UNIVERSITÀ DI TORINO

Analisi e Visualizzazione di Reti Complesse

DV01 - Introduction to the course

Prof. Rossano Schifanella

Instructor

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Course

- **INF0007 Analisi e Visualizzazione di Reti Complesse** (9 credits)
  - Magistrale in Informatica
- Borrowed by:
  - **MFN0954 Reti Complesse** (6 credits)
    - Magistrale in Informatica
- The course is divided into two sub-modules:
  - **Network Science** (NS) (48h)
  - **Data Vizualization** (DV) (24h)

Schedule

	Tuesday	Wednesday	Friday
Module	NetSci	**DataViz**	NetSci
When	4pm-6pm	**11am-1pm**	2pm-4pm
Where	Aula F	**Aula E**	Aula E

The schedule could be subject to variations that will be communicated via the proper channels (e.g., Moodle forum, email).

This is why it is **crucial** that all students are registered to the Moodle module to be up-to-date.

Material

- Course on Moodle:
  - https://informatica.i-learn.unito.it/course/view.php?id=3026
- GitHub code repo:
  - https://github.com/rschifan/avrc-2425
- External references listed in Moodle
- The material will be updated throughout the course, so make sure to **download the latest version** when available.

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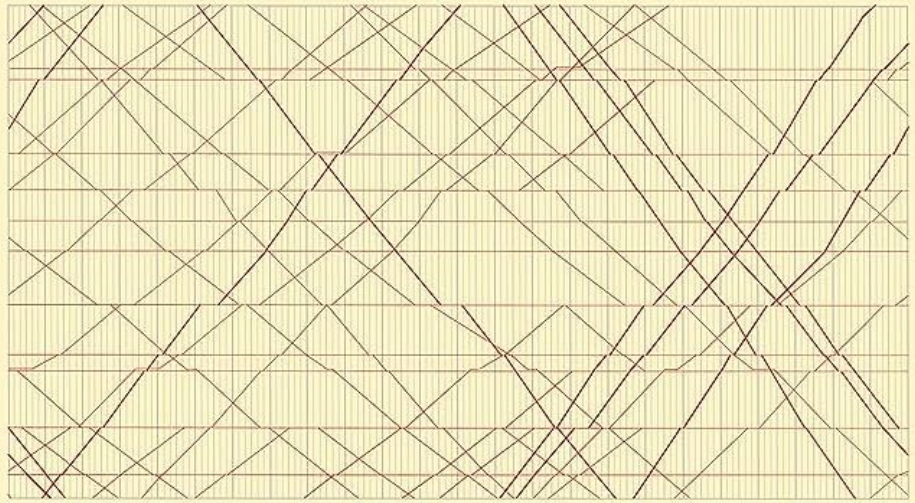
Textbooks

> Tufte, E. R. (2013). The Visual Display of Quantitative Information. United Kingdom: Graphics Press.

- A classic book in the data visualization field



SECOND EDITION

The Visual Display of Quantitative Information

EDWARD R. TUFTE

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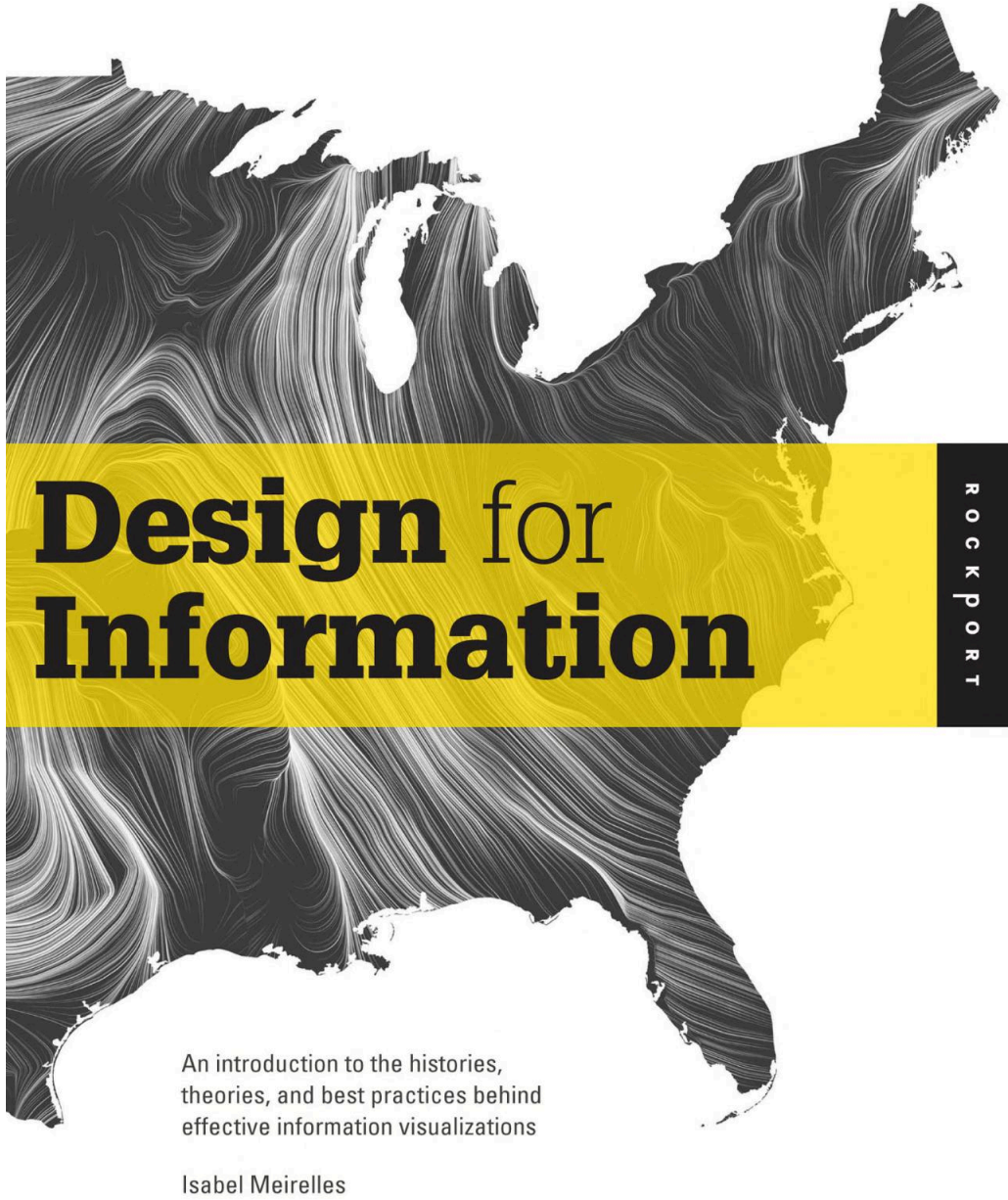
Textbooks

> Meirelles, I. Design for Information: An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations. Rockport Publishers, 2013.

Book website



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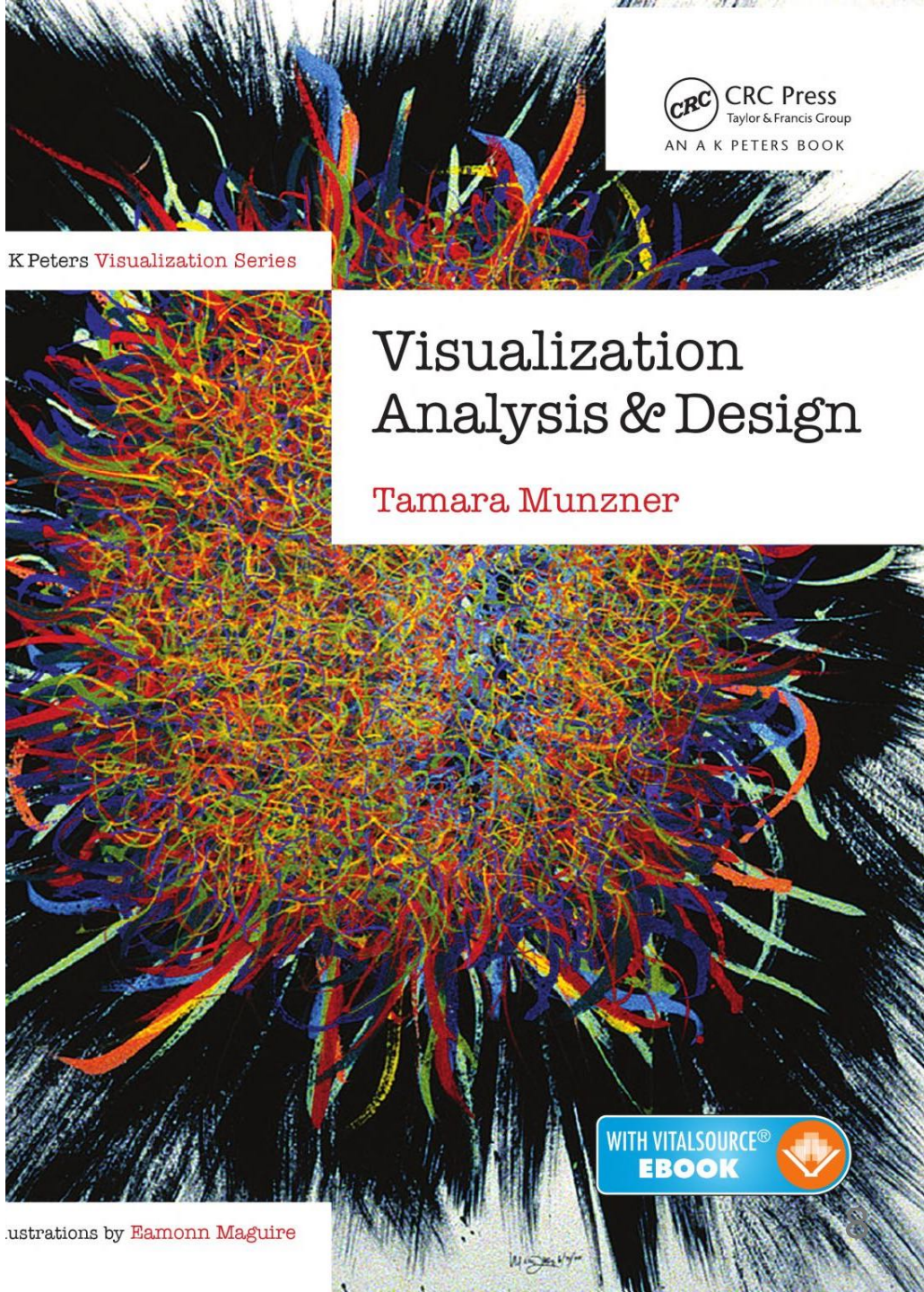
Textbooks

> Munzner, T. Visualization Analysis and Design. AK Peters Visualization Series. CRC Press, 2014.

