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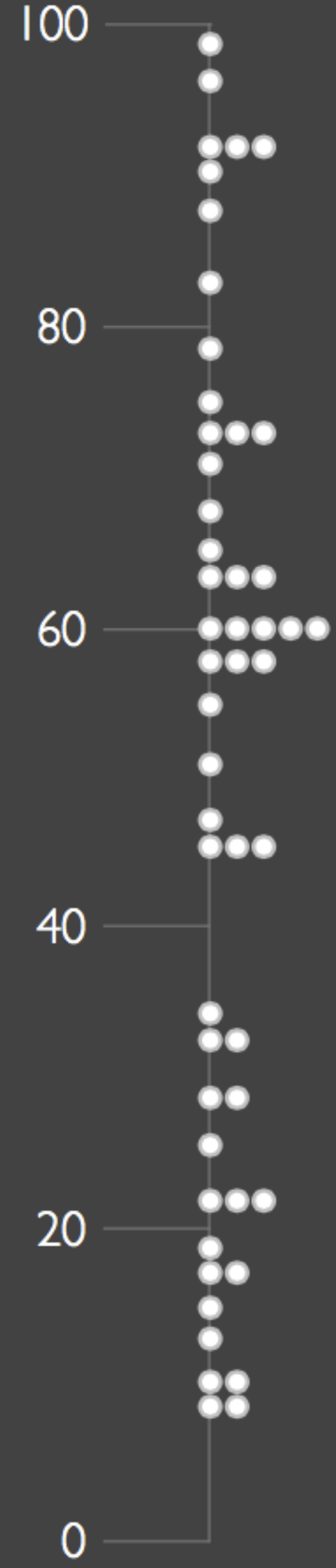
45POJ34X09345J08EFJ825HJDFSJIPADOPQWIXERWNVF

Based on a slide by John Stasko

15	19	60
33	11	75
57	34	79
18	51	92
73	22	13
71	60	22
17	10	68
73	18	55
65	46	29
60	73	22
46	92	97
10	58	46
57	17	83
26	99	33
88	92	60
91	29	57
96	12	47

Given these 50 numbers
what number appears most often?



Given these 50 numbers
what number appears most often?

Slide by Miriah Meyer, University of Utah
http://www.cs.utah.edu/~miriah/teaching/cs6630/

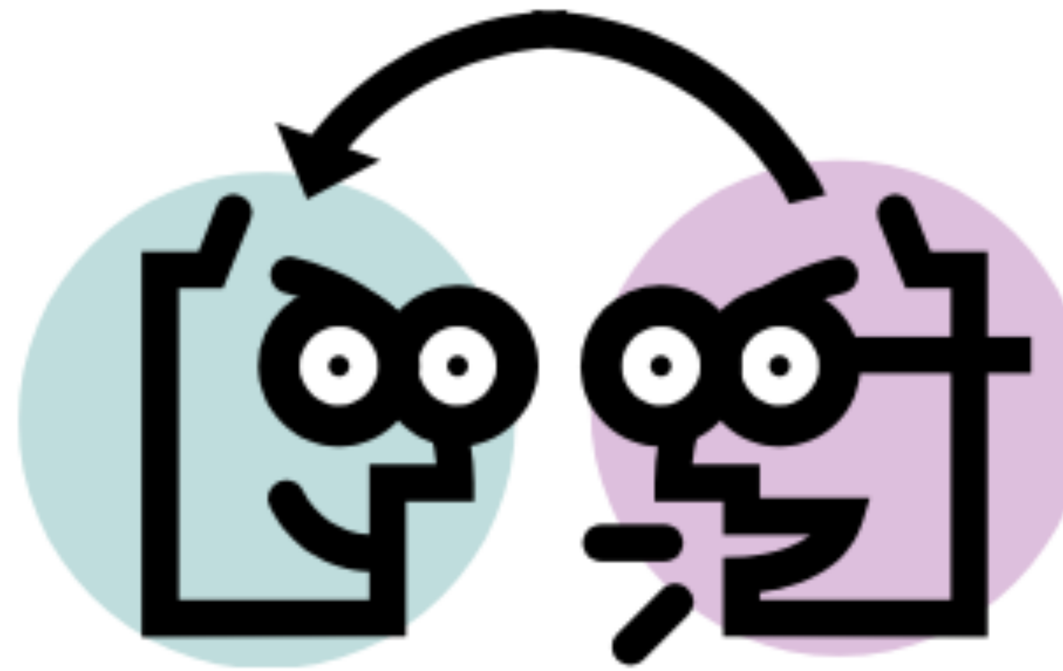
Why use **vision** to analyze information?

1. Vision is the highest bandwidth channel into our brain

2. Cognition is limited. Perception beats cognition

3. Visuals are an integral part of our culture

- “I see what you’re saying”
- “Seeing is believing”
- “I now see the big picture”
- “A picture is worth a thousand words”



Based on a slide by John Stasko

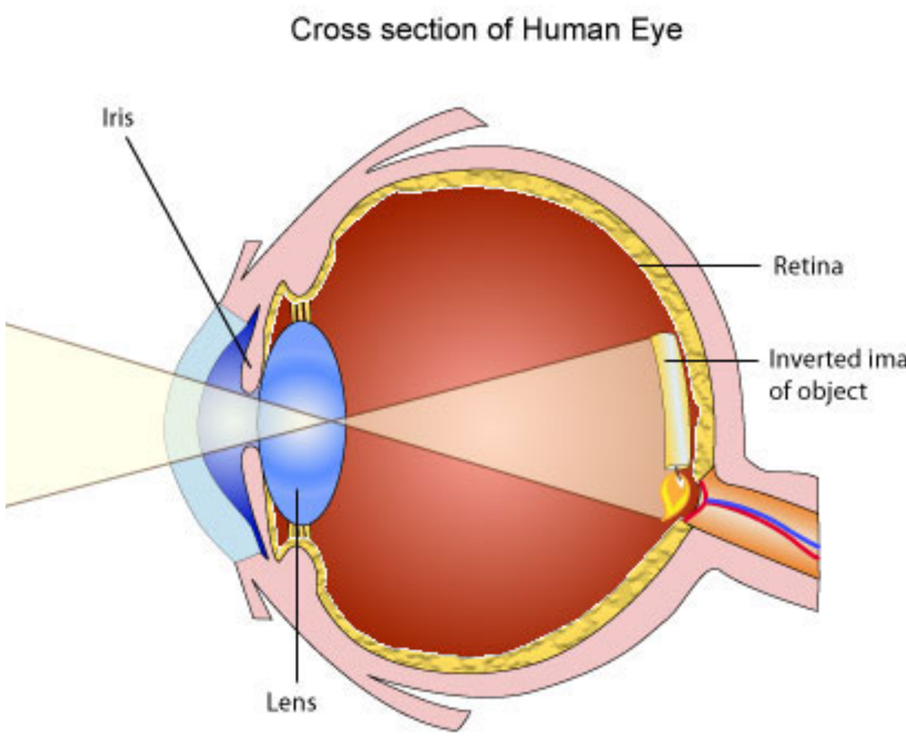
- data
- **visual representations**
- people
- computers

- data
- visual representations
- **people**
- computers

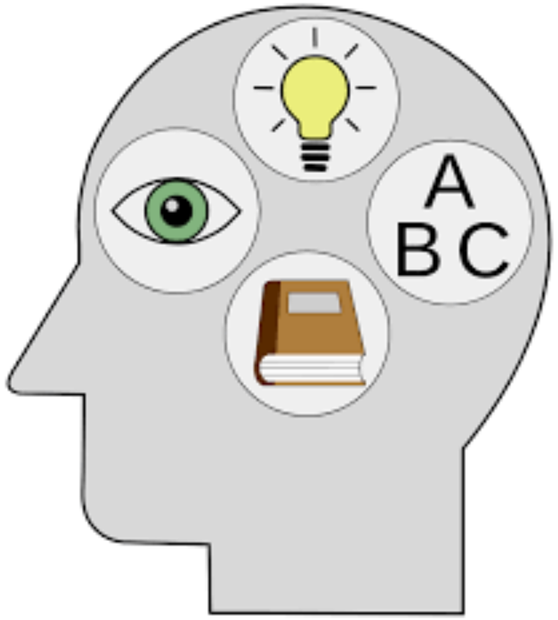
Why involve **people** in the analysis of data?

- Computers are very good at computing an answer to a **specific question**
- They are less useful good when we **do not know** what we are looking for in advance
  - How does the employment market react to changes in interest rate?
  - What is the effect of gene mutation on cancer risk?
- Computers are bad at **“hunches”**

Why involve **people** in the analysis of data?



- However, the visual perceptual system has clear capacity limits
- Need to understand what the “**architecture**” of the visual system is to design around those limits
- Need to evaluate **visualization** and **VR experiences** to see if they achieve the intended goal



What we will study in this course

- **Perception:** We will study the perceptual and cognitive mechanism behind visual perception

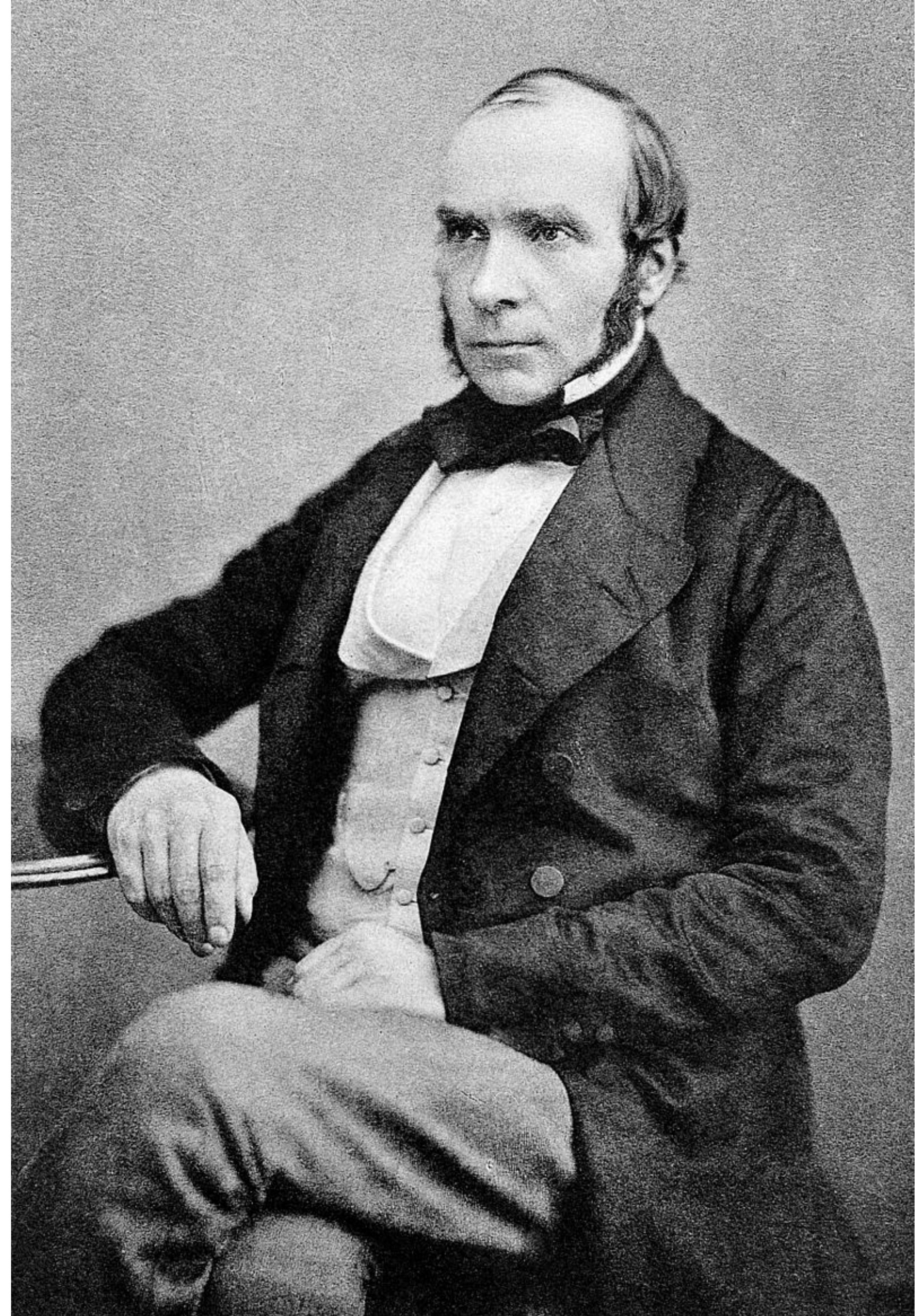
- **Human-subjects Experiments**: Students will learn how to design experiments to collect data about the efficacy of visualizations/VR environments

- **Evaluation/Design:** You will develop research projects to measure human performance in visual analysis, or to develop new perceptually inspired tehcniques

- We will learn how to use web-based visualization libraries (D3/ThreeJS)

Some history

Bailee Clift

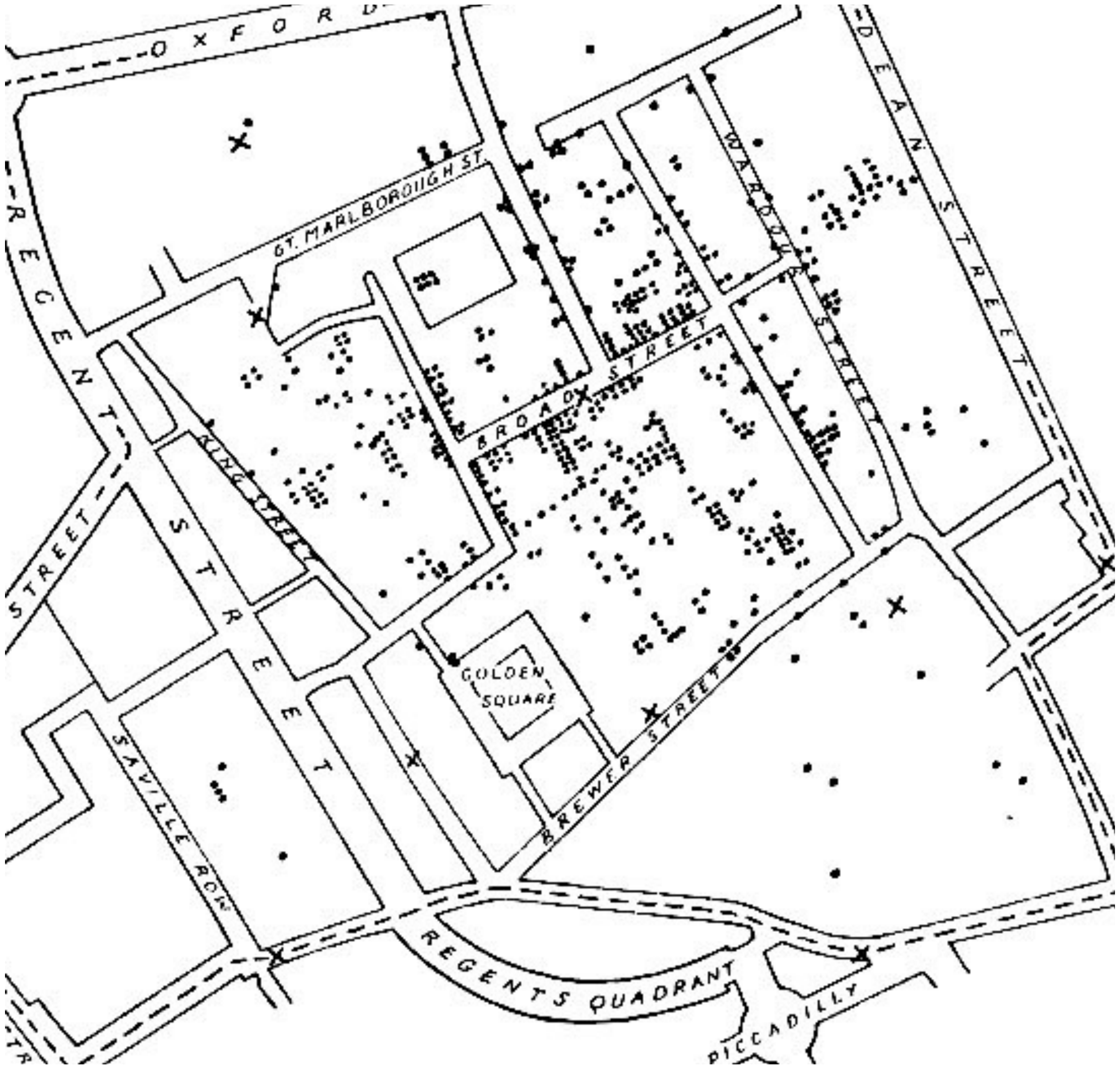


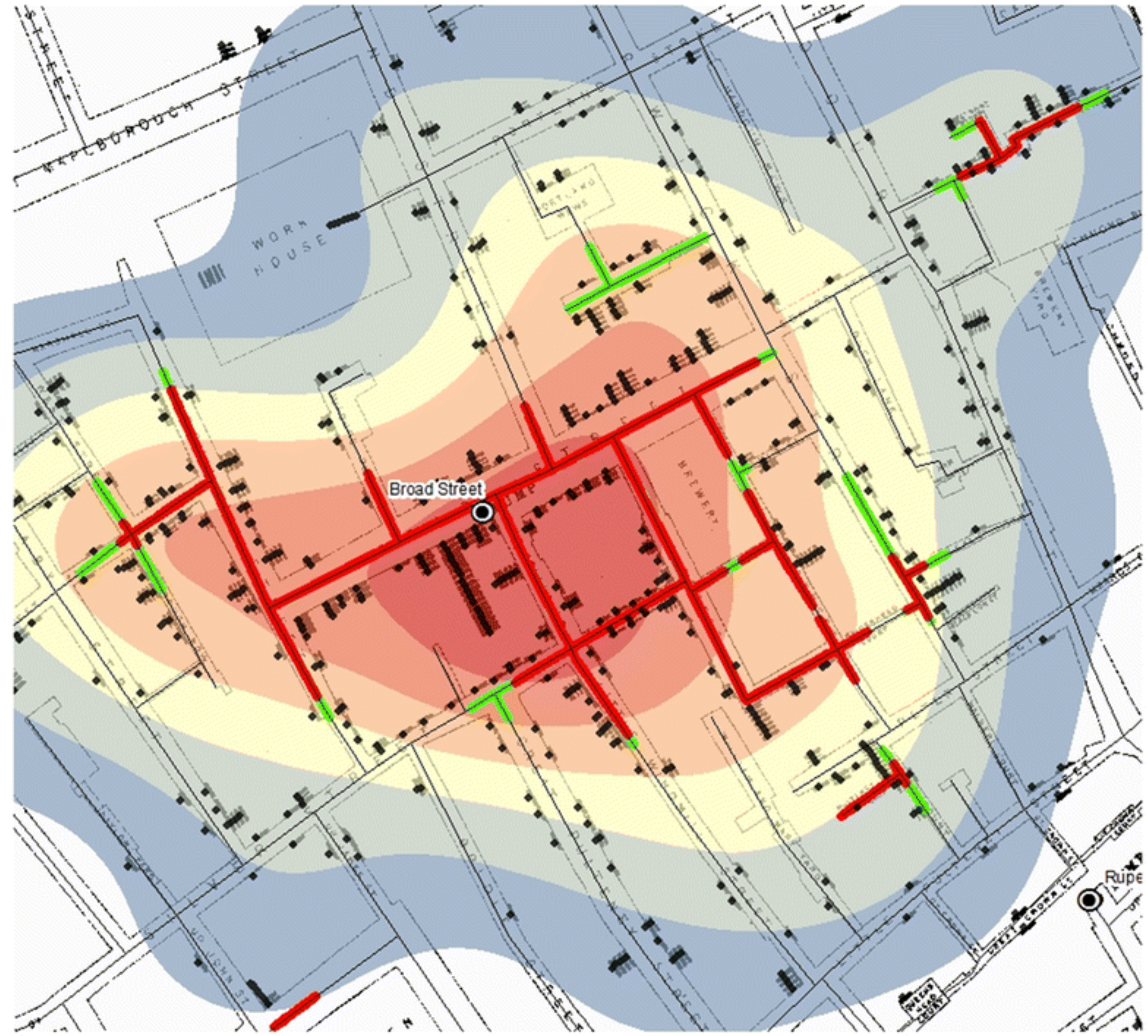
John Snow

C. F. Cheffins, Lith, Southampton Bgs. London.

SCALE 30 INCHES TO A MILE.