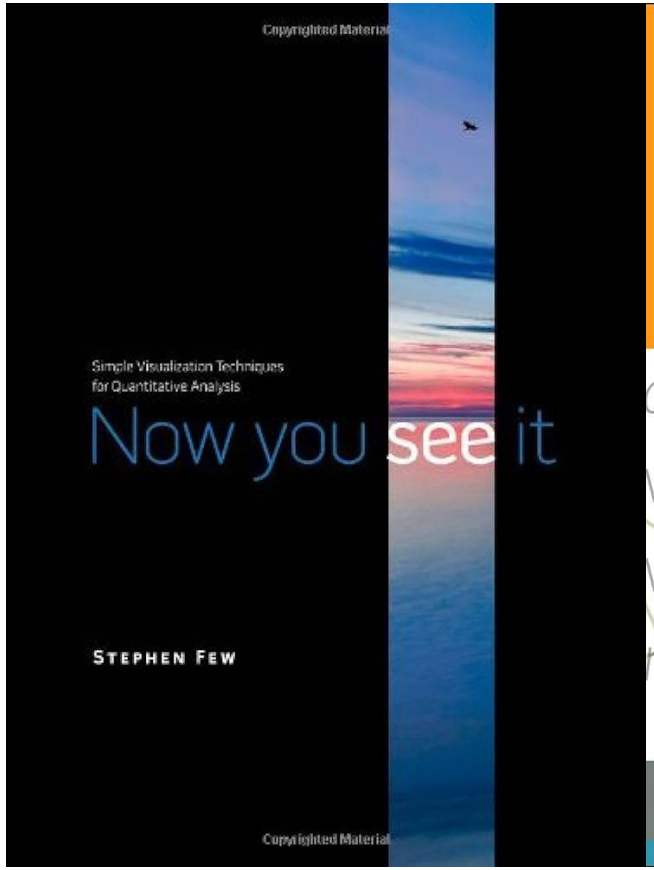
Book website

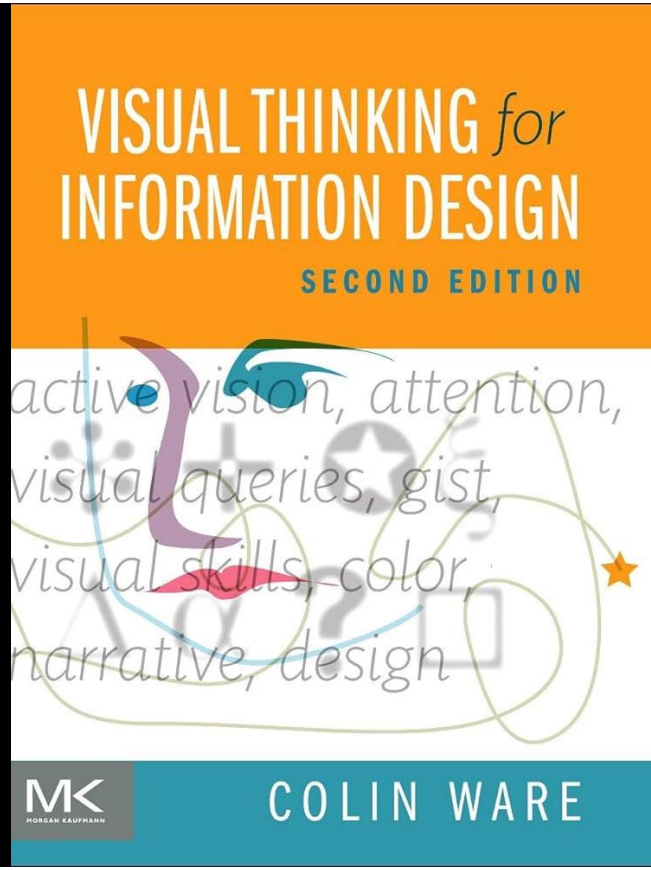


Focus on perception

> Few, Stephen. Now You See it: Simple Visualization Techniques for Quantitative Analysis. United States: Analytics Press, 2009.

> Ware, Colin. Visual Thinking for Design. Germany: Elsevier Science, 2008.

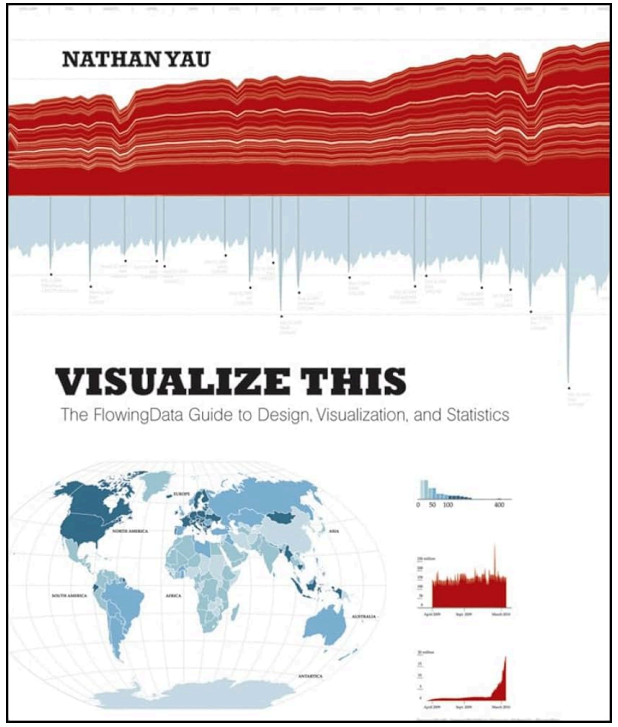


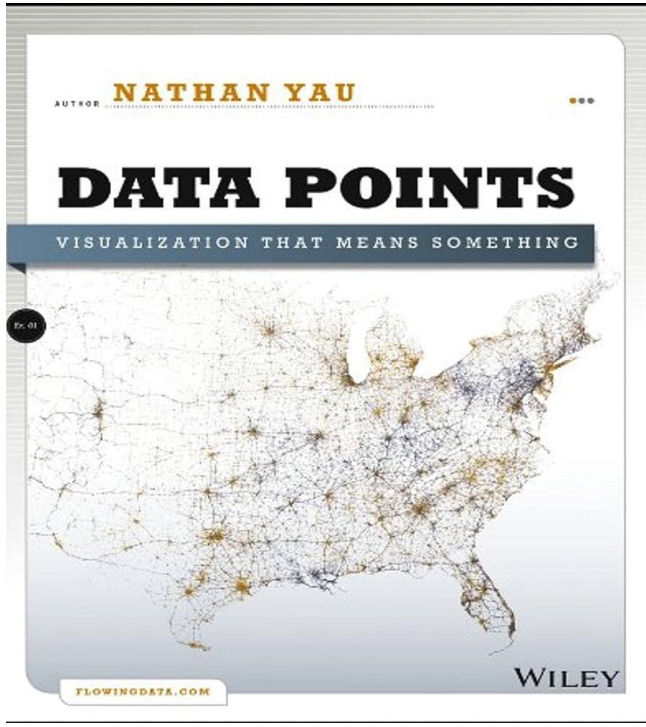


Data Visualization

Yau, Nathan. Visualize this: The Flowingdata Guide to Design, Visualization and Statistics. India: Wiley Publishing, Incorporated, 2014

Yau, Nathan. Data Points: Visualization That Means
Something. Germany: Wiley, 2013

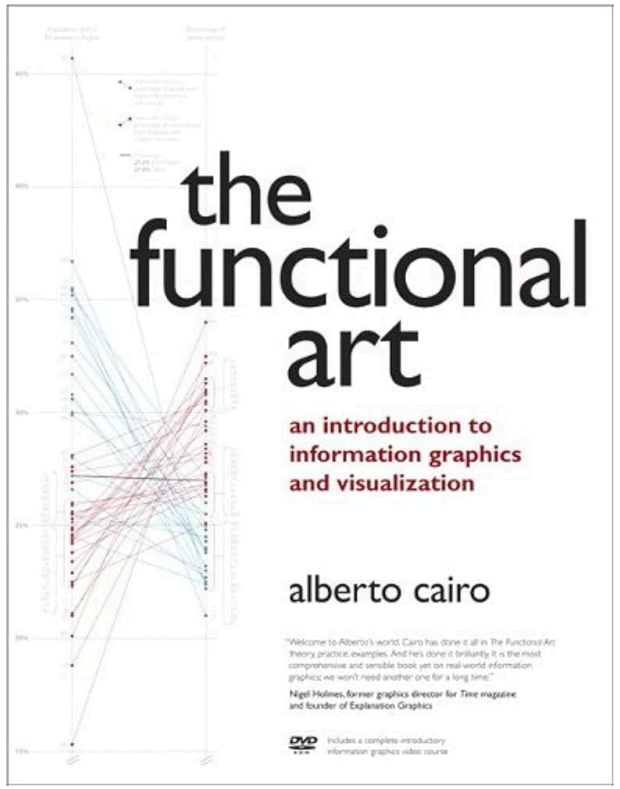


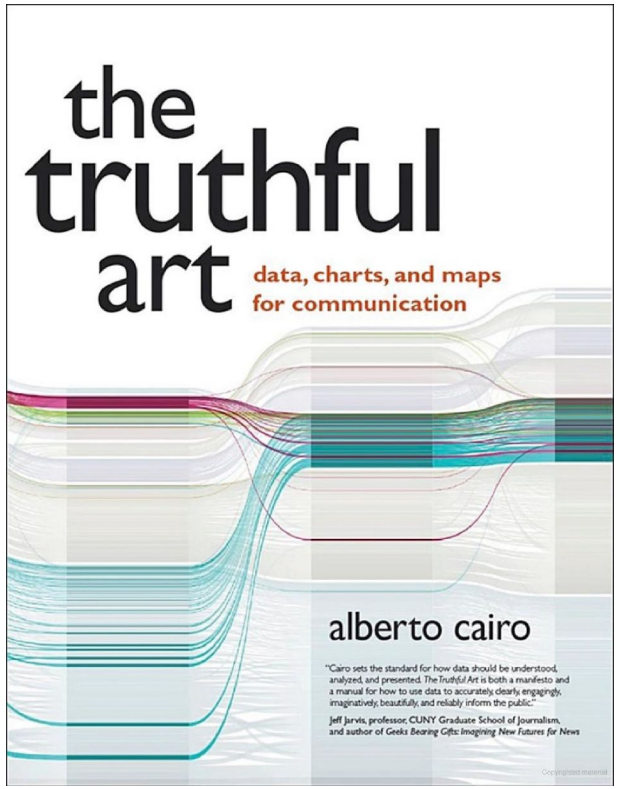


Data Journalism

> Cairo, Alberto. The Functional Art: An Introduction to Information Graphics and Visualization. United Kingdom: Pearson Education, 2012.

> Cairo, Alberto. The Truthful Art: Data, Charts, and Maps for Communication. United Kingdom: Pearson Education, 2016.

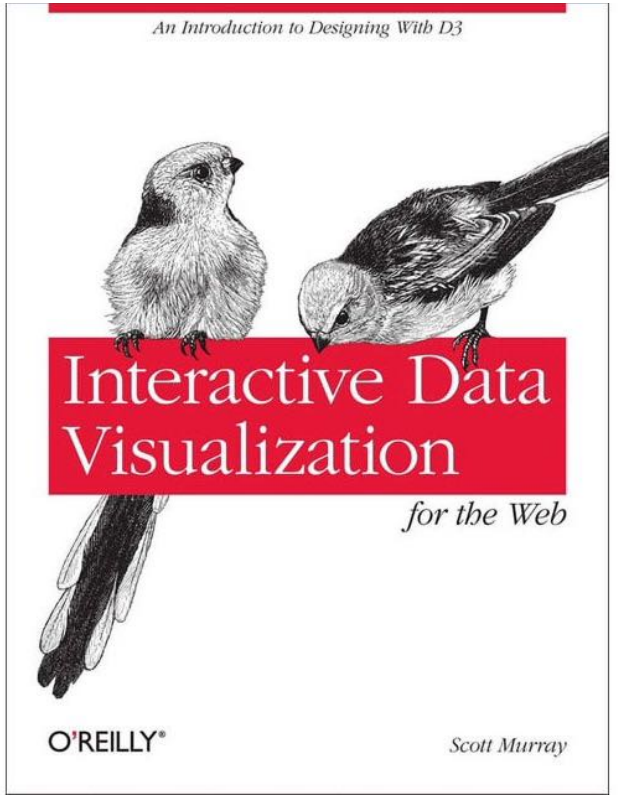


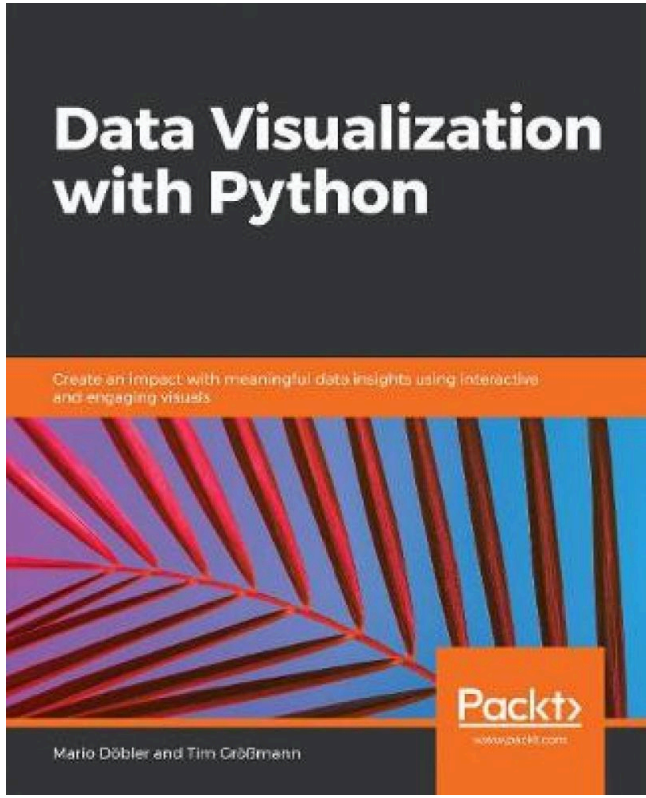


Coding and practical books

Murray, Scott. Interactive Data Visualization for the Web: An Introduction to Designing with D3. Taiwan: O'Reilly Media, 2017.