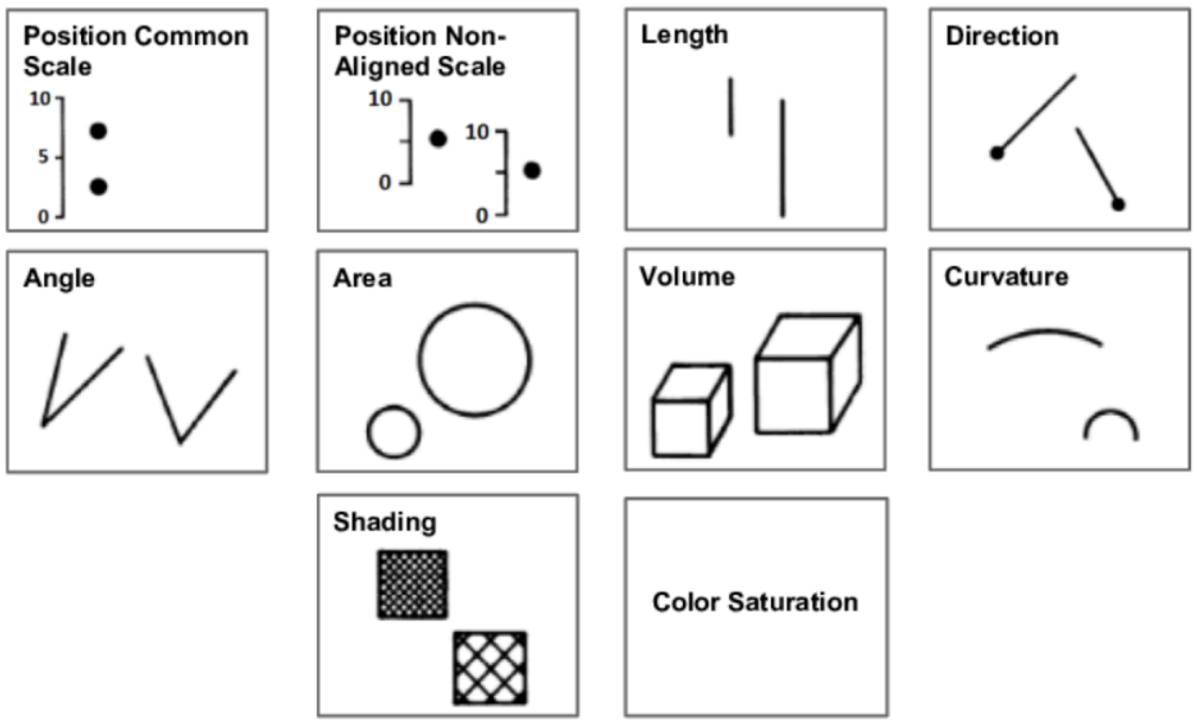
Alternative designs

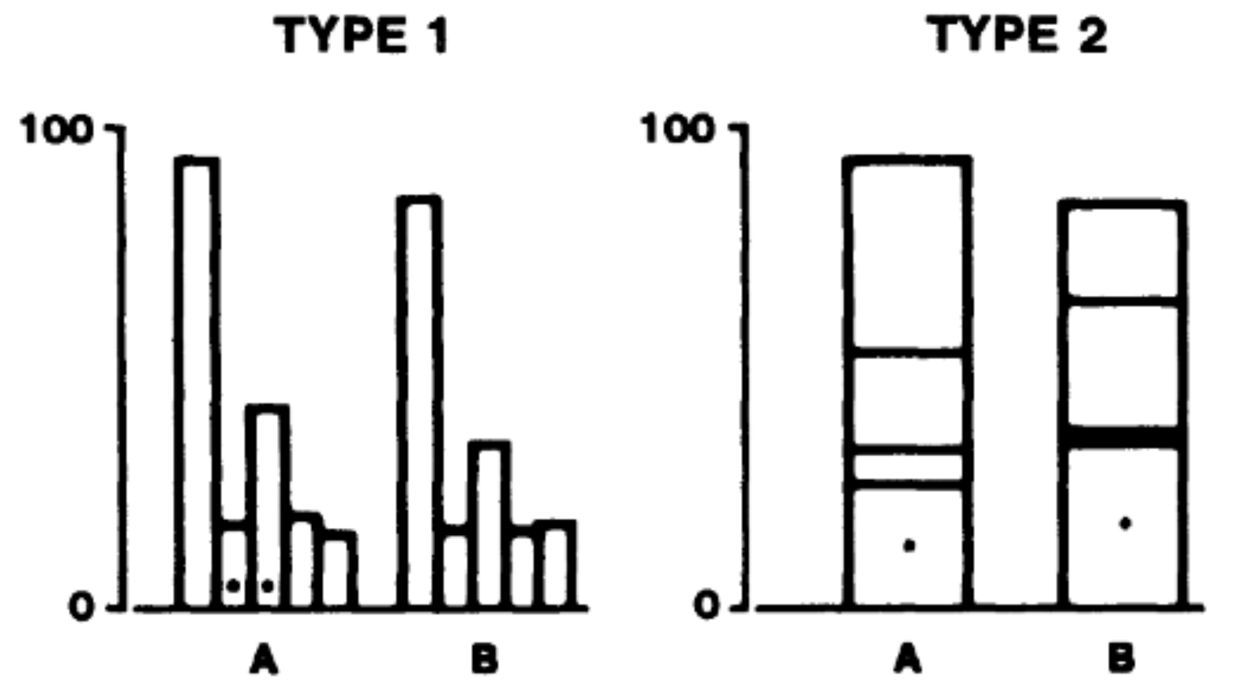


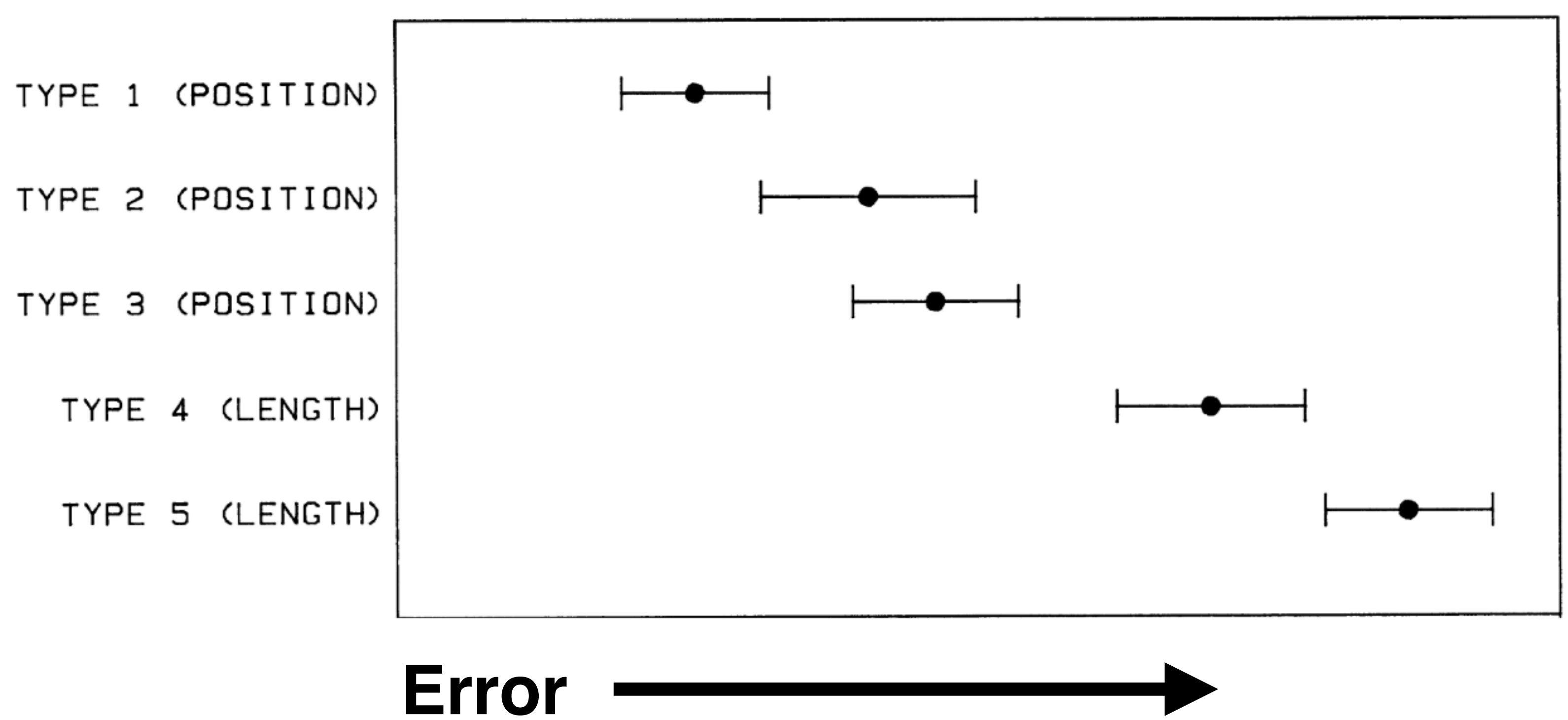


E. W. Gilbert. Simplified version of Snow's map: http://www.ph.ucla.edu/epi/snow/cartographica39%284%291_14_2004.pdf

How do we know which visualization technique is better for a given task?







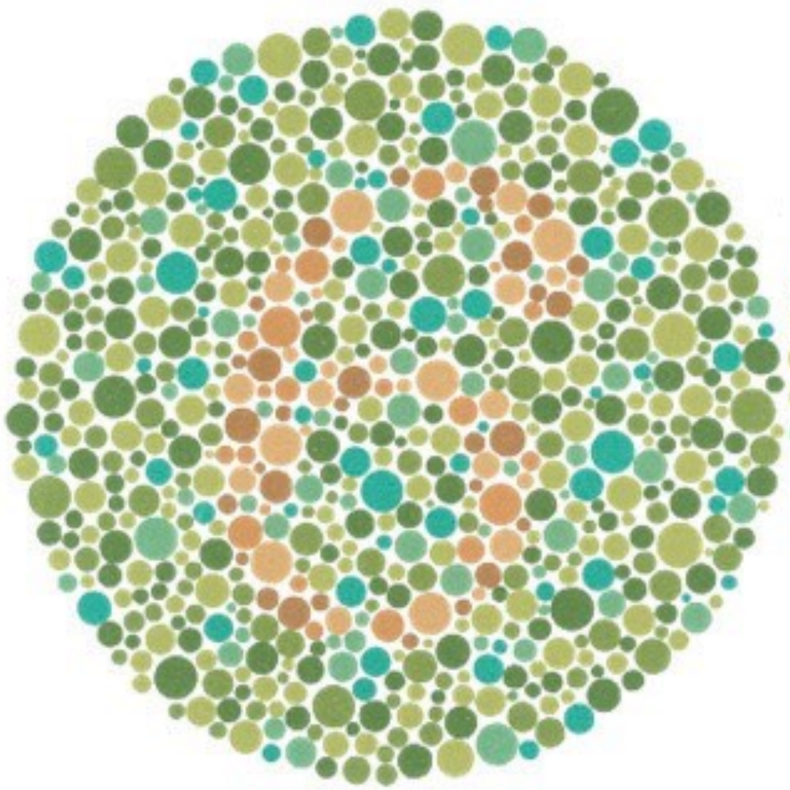
Graphical Perception

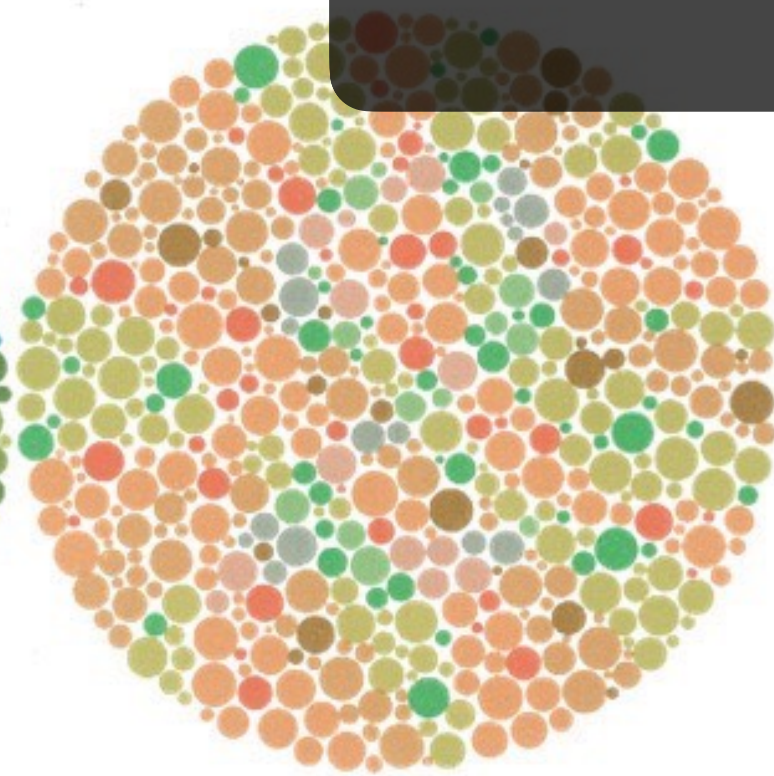
Cleveland and McGill

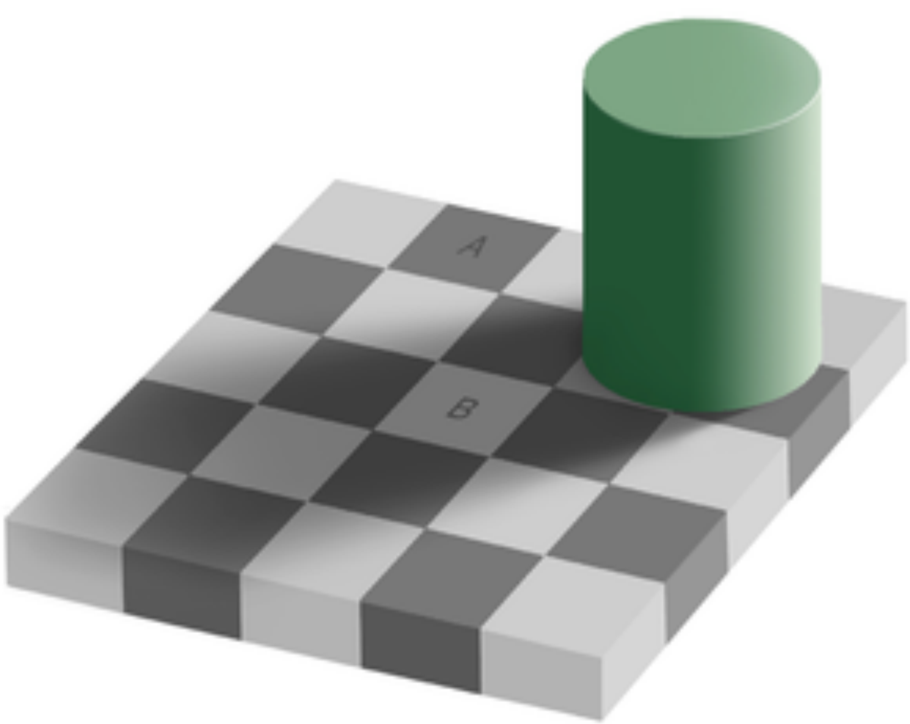
Key insights for creating effective visualizations

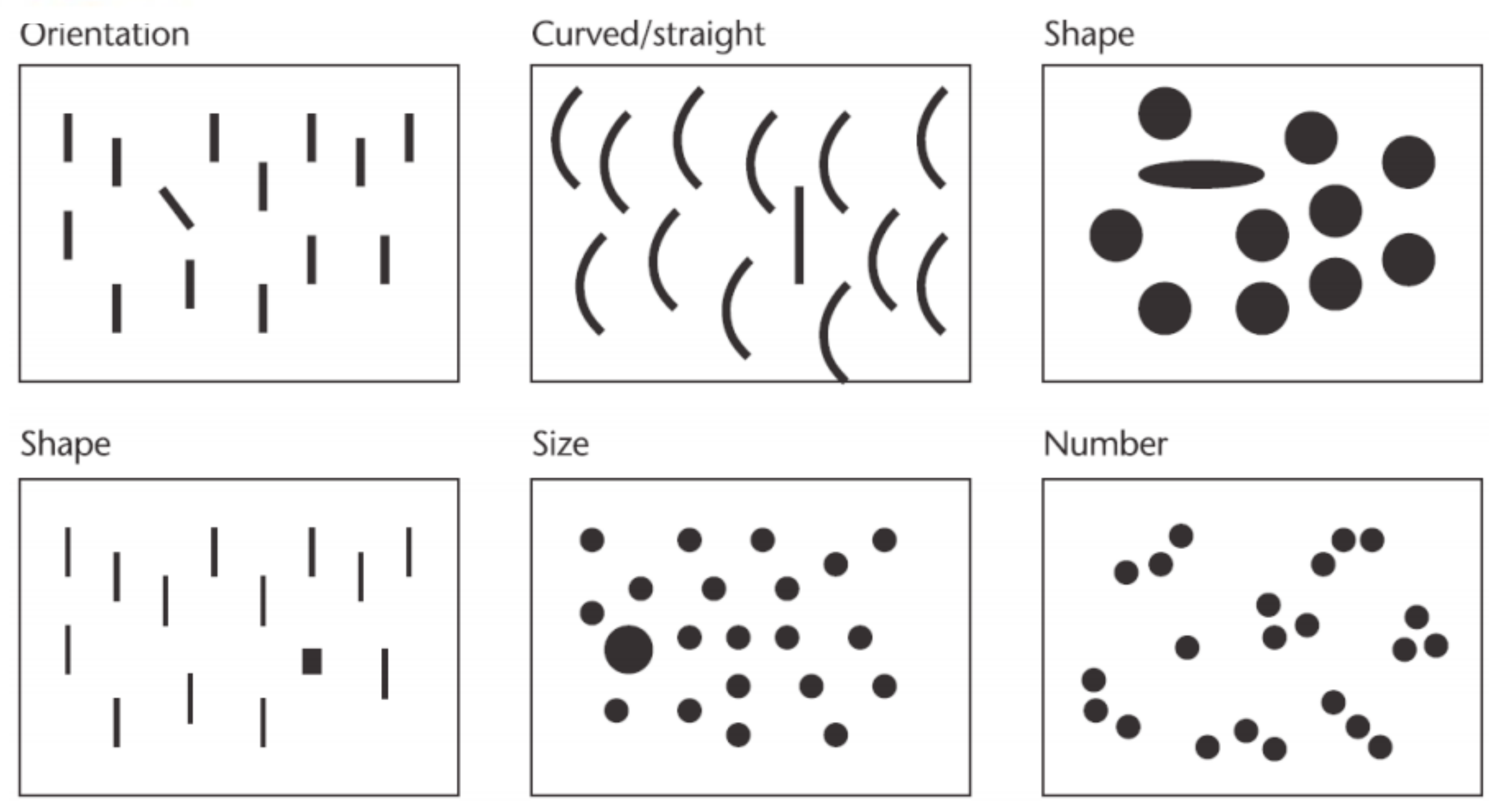
- **Tasks matter!** Visualizations that are good for one task may not be optimal for another task
- When creating visualizations, we should tailor design based on our knowledge of how the **human visual system** works
- **Evaluation** with people is the best way we can verify that a visualization / VR environment is effective at the task