Döbler, Mario., Größmann, Tim. Data Visualization with Python: Create an Impact with Meaningful Data Insights Using Interactive and Engaging Visuals. United Kingdom: Packt Publishing, 2019.





Exam

- **Network Science**:
  - Report: network analysis with real data and interpretation of the results
    - E.g., in the form of a commented Jupyter Notebook
  - Oral Examination
- **Data Visualization**:
  - Project: design and implementation of a data visualization platform to explore some real dataset(s)
    - It could take different forms: e.g., a d3.js project, a Jupyter Notebook using Python visualization libraries
- **Active class participation**:
  - up to +10%
  - You can get the maximum evaluation even if you do not attend classes actively. However, students who participate in Q&A sessions will be more likely to get some extra points.

DataViz description and objectives

- **Visualizations are extremely powerful** ("a picture is worth a thousand words")
- However, not all the visualizations are designed or implemented correctly, and sometimes they misrepresent underlying data.
- Students will learn basic visualization design and evaluation principles and how to acquire, parse, analyze, and visualize large datasets.
- Students will learn techniques for visualizing multivariate, temporal, text-based, geospatial, hierarchical, and network/graph-based data.
- Students will utilize Gephi, D3.js, Python, matplotlib, and other tools to prototype these techniques on existing datasets.

Definitions

Defining visualization (vis)

> Computer-based visualization systems provide **visual representations** of datasets designed to help people **carry out tasks more effectively**.

> Visualization is suitable when there is a need to **augment human capabilities** rather than replace people with computational decision-making methods.

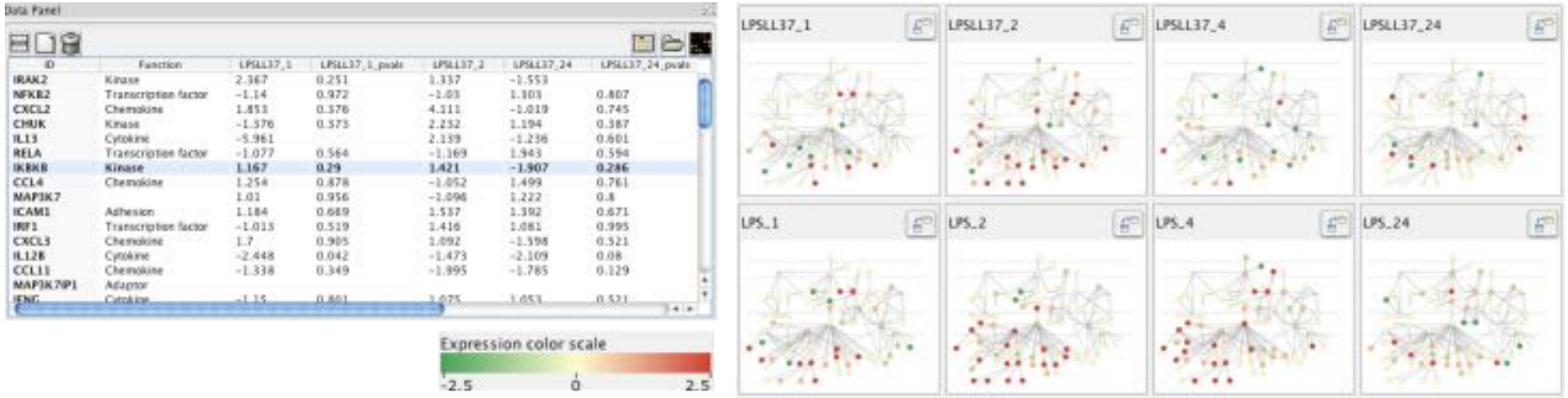
- From Munzner, T. Visualization Analysis and Design
- As you might expect, there are tons of different definitions of what a data visualization is, focusing on different dimensions

Visualization (vis) defined & motivated

- Human in the loop needs the details & no trusted automatic solution exists
- **doesn't know exactly what questions to ask in advance**
- **exploratory data analysis**
  - speed up through human-in-the-loop visual data analysis
- **present known results to others**
- **stepping stone towards automation**
  - before model creation to provide understanding
  - during algorithm creation to refine, debug, set parameters
  - before or during deployment to build trust and monitor

Why use an external representation?

Replace cognition with perception



[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE TVCG (Proc. InfoVis) 14(6):1253-1260, 2008.]

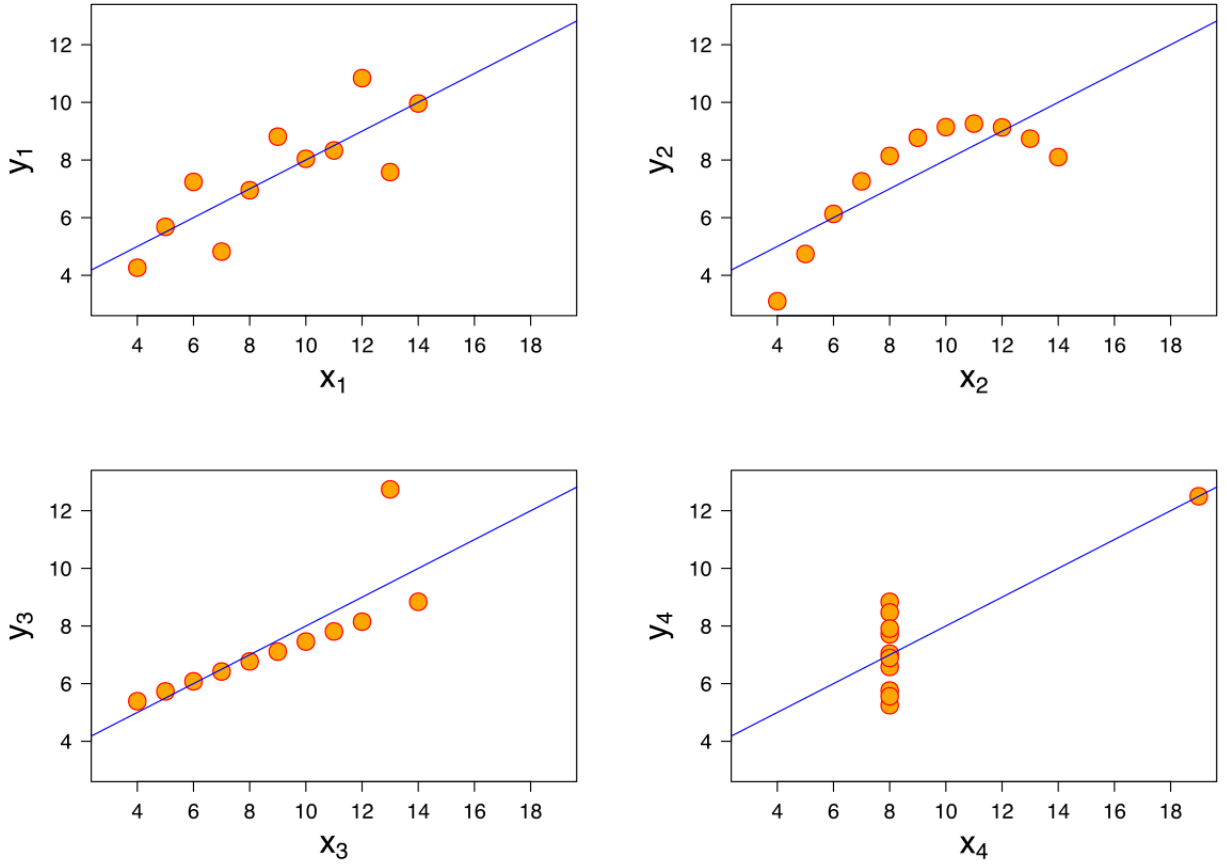
Why depend on vision?

- **human visual system is a high-bandwidth channel to the brain**
  - overview possible due to background processing
  - subjective experience of seeing everything simultaneously
  - significant processing occurs in parallel and pre-attentively
- **sound: lower bandwidth and different semantics**
  - overview not supported
    - subjective experience of sequential stream
- **touch/haptics: impoverished record/replay capacity**
  - only very low-bandwidth communication thus far
- **taste, smell: no viable record/replay devices**
- current research on **multi-sensory visualizations**

Anscombe's Quartet

- **summaries lose information, details matter**
  - confirm expected and find unexpected patterns
  - assess the validity of the statistical model
- **Anscombe's Quartet**
  - Same summary stats, different plots

x mean	9
x variance	10
y mean	7,5
y variance	3,75
x/y correlation	0,816



Why focus on tasks and effectiveness?

- **effectiveness requires a match between data/task and representation**
  - set of representations is huge
  - many are ineffective mismatch for specific data/task combo
  - increases chance of finding good solutions if you understand full space of possibilities
- **what counts as effective?**
  - novel: enable entirely new kinds of analysis
  - faster: speed up existing workflows
- **how to validate effectiveness**
  - many methods, must pick appropriate one for your context

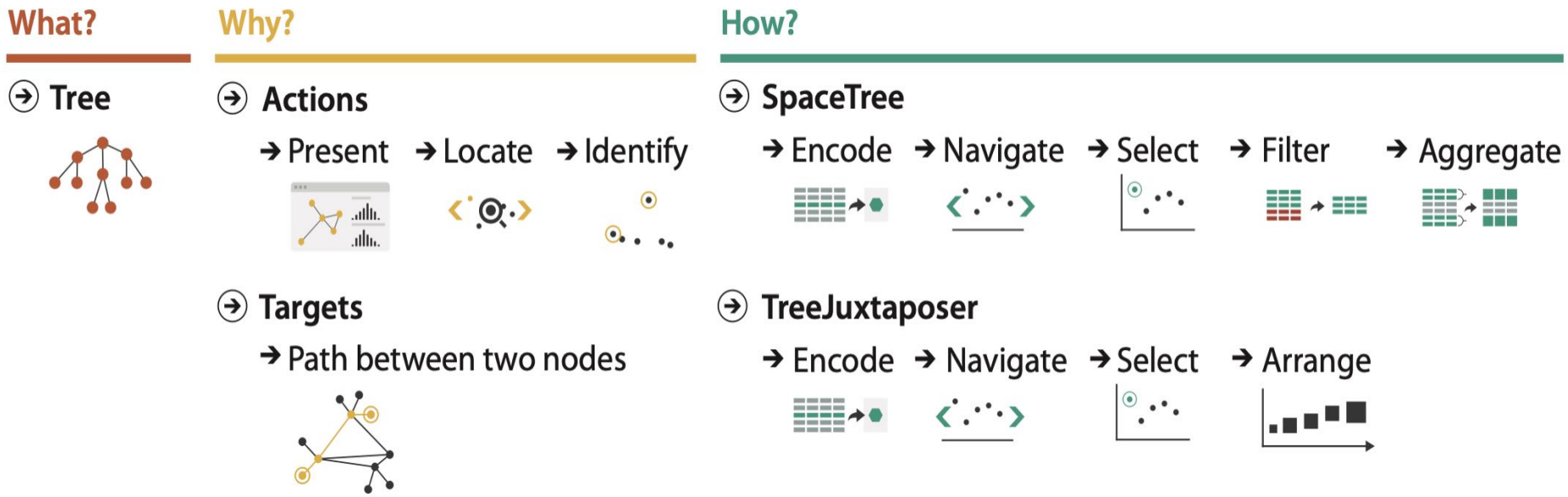
What resource limitations are we faced with?