Visual Perception and Cognition



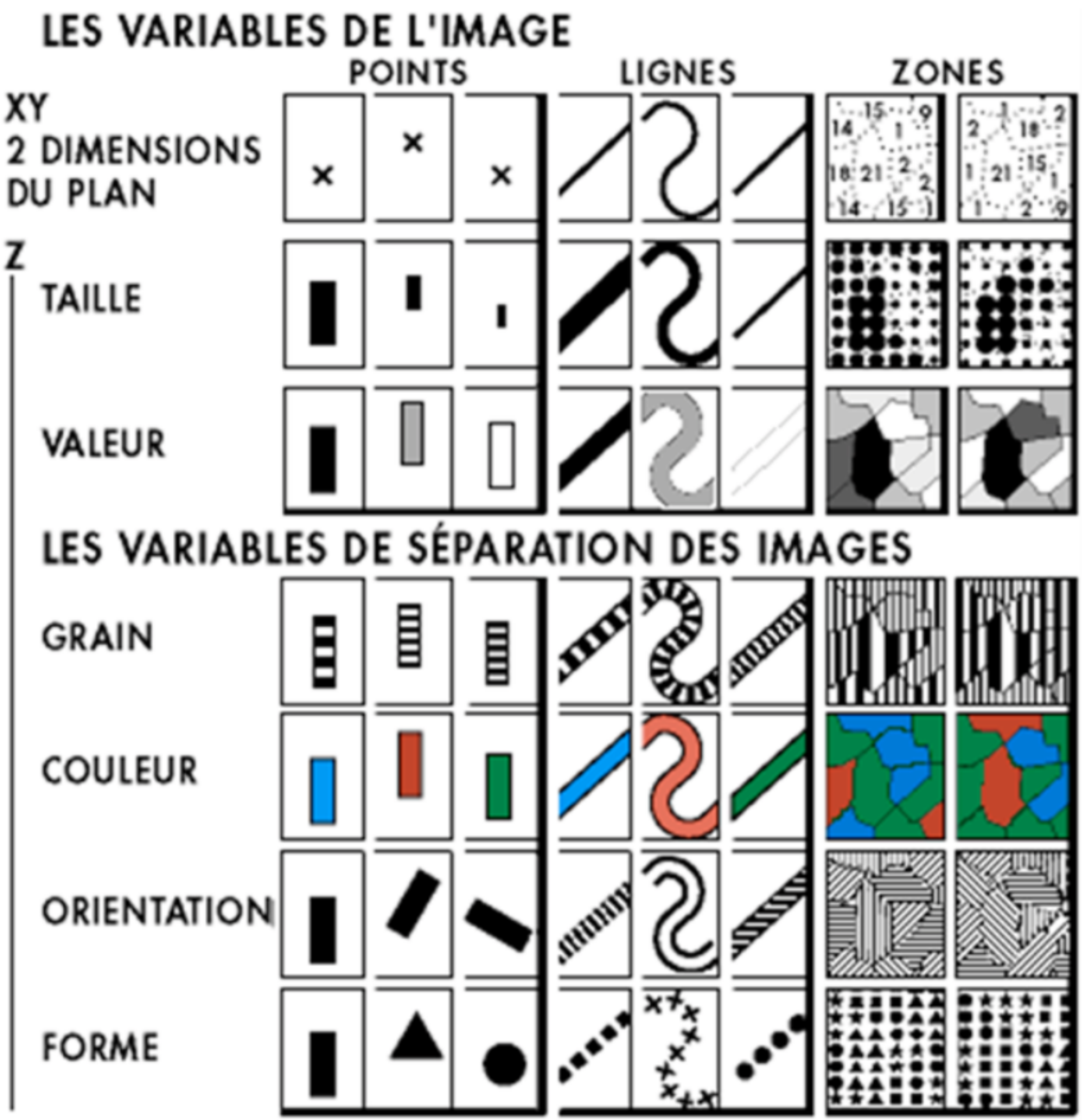






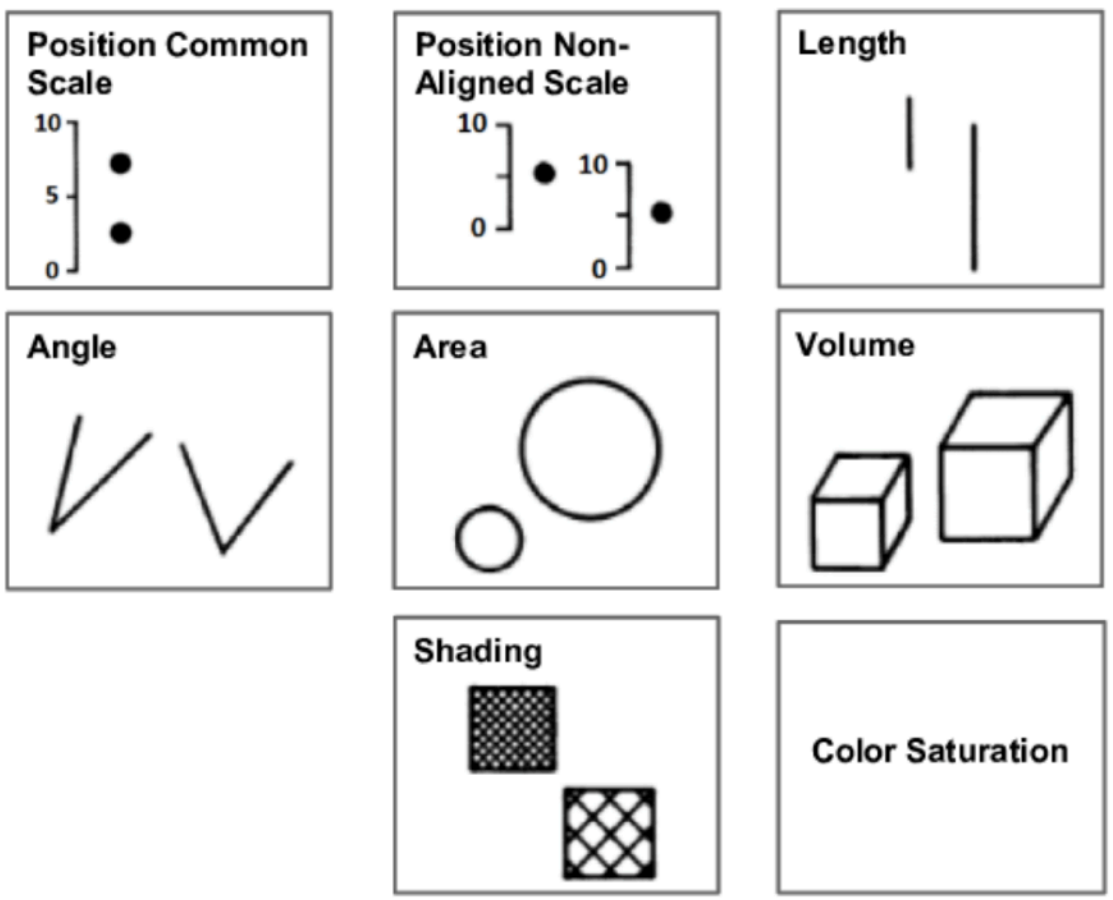
Collin Ware

Visual Marks & Channels



Semiology of Graphics
J. Bertin

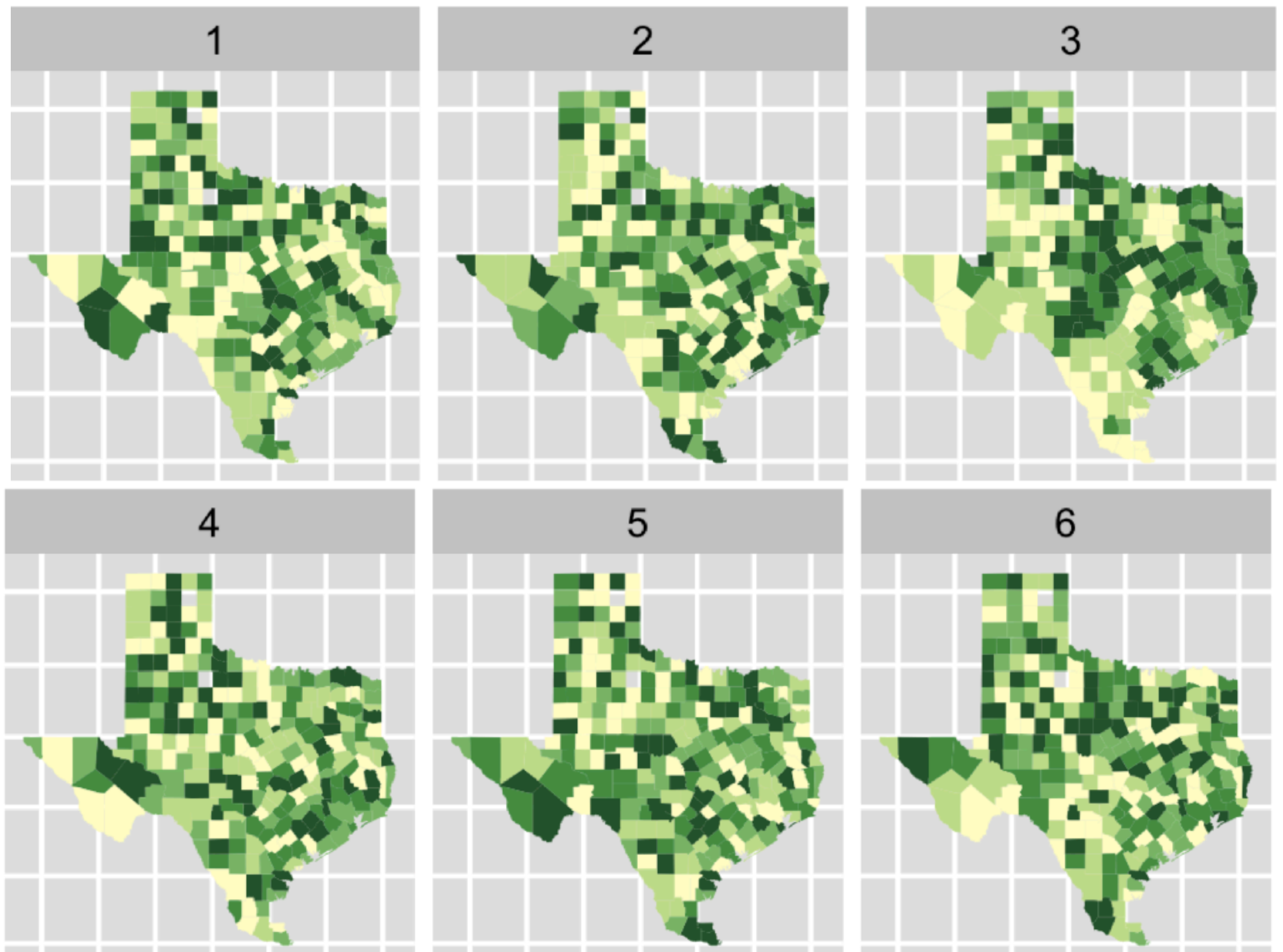
Visualization Evaluation



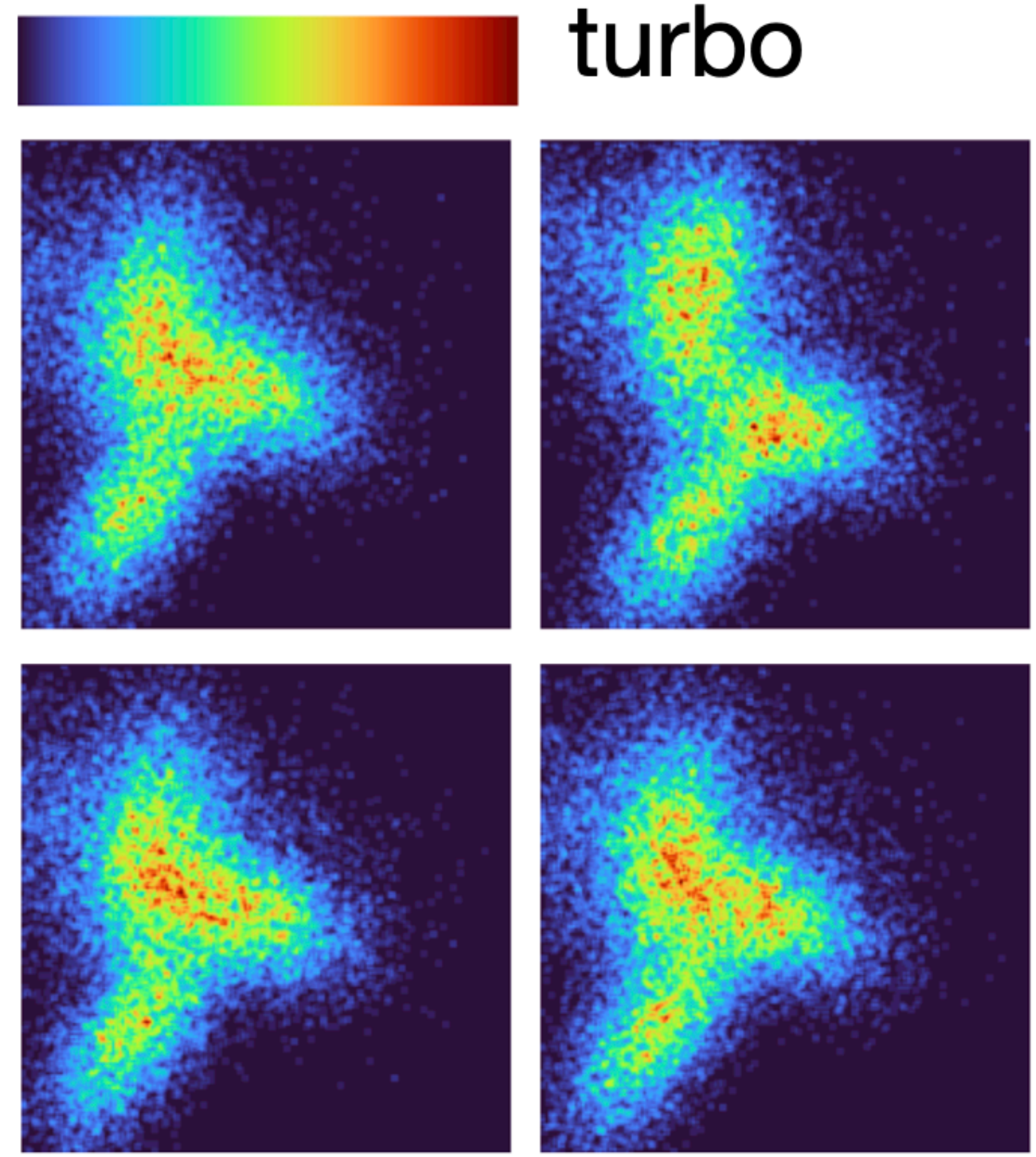
Graphical Perception
Cleveland and McGill

Useful junk
Bateman et al.

Visualization Evaluation

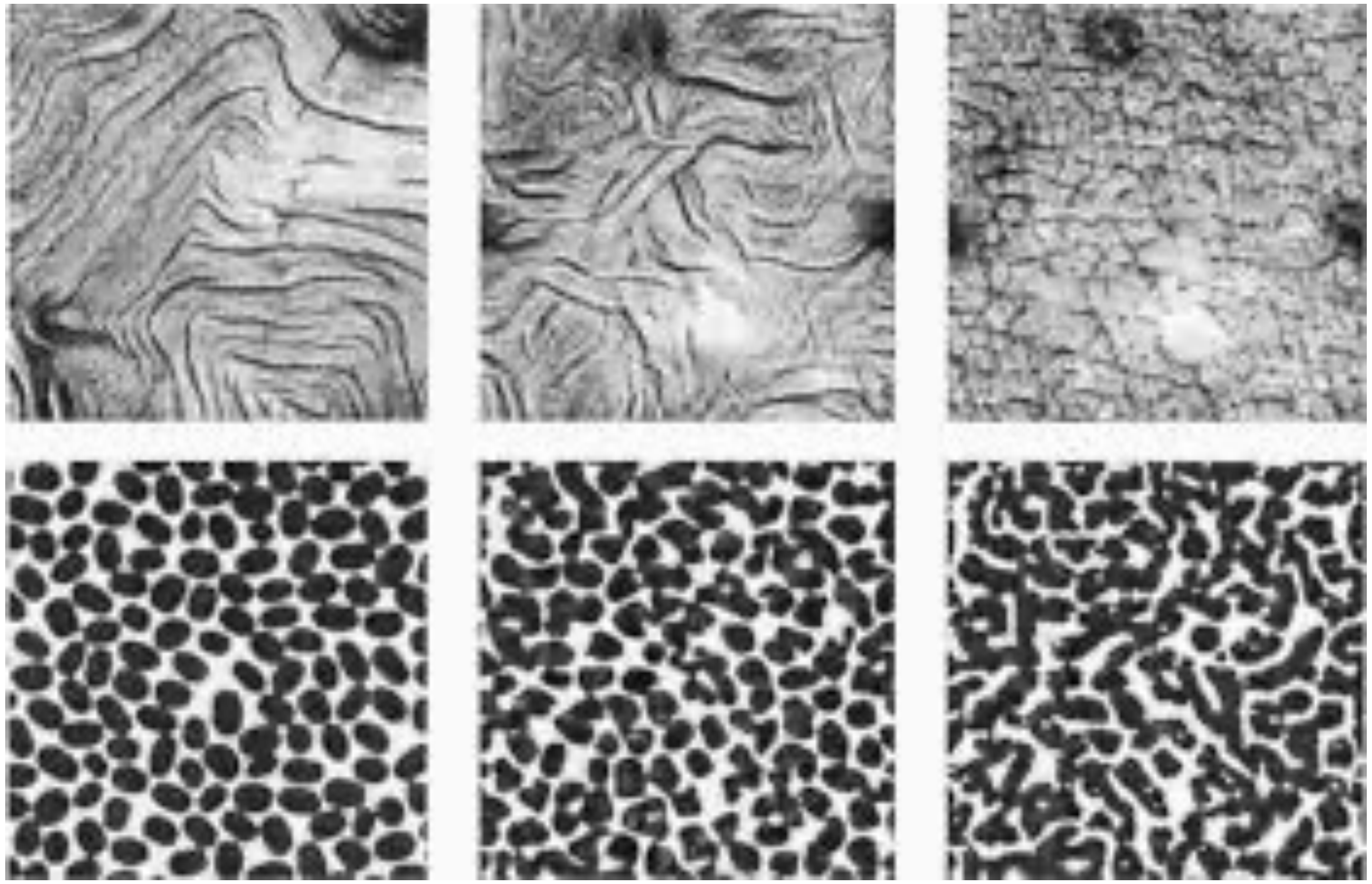


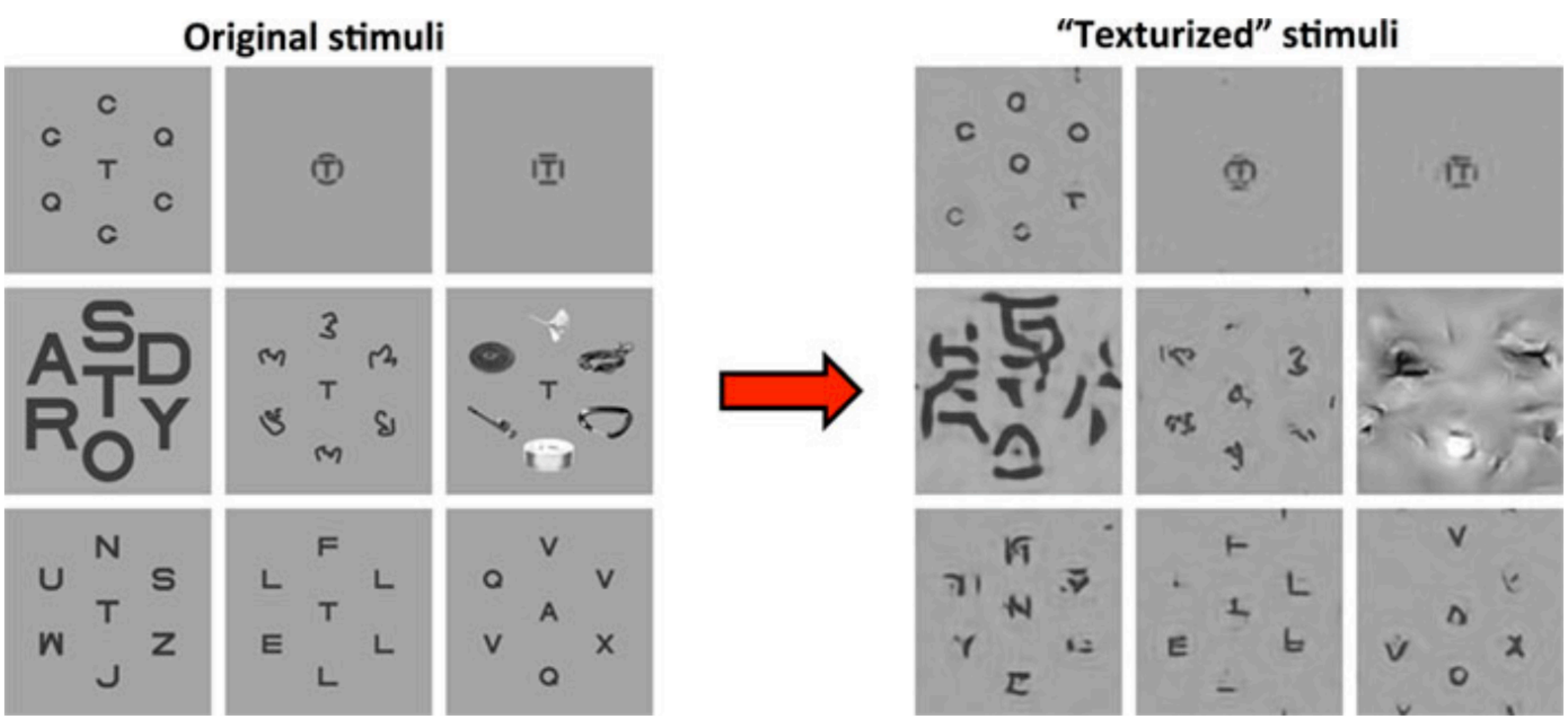
Graphical inference
Wickham et al.