Vis designers must take into account three very different kinds of resource limitations

- **computational limits**
  - processing time
  - system memory
- **human limits**
  - human attention and memory
- **display limits**
  - pixels are precious resource, the most constrained resource
  - information density: ratio of space used to encode info vs unused whitespace
    - tradeoff between clutter and wasting space, find sweet spot between dense and sparse

Why do we need an analysis framework?

- **imposes structure on huge design space**
  - scaffold to help you think systematically about choices
  - analyzing existing as stepping stone to designing new
  - most possibilities ineffective for particular task/data combination

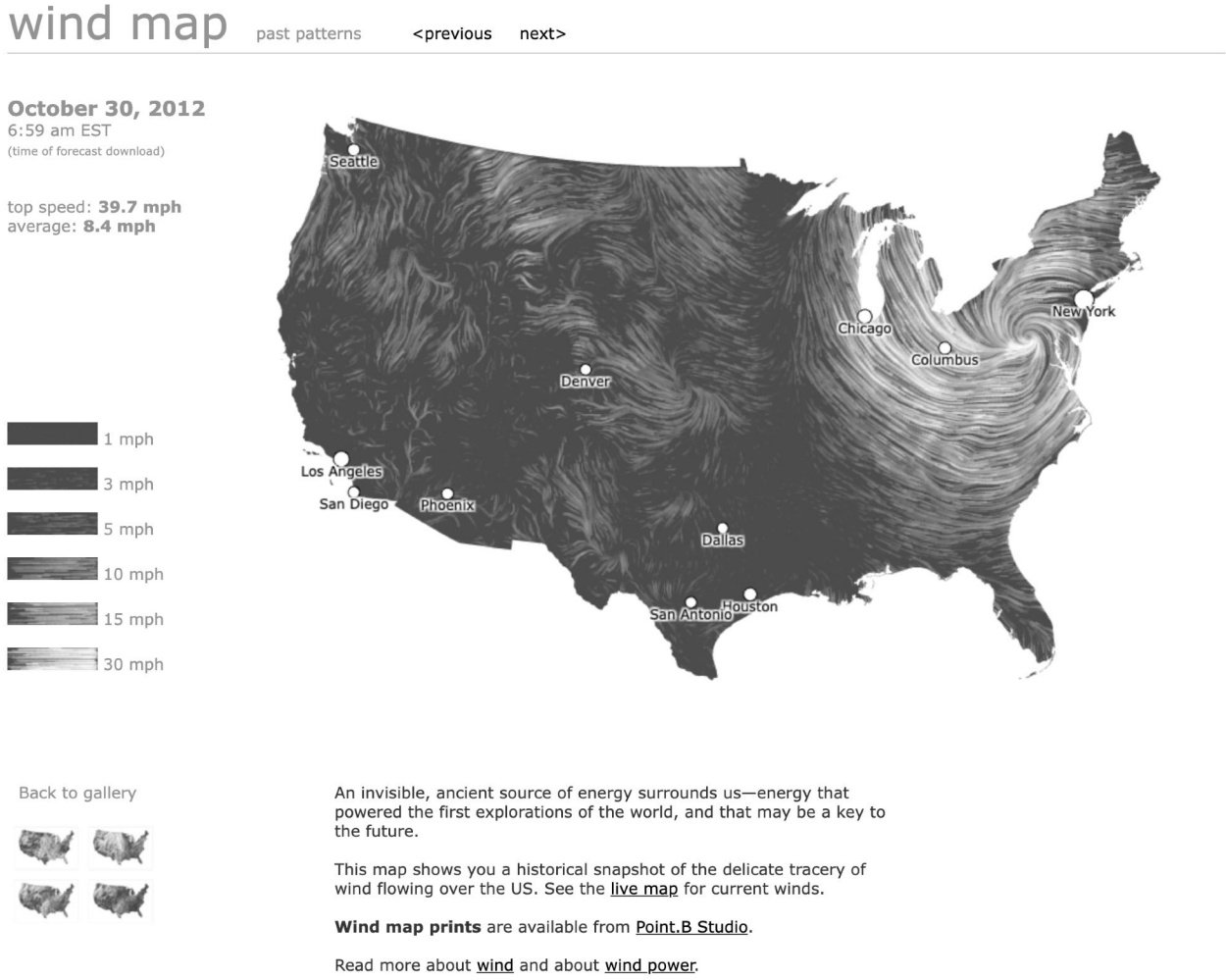


Terminology

- As you might expect, **there are dozens of different definitions that focus on complementary aspects**
- There are also different terms related to the domain of visualization
- Differences between terms are often fuzzy
  - Information visualization versus infographics
- Differences between terms are sometimes highly contested
  - Information visualization versus statistical graphics
- Differences often come down to two aspects
  - Type of data being visualized
  - Why data is being visualized

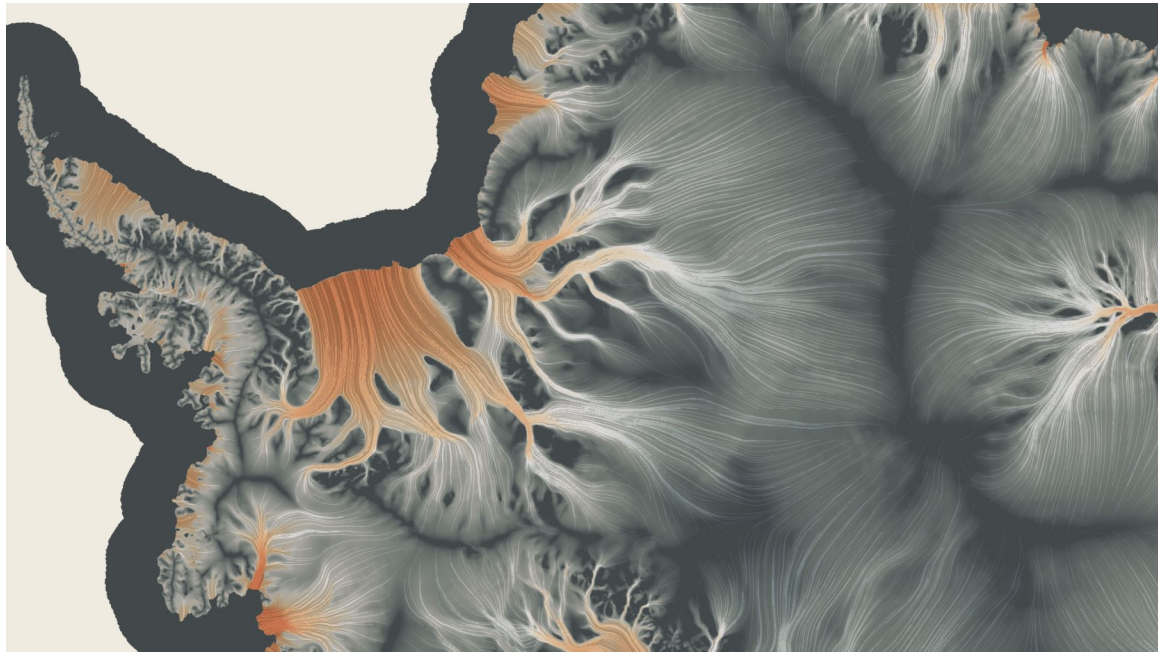
Data Visualization

- Communicates non-visual data visually
- Result should be readable and recognizable
- Two Subfields
  - Scientific visualization
  - Information visualization
- Transforms raw data into information
  - e.g., wind map



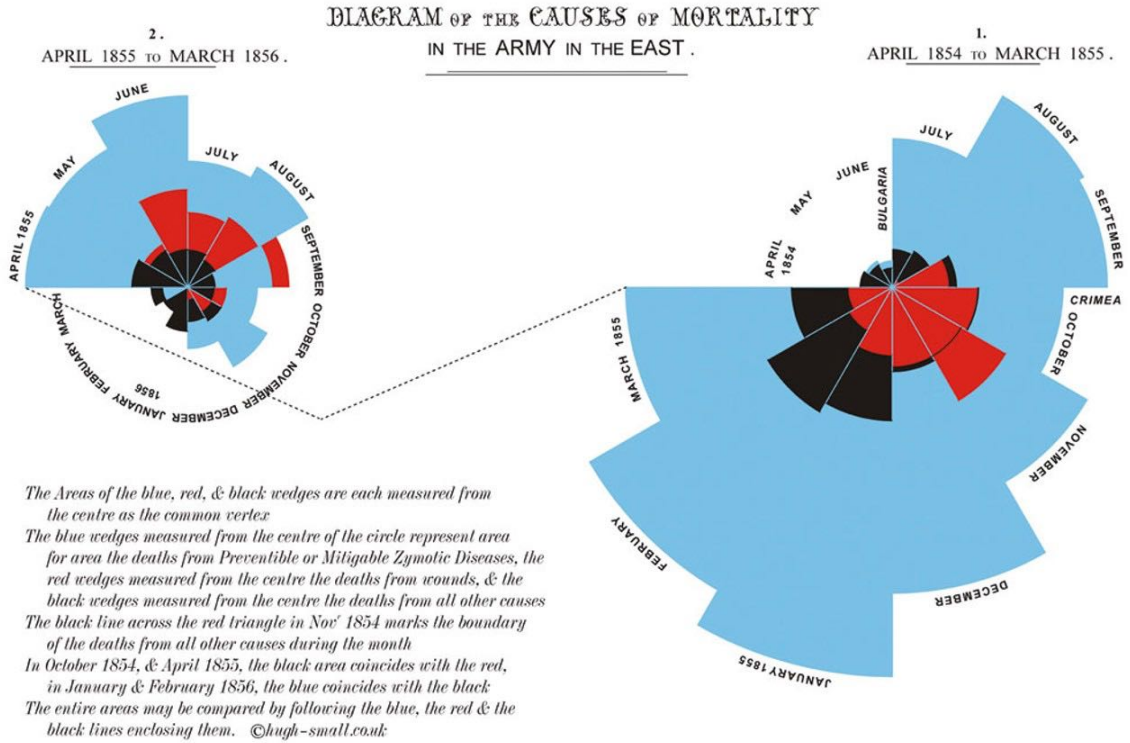
Scientific Visualization

- Type of Data
  - Scientific data (objects exist in 1D, 2D, or 3D space)
  - Often scalar or vector fields from computer simulations
- Primary Purpose
  - Aims to convey scientific data accurately
  - Aims to reveal underlying structure in data
  - Aims to encourage exploration of data (interactivity)
  - e.g., climate simulations



Information Visualization

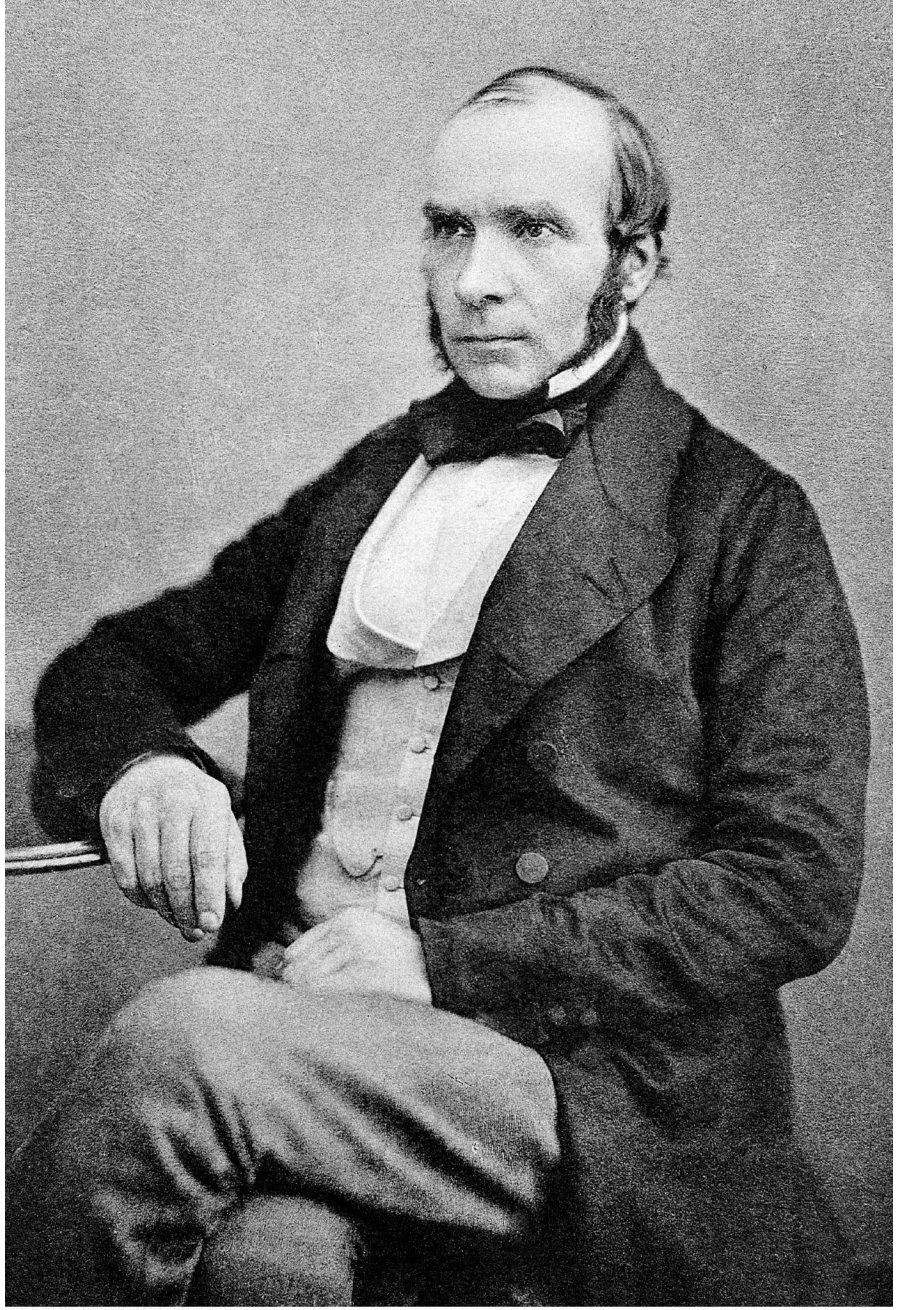
- Type of Data
  - Abstract data (has no inherent physical form)
  - May be numerical, categorical, temporal, geospatial, or text data
- Primary Purpose
  - Aims to convey abstract data accurately
  - Aims to reveal underlying structure in data
  - Aims to encourage exploration of data (interactivity)
  - Aims to display data aesthetically
- e.g., causes of mortality in the army in the East

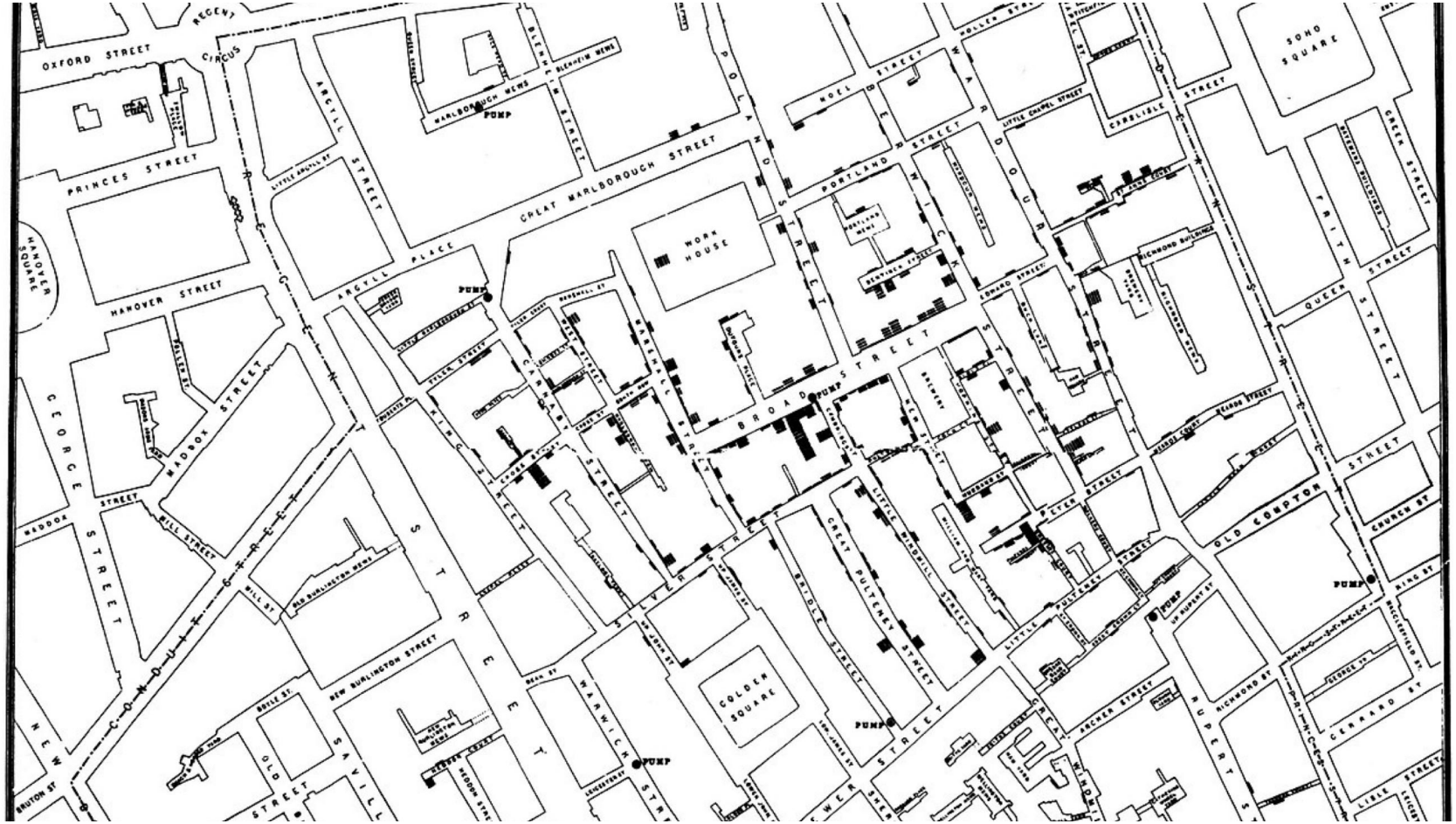


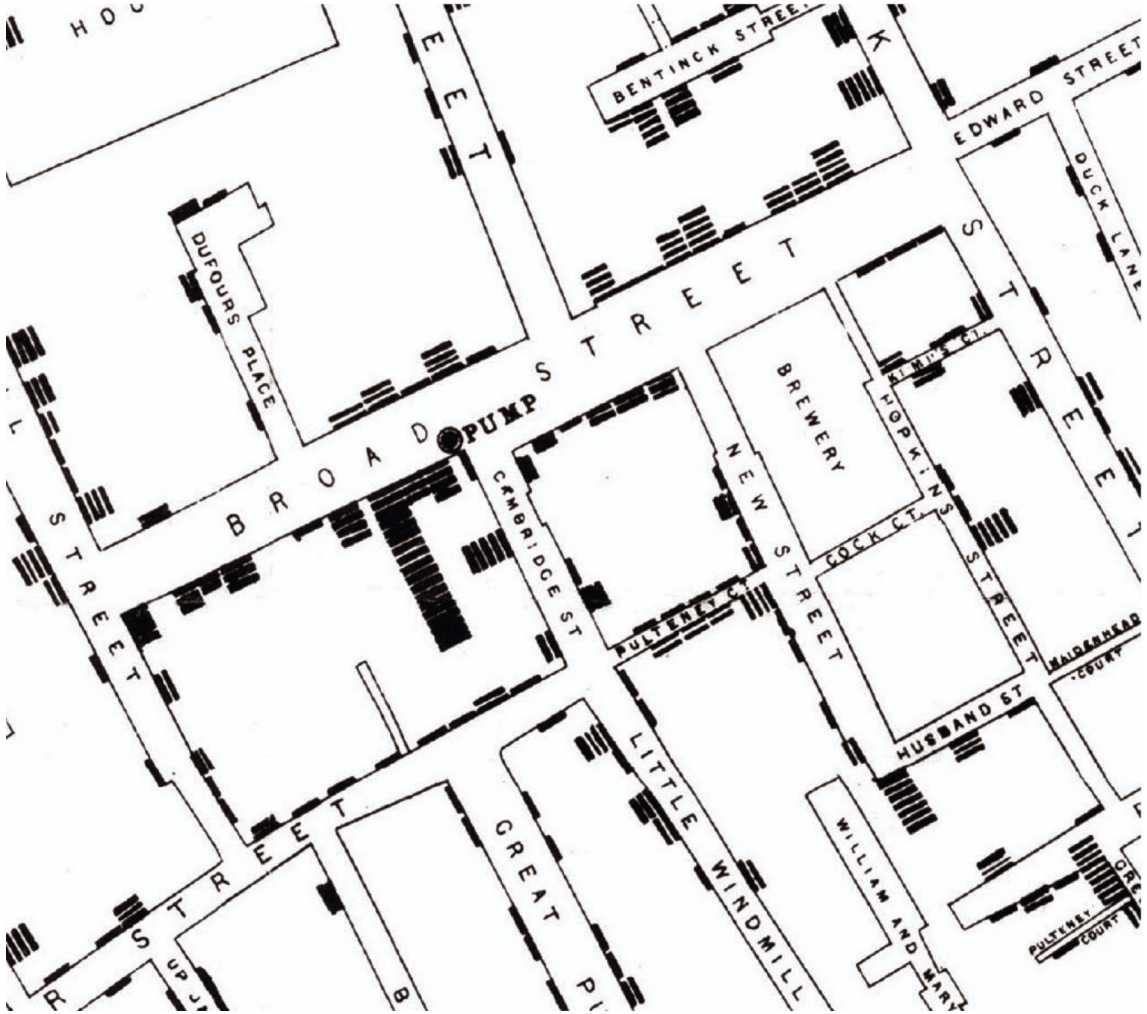
John Snow's Cholera Map

1854 Cholera Outbreak

- Tens of thousands people in England were **dying of cholera between 1831 and 1854**
  - Many assumed cholera was airborne (caused by breathing vapors or a miasma in the atmosphere)
  - People did not have running water or modern toilets
    - John Snow and the Broad Street pump
    - John Snow (1813 - 1858)
- Terrible cholera in Soho, near where physician John Snow lived
- Tracked down data from hospitals and public records
- Created simple plot of where victims lived and location of water pumps




OXFORD STREET
REGENT
CIRCUS
PRINCES STREET
HANOVER SQUARE
HANOVER STREET
GEORGE STREET
MADDOX STREET
ARGYLL STREET
ARGYLL PLACE
GREAT MARLBOROUGH STREET
MARLBOROUGH MEWS
PUMP
WORK HOUSE
POLAND STREET
PORTLAND STREET
NOEL STREET
SOHO SQUARE
CARLISLE STREET
BROAD STREET
BROWNLOW STREET
NEW COMPTON STREET
QUEEN STREET
OLD COMPTON STREET
CHURCH ST
KING ST
GERRARD ST
RICHMOND BUILDINGS
RICHMOND MEWS
PETER STREET
GREAT PULTENEY STREET
LITTLE PULTENEY STREET
ARCHER STREET
NEW BURLINGTON STREET
NEW BURLINGTON MEWS
BURLINGTON MEWS
BOYLE ST
BRUTON ST
OLD BURLINGTON STREET
SAVILLE ROW
WARWICK STREET
GOLDEN SQUARE
BRIDGE STREET
NEW STREET
S T R E E T