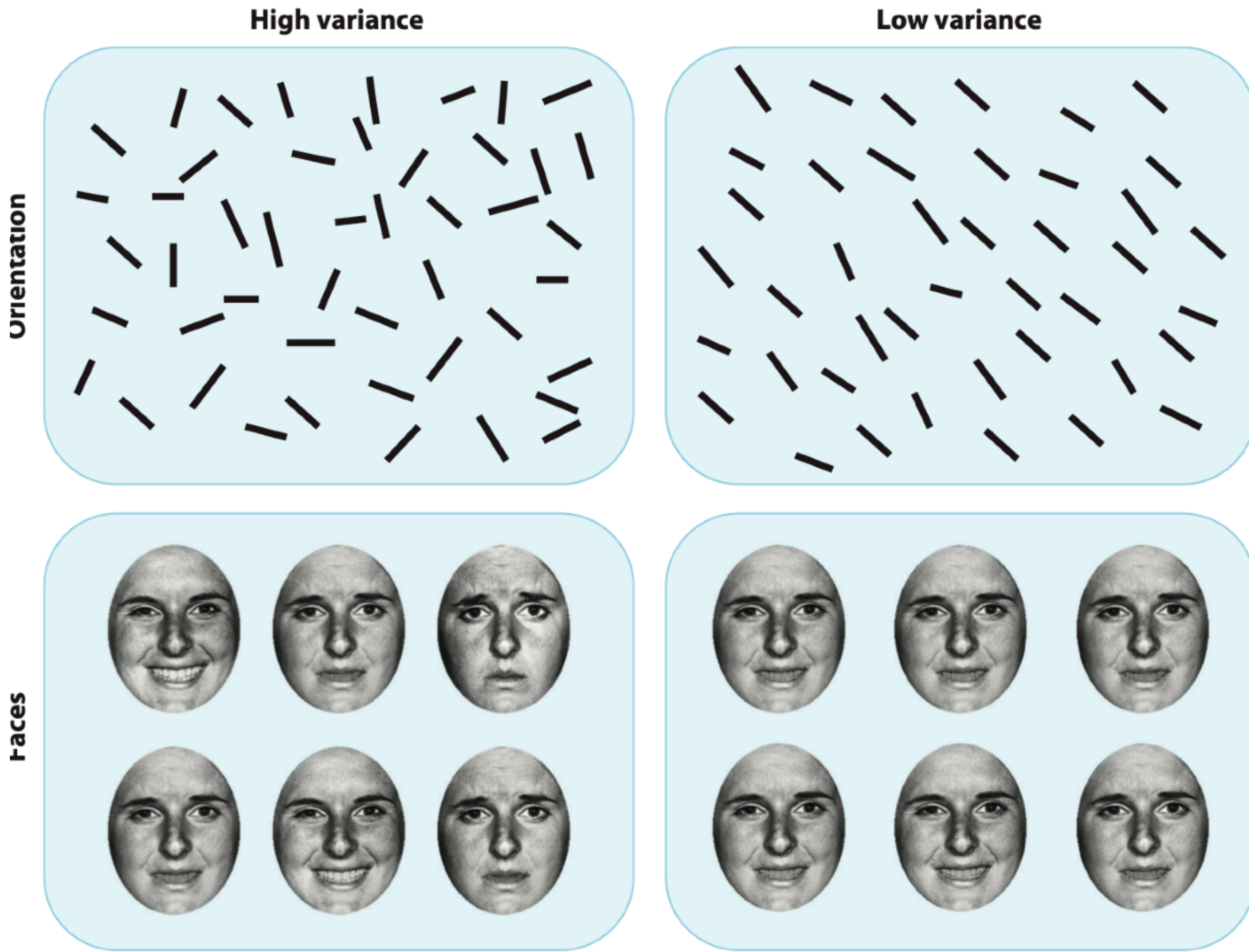
Color perception
Reda & Szafir

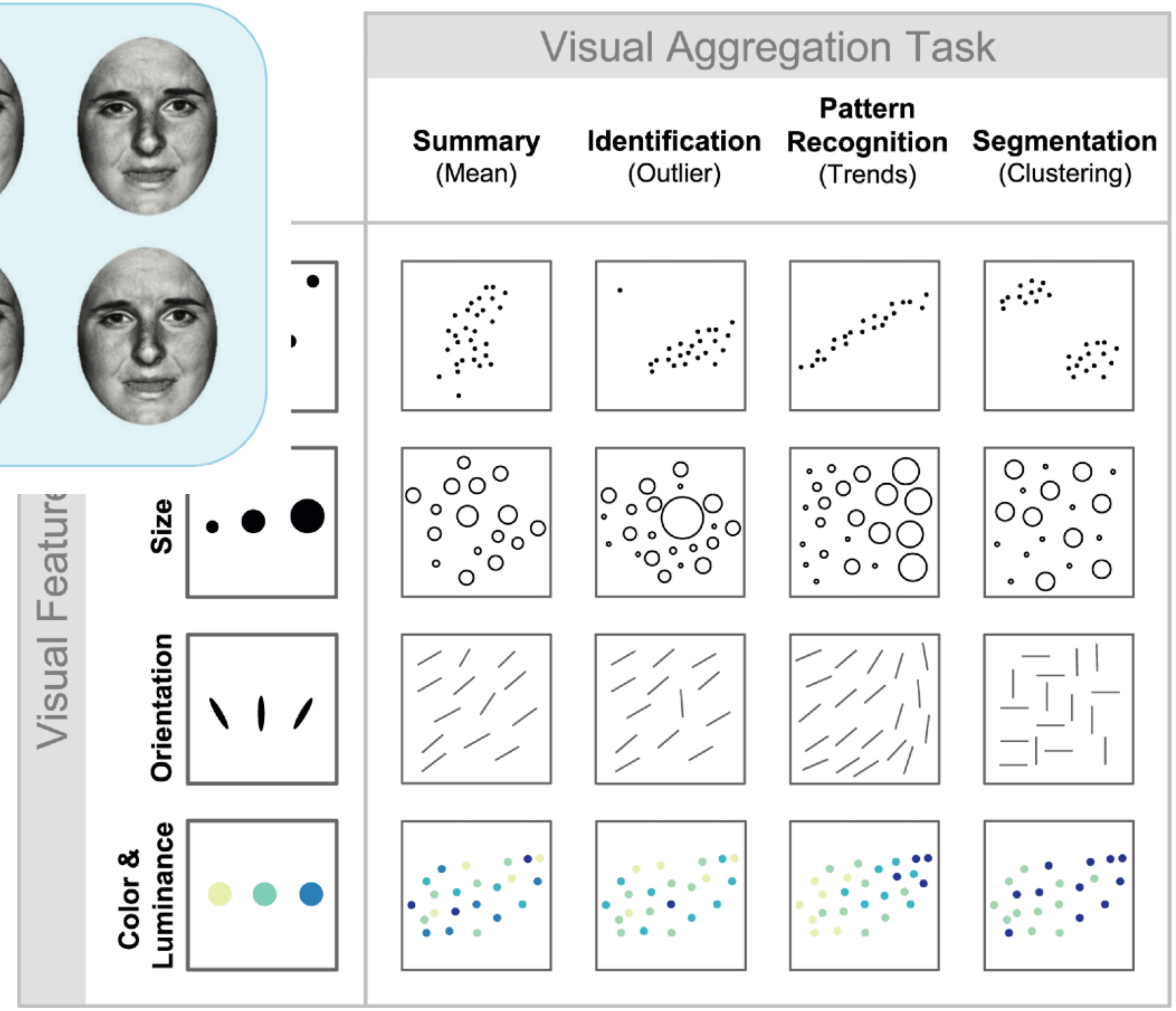
Texture perception & synthesis



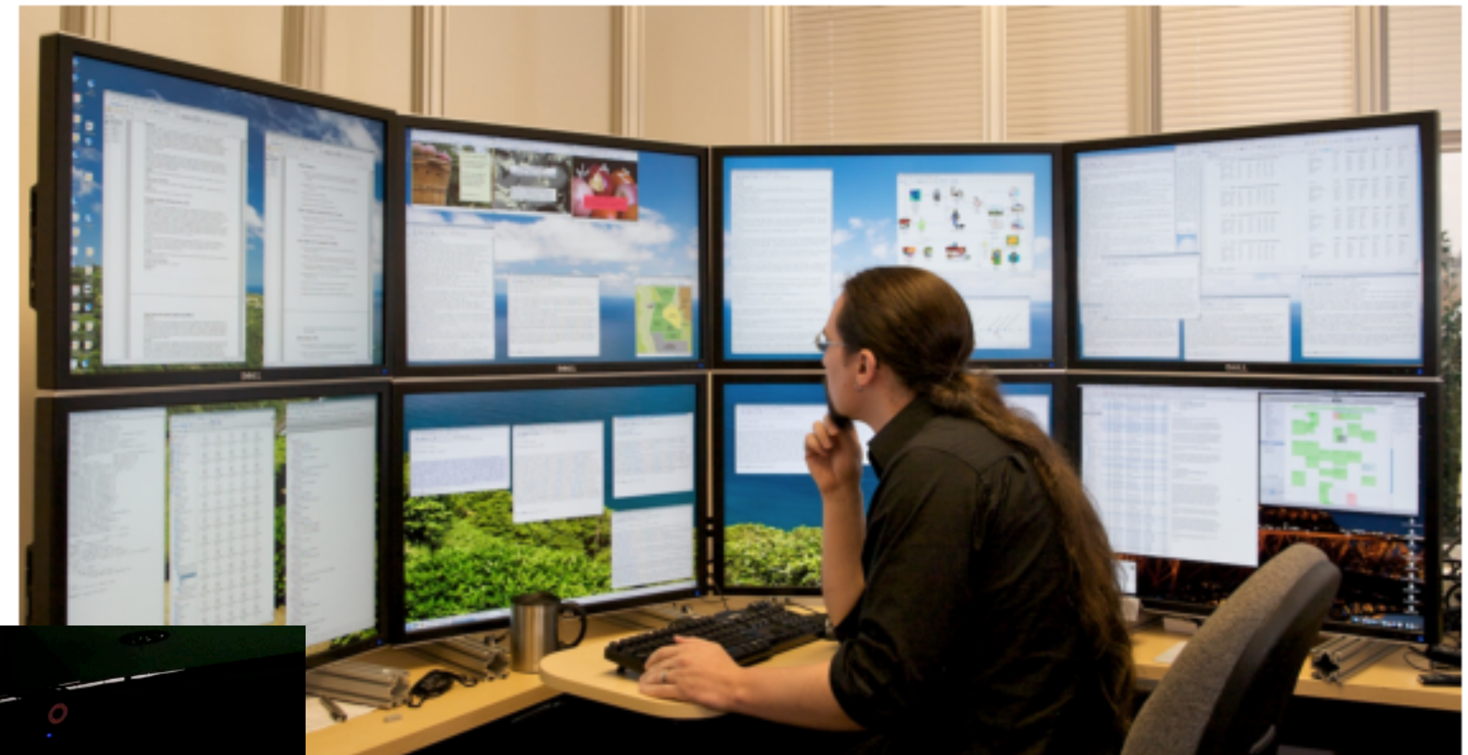


Ensemble perception

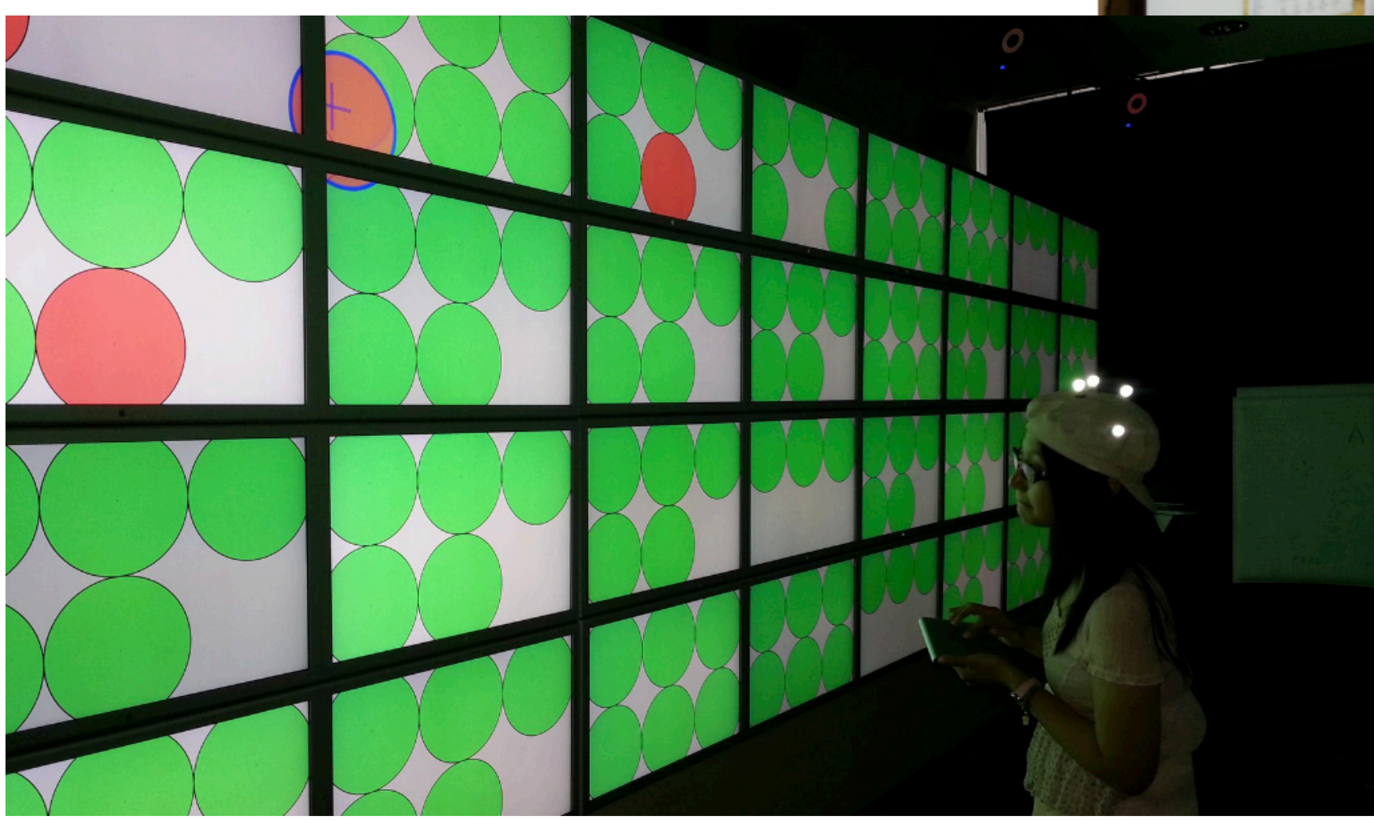




Large Display Evaluations

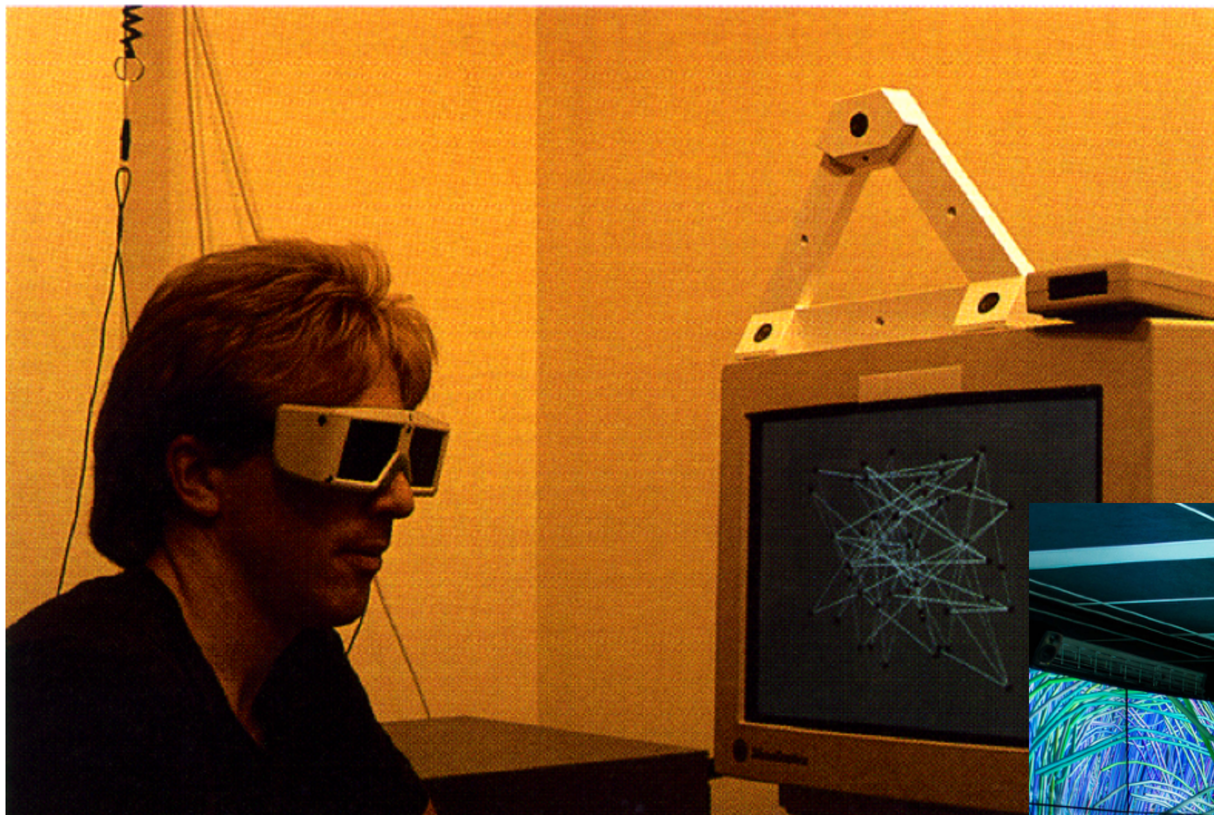


Space to think
Andrews et al.



Liu et al.

VR and immersive analytics



"FishTank" stereo
Ware and Franck

Required reading

Neural Modeling of Flow Rendering Effectiveness

Daniel Pineo[*]
University of New Hampshire

Colin Ware[†]
University of New Hampshire

Abstract

It has been previously proposed that understanding the mechanisms of contour perception can provide a theory for why some flow rendering methods allow for better judgments of advection pathways than others. In the present paper we develop this theory through a numerical model of the primary visual cortex of the brain (Visual Area 1) where contour enhancement is understood to occur according to most neurological theories. We apply a two-stage model of contour perception to various visual representations of flow fields evaluated by Laidlaw et al [2001]. In the first stage, contour *enhancement* is modeled based on Li's [1998] cortical model. In the second stage, a model of contour *integration* is proposed designed to support the task of advection path tracing. The model yields insights into the relative strengths of different flow visualization methods for the task of visualizing advection pathways.

CR Categories: H.1.2 [Models and Principles]: User/Machine Systems—Human Factors, human information processing.

Keywords: Flow visualization, contour perception, visual cortex, visualization, perceptual theory.

1 Introduction

Many techniques for 2D flow visualization have been developed and applied. These include grids of little arrows, still the most common for many applications, equally spaced streamlines [Turk and Banks 1996], and line integral convolution (LIC) [Cabral and Leedom 1993]. But which is best and why? Laidlaw et al [2001] showed that the "which is best" question can be answered by means of user studies in which participants are asked to carry out tasks such as tracing advection pathways or finding critical points in the flow field. Ware [2008] proposed that the "why" question may be answered through the application of recent theories of the way contours in the environment are processed in the visual cortex of the brain. But Ware only provided a descriptive sketch with minimal detail and no formal expression. In the present paper, we show, through a numerical simulation of neural processing in the cortex, how the theory predicts which methods will be best for an advection tracing task.

[*]e-mail: dspineo@comcast.net
[†]e-mail: cware@ccom.unh.edu

APGV 2008, Los Angeles, California, August 9–10, 2008.
© 2008 ACM 978-1-59593-981-4/08/0008 $5.00

Our basic rational is as follows: Tracing an advection pathway for a particle dropped in a flow field is a perceptual task that can be carried out with the aid of a visual representation of the flow. The task requires that an individual attempts to trace a continuous contour from some designated starting point in the flow until some terminating condition is realized. This terminating condition might be the edge of the flow field or the crossing of some designated boundary. If we can produce a neurologically plausible model of contour perception then this may be the basis of a rigorous theory of flow visualization efficiency.

The mechanisms of contour perception have been studied by psychologists for at least 80 years, starting with the Gestalt psychologists. A major breakthrough occurred with the work of Hubel and Wiesel [1962; 1968] since which time, neurological theories of contour perception have begun to develop.

In the present paper, we show that a model of neural processing in the visual cortex can be used to predict which flow representation methods will be better. Our model has two stages. The first is a contour enhancement model. Contour enhancement is achieved through lateral connections between nearby local edge detectors. This produces a neural map in which continuous contours have an enhanced representation. The model or cortical processing we chose to apply is adapted from Li [1998]. The second stage is a contour integration model. This represents a higher level cognitive process whereby a pathway is traced.

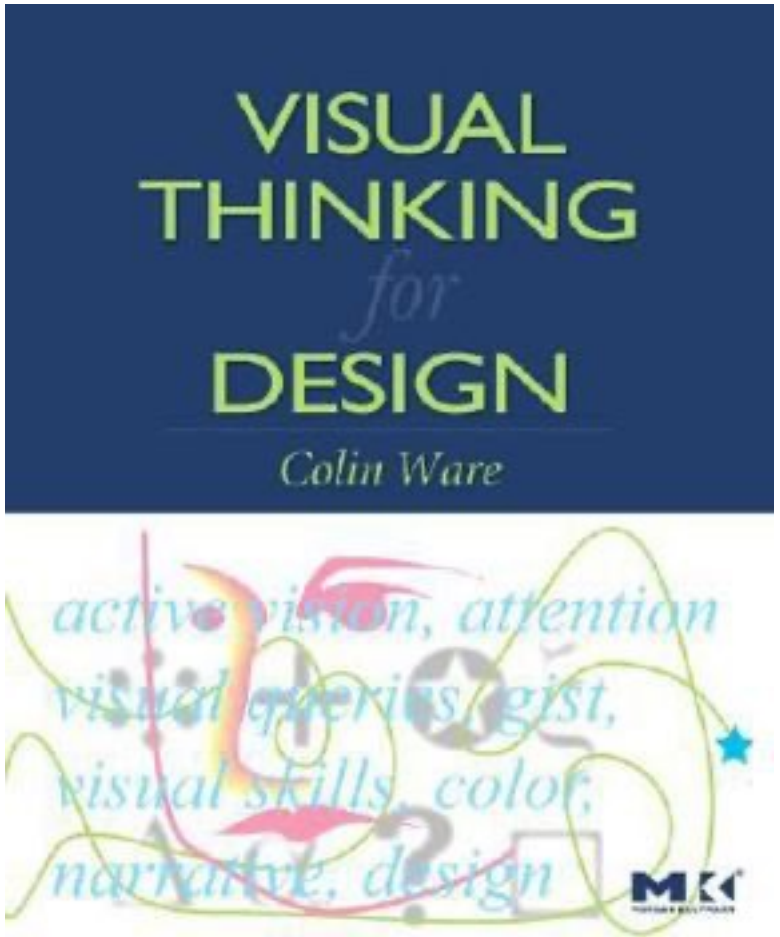