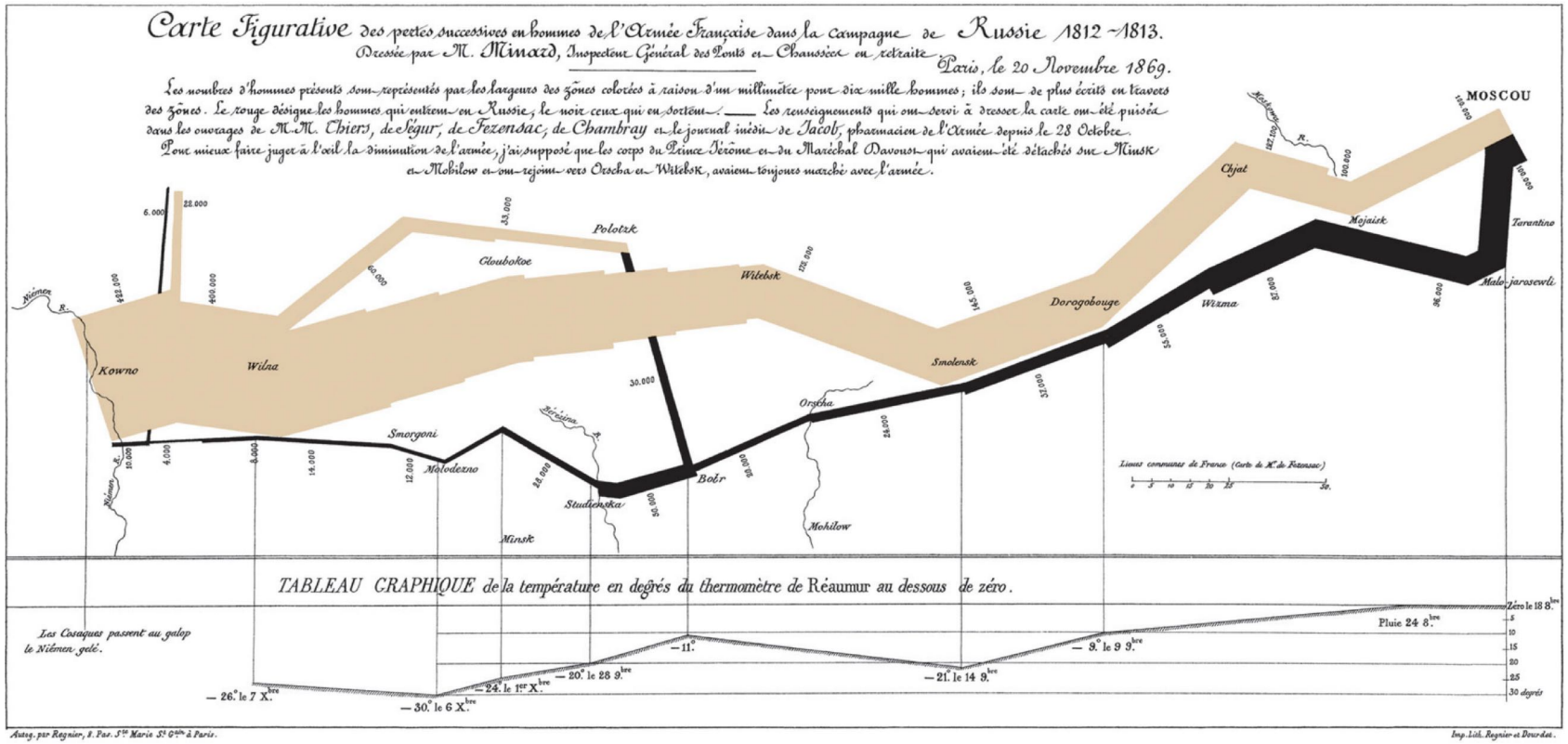

BENTINCK STREET
EDWARD STREET
DUCK LANE
DUFOURS PLACE
BROAD STREET
PUMP
BREWERY
NEW STREET
HOPKINS STREET
COCK CT
CAMBRIDGE ST
FULTENEY CT
HUSBAND ST
MARLBOROUGH COURT
LITTLE WINDMILL
GREAT
WILLIAM AND
FULTENEY COURT

1854 Cholera Outbreak

- Identified contaminated water pump in Broad Street
- Eventually able to trace many cases to “sherbert” a bubbly drink with a fizzy powder mixed in, served from water coming from the Broad Street area pump
- In a broad sense, he pioneered the field of epidemiology.
- It took a while before the policy makers embraced Snow’s intuition.
    - 1883: German physician Robert Koch discovers the bacterium that is the cause of cholera
- Reference:
    - The Ghost Map - TED talk

Probably the best visualization ever created: Joseph Minard 1861

(According to Edward R. Tufte, The Visual Display of Quantitative Information)



Legend

> Figurative chart of the successive losses in men by the French army in the Russian campaign 1812-1813. Drawn up by Mr. Minard, inspector-general of bridges and roads (retired). Paris, 20 November 1869.

> The **number of men** present is symbolized by the **broadness of the colored zones** at a rate of one millimeter for ten thousand men; furthermore, those numbers are written across the zones. **The red signifies the men who entered Russia, the black those who got out of it**.

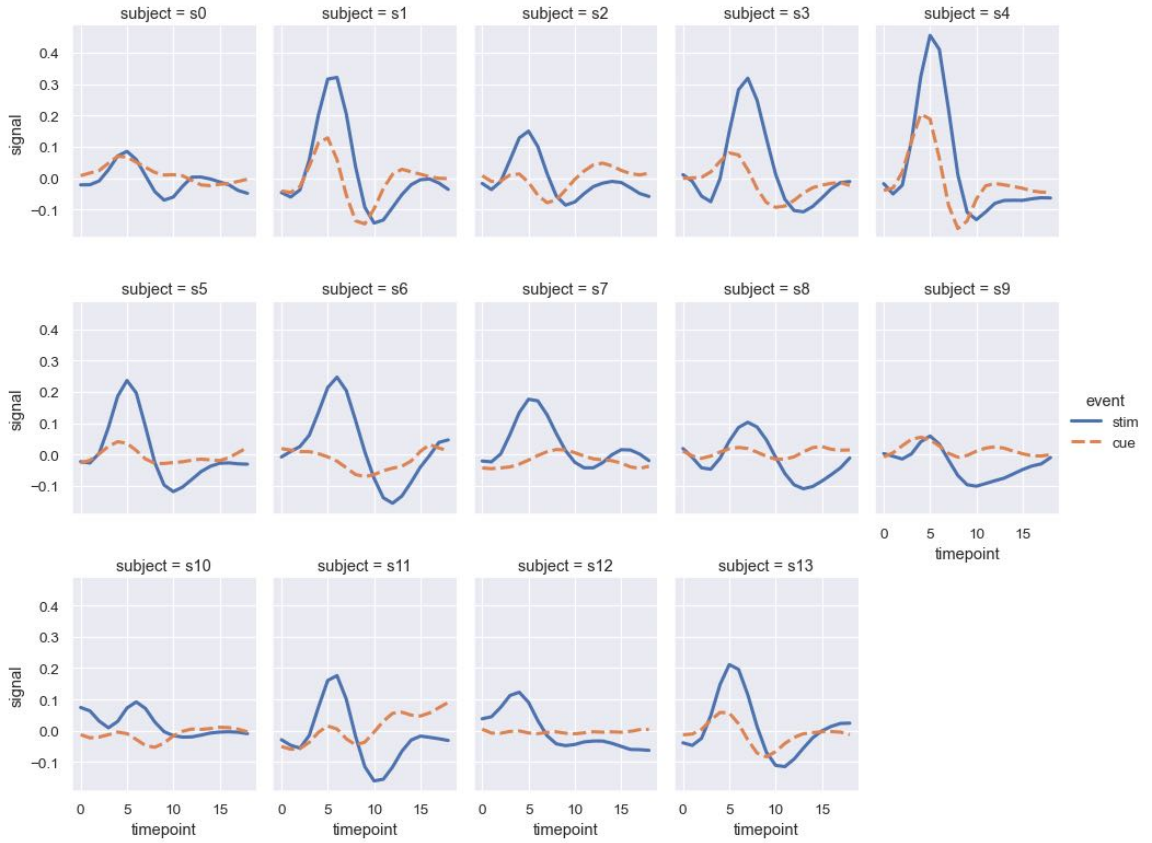
> The data used to draw up this chart were found in the works of Messrs. Thiers, de Ségur, de Fezensac, de Chambray and the unpublished journal of Jacob, pharmacist of the French army since 28 October. To better represent the diminution of the army, I've pretended that the army corps of Prince Jerôme and of Marshall Davousz which were detached at Minsk and Mobilow and rejoined the main force at Orscha and Witebsk, had always marched together with the army.

The Minard Map – "The best statistical graphic ever drawn"

DATAVIZ HISTORY: CHARLES MINARD'S FLOW MAP OF NAPOLEON'S RUSSIAN CAMPAIGN OF 1812

Statistical Graphics

- Type of Data
  - Abstract data
  - Mostly statistical, quantitative, or numerical data
- Primary Purpose
  - Aims to convey data accurately
  - Aims to convey underlying structure in data
- Not Emphasized
  - May not be aesthetically pleasing
  - May not encourage exploration or be interactive
- e.g., time series



Visual Analytics

- Type of Data
  - Abstract data
- Primary Purpose
  - Aims to answer a specific question (goal-oriented)
  - Aims to support analytical reasoning with interactive visual interfaces
  - Aims to facilitate human-data interaction, enabling the discovery of patterns, anomalies, or insights that may not be immediately apparent
  - Stronger emphasis on processing and analysis rather than presentation
- Not Emphasized
  - May not be aesthetically pleasing
  - May not be constrained by a single display
- e.g., omni sci

omni·sci DASHBOARDS DATA MANAGER HELP Start the Walk-Thru

Filter set: Cases and Spread - Glob...

Global Confirmed COVID-19 Cases and Spread

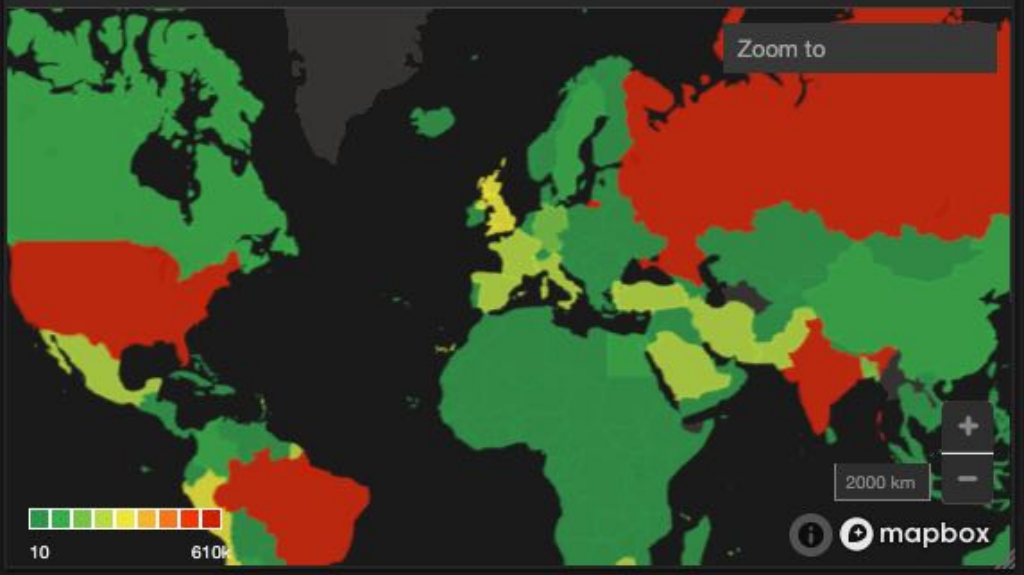
covid_daily_global · 34,356 of 34,356

Refresh + Add Chart

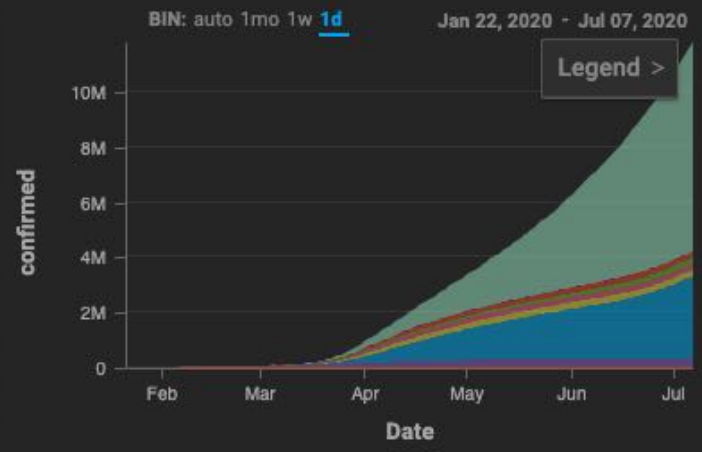
See Data for US States (Source - COVID19 Tracking Project)

Confirmed	Deaths	Daily Case Growth	Mortality (%)
11,829,603	544,163	0.16%	4.60%

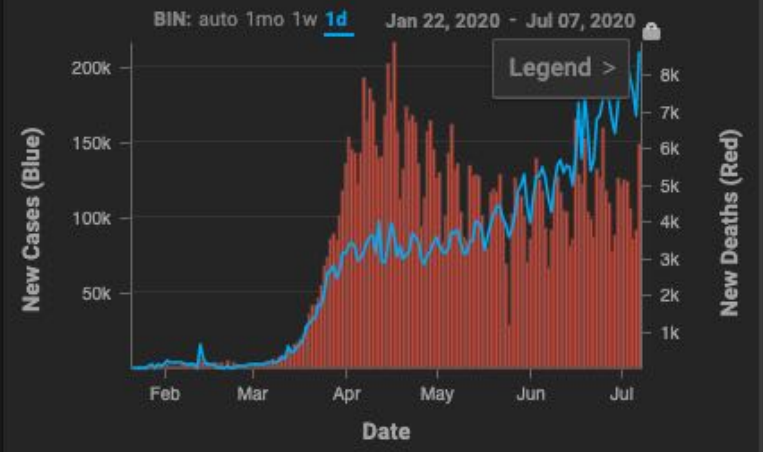
Total Confirmed by Country



Total Confirmed Cases by Day



New Cases (Blue) and Deaths (Red) by Day



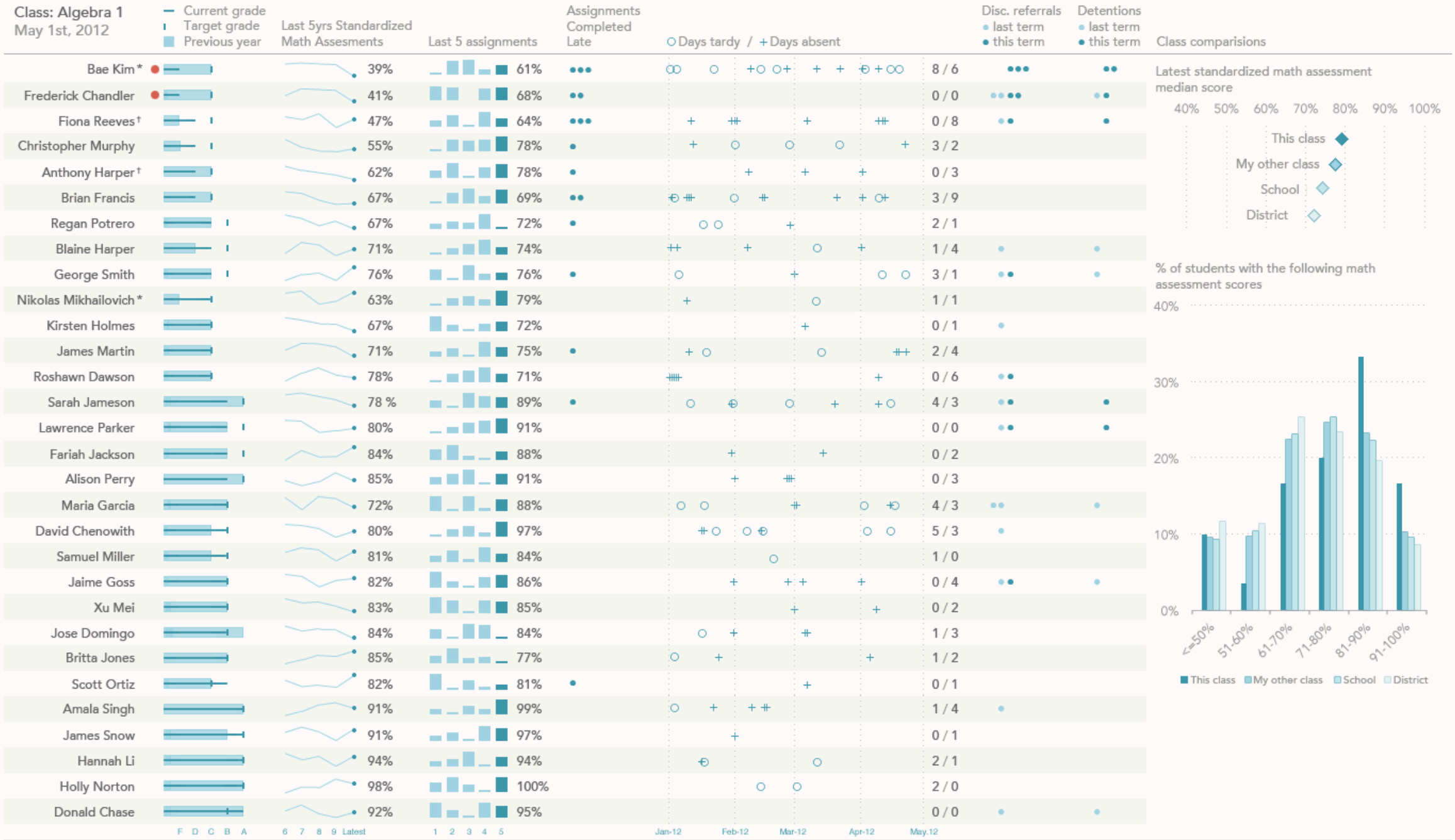
Country Statistics

country_region	Total Confirmed	Total Deaths	Mortality Rate (%)
United States	2,996,098	131,480	4.3
Brazil	1,668,589	66,741	3.9
India	742,417	20,642	2.7
Russian Federation	693,215	10,478	1.5
Peru	309,278	10,952	3.5

Daily Cases Growth (%) by Country

Information Dashboards

- Type of Data
  - Abstract data
  - Temporal data or time series
- Primary Purpose
  - Aims to provide at-a-glance views of key metrics relevant to a particular objective or business process
  - Aims to enable quick, informed decisions, often in a business or operational context.
  - Aims to convey outliers and trends
- Not Emphasized
  - May be extremely dense
- e.g., dashboard



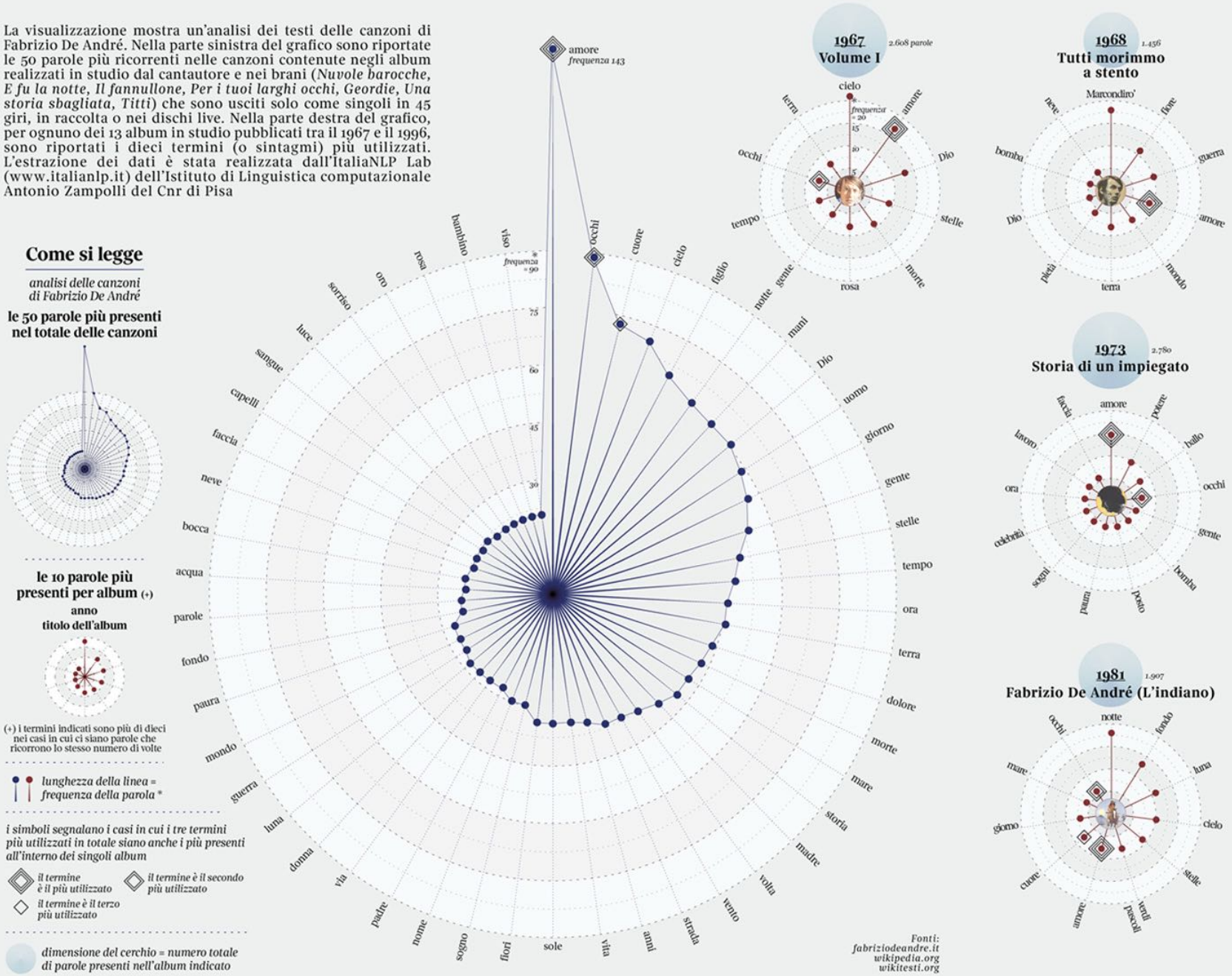
* No english language proficiency † Special education

Note: Assessment and assignment scores are being expressed as the percentage of points that were earned out of the total points possible.