We apply the model to a set of 2D flow visualization methods that were previously evaluated by humans carrying out an advection pathway prediction task [Laidlaw et al. 2001]. This allows us to carry out a qualitative comparison between the model and how humans actually performed.

Our paper is organized as follows. First we summarize what is known about the cortical processing of contours and introduce Li's model of the cortex. Next we show how a slightly modified version of Li's model differentially enhances various flow rendering methods. Following this we develop a perceptual model of contour tracing and show how it predicts different outcomes for an advection path estimation task based on Laidlaw et al's prior work. Finally we discuss how this work relates to other work that has applied perceptual modeling to data visualization and suggest other uses of the general method.

Figure 1. The neural response to oriented contours and edges can be approximated by means of a Gabor function for many V1 neurons. Three receptive fields of different sizes are shown. Each is excited when a bright horizontal bar falls on the central dark bar. Each is inhibited when the bar falls on the adjacent regions. These neurons are tuned to orientation. Their response pattern weakens as the orientation departs from horizontal.

171

Research papers
(2 per week)



Ware, C. Visual thinking for design
(select chapters)

S. Murray. **Interactive Data Visualization for the Web**
(Reference)

Paper presentation

Each student will present 1 paper

- 30 minutes presentation
- Lead discussion about the paper for 20 minutes
  - Critically analyze claims/evidence
  - Describe method
  - Discuss findings / implications
-

Everyone should read papers (2x papers per week)

- Participate in discussion, contribute comments, insights, questions
- A substantial part your grade will be based on participation
- Attendance required. I will track how many times you've participated and the quality of your engagement

Projects

Project 1: Introduction to visualization evaluation

- Replicate and extend a seminal visualization experiment
- Create an experiment interface to generate stimuli
- Collect data from participants, analyze, and report

Project 2: Student-driven research

- Write a proposal on human-centered evaluation/design
- Complete project in about 8 weeks
- Write a final report

Course website

https://go.uic.edu/CS526

CS 526 - Computer Graphics II (Spring 2026)

Table of Contents

Overview

Welcome to CS 526 Computer Graphics II

This is a graduate-level course that exposes students to state-of-the-art topics in computer graphics and visualization. The focus for this Spring 2026 term will be on **human factors in visualization, visual analytics, and virtual reality (VR)**. The course will emphasize perceptual theory, human-centered design, and empirical evaluation. We will study how properties of the human visual perception and cognition shape the effectiveness of visualization techniques and immersive environments. We will also discuss perceptual and cognitive models relevant to the design of these systems. We will study how to apply experimental techniques from psychology and HCI to conduct user studies to evaluate the effectiveness of graphical encodings, or to measure the user experience.

The course will be research-oriented, with many of the topics driven by papers in the field, which we will present, discuss, and critique in class. Students will also undertake research proejcts to validate specific visualizaitons/VR techniques through user studies, develop models to predict the effectiveness of these techniques, or create new techniques that enable better perception, sensemaking, or engagement. As part of the course, students will learn how to use web-based graphics and visualization libraries (D3 and Three.js) to design prototypes and experimental aparatus for data collection.

Piazza

piazza.com/uic/spring2026/cs526

vrdnylplztm

Signup for paper slots!

Out soon

Grading

		Percentage
Paper presentation	Present to class and lead critique	**20%**
Participation	Participate in paper discussion	**15%**
Project 1	Replicate and extend a visualization evaluation experiment	**25%**
Project 2 proposal	Write a proposal, present to class, revise	**10%**
Project 2 deliverable	Write final project paper, present to class	**30%**

Prerequisites and expectations

- You should have prior programming experience (e.g., C,   C++, Python, R, Java, JavaScript)
- Willingness to learn new tools: **You** have to teach yourself new skills, including JavaScript, D3, ThreeJS
- **This is a research-centered course: Most of this class will require engagement with research papers**