Infographics

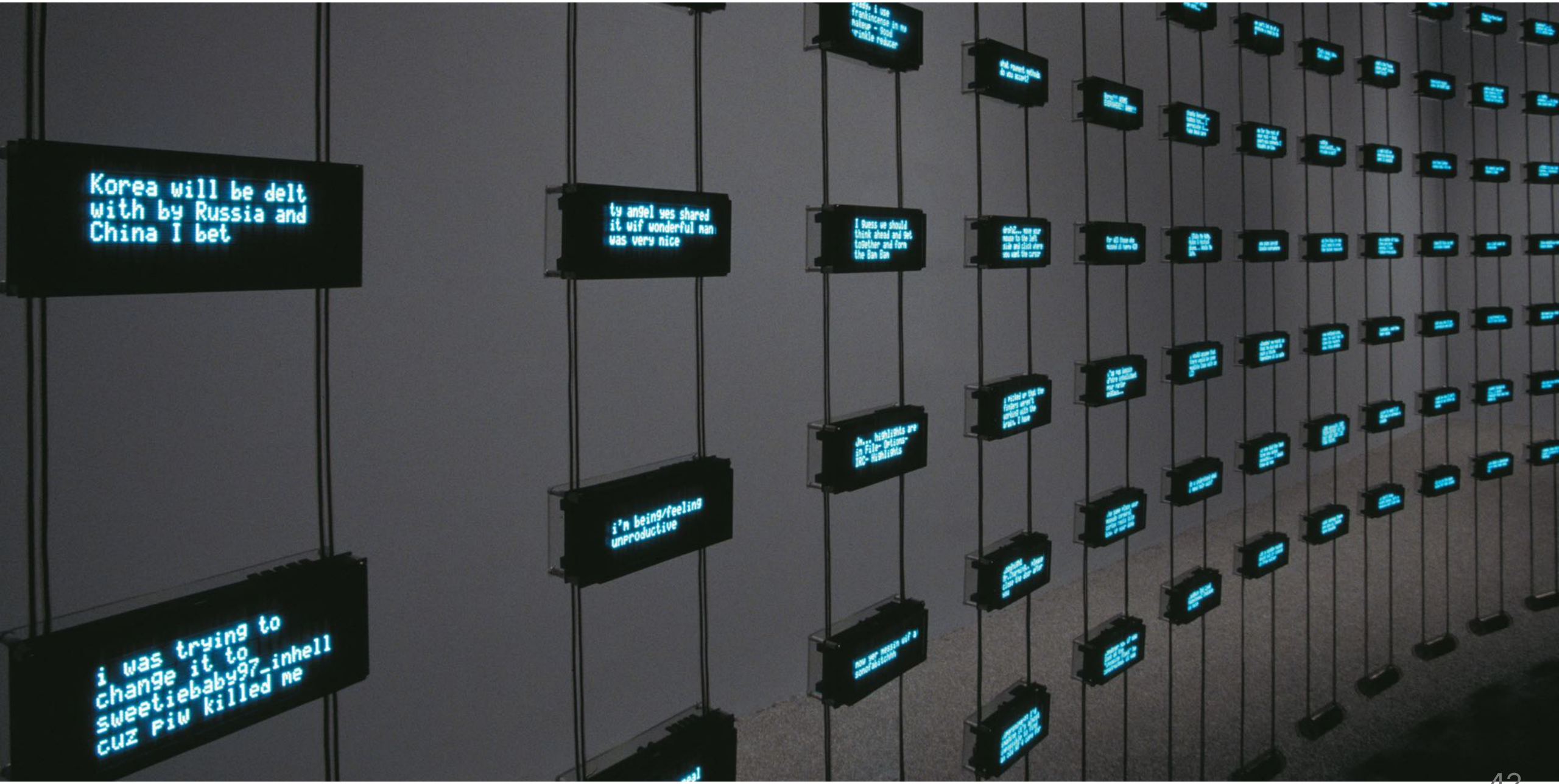
- Type of Data
  - Abstract data
- Primary Purpose
  - Aims to be eye-catching, capture attention, easy to understand (general audience)
  - Aims to convey information quickly (mainly static)
  - Often for educational or marketing purposes
  - It is less about data exploration and more about data presentation
- Not Emphasized
  - May not be accurate
  - May not use space efficiently
  - May not encourage exploration of data
- e.g., Analisi delle canzoni di De André

La visualizzazione mostra un'analisi dei testi delle canzoni di Fabrizio De André. Nella parte sinistra del grafico sono riportate le 50 parole più ricorrenti nelle canzoni contenute negli album realizzati in studio dal cantautore e nei brani (*Nuvole barocche, E fu la notte, Il fannullone, Per i tuoi larghi occhi, Geordie, Una storia sbagliata, Titti*) che sono usciti solo come singoli in 45 giri, in raccolta o nei dischi live. Nella parte destra del grafico, per ognuno dei 13 album in studio pubblicati tra il 1967 e il 1996, sono riportati i dieci termini (o sintagmi) più utilizzati. L'estrazione dei dati è stata realizzata dall'ItaliaNLP Lab (www.italianlp.it) dell'Istituto di Linguistica computazionale Antonio Zampolli del Cnr di Pisa



Informative Art

- Type of Data
  - Abstract data
- Primary Purpose
  - Aims to make visualization ambient or part of everyday life
  - Aims to provoke thought, convey a narrative, or evoke emotional responses from the audience
    - It's more about the experience and the message than about the precise analysis or dissemination of data
  - Aims to be aesthetically pleasing and prioritizes aesthetic value and interpretive possibilities over straightforward data interpretation
- Not Emphasized
  - May not be informative
  - May not be eye-catching
- e.g., Listening Post


Korea will be delt with by Russia and China I bet
ty angel yes shared it vif wonderful nan was very nice
I Russ we should think ahead and get together and form the Dan Dan
i'n being/feeling unproductive
i was trying to change it to sweetiebaby97_inhell cuz PiW killed me

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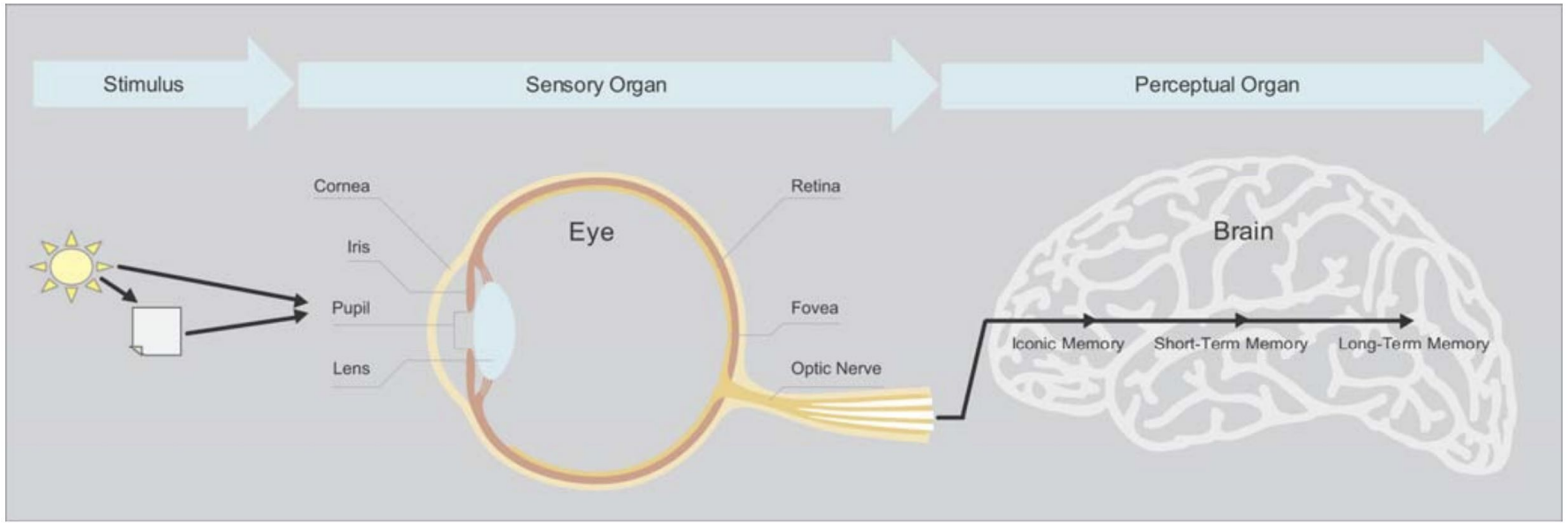
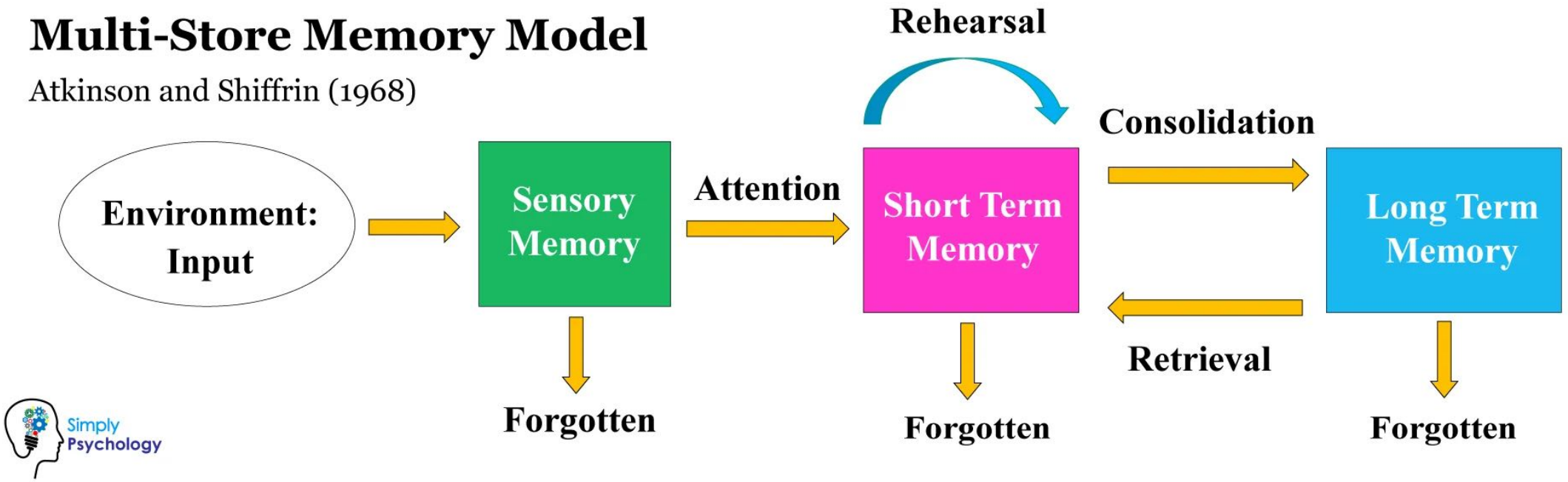
Visual Perception

Visual perception system

- **Human perception plays a fundamental role in the area of visualization**
- An understanding of perception can significantly improve both the quality and the quantity of information being displayed



Atkinson–Shiffrin memory model



- The original model has been criticized and refined along several dimensions
  - e.g., [Raaijmakers, Jeroen G. W. (1993). The story of the two-store model of memory: past criticisms, current status, and future directions]

Sensory Memory (SM)

- Temporarily stores **sensory information from the environment** and **retains impressions after the original stimulus has ceased**.
    - e.g., sights, sounds, and other sensory inputs
- The sensory information is being taken in by **sensory receptors** and **processed by the nervous system**.
- The SM is considered to be **outside of cognitive control** and is instead an **automatic response**
- The information stored in SM is **modality specific**
    - e.g., **iconic memory** (vision), **echoic memory** (hearing), **haptic memory** (taste)
- **High capacity**, **high resolution**, but **very brief retention time**

Short-term store (also short-term memory or working memory)

- Holds information **currently in use or being processed**
- **Limited capacity** (typically thought to be around 7±2 items)
- **Short duration** (lasting about 15-30 seconds unless the information is actively rehearsed)
- Where **conscious thought processes** such as reasoning and decision-making occur
- Information can be lost through **decay** or **displacement by new information**

Long-term store (also long-term memory)

- Potentially unlimited capacity to store information over long periods, ranging from minutes to a lifetime
- Transferred from short-term memory through processes like **rehearsal**, **encoding**, and **consolidation**
- Divided into **explicit (declarative)** memory, e.g., facts and events, and **implicit (non-declarative)** memory, e.g., skills

Iconic Memory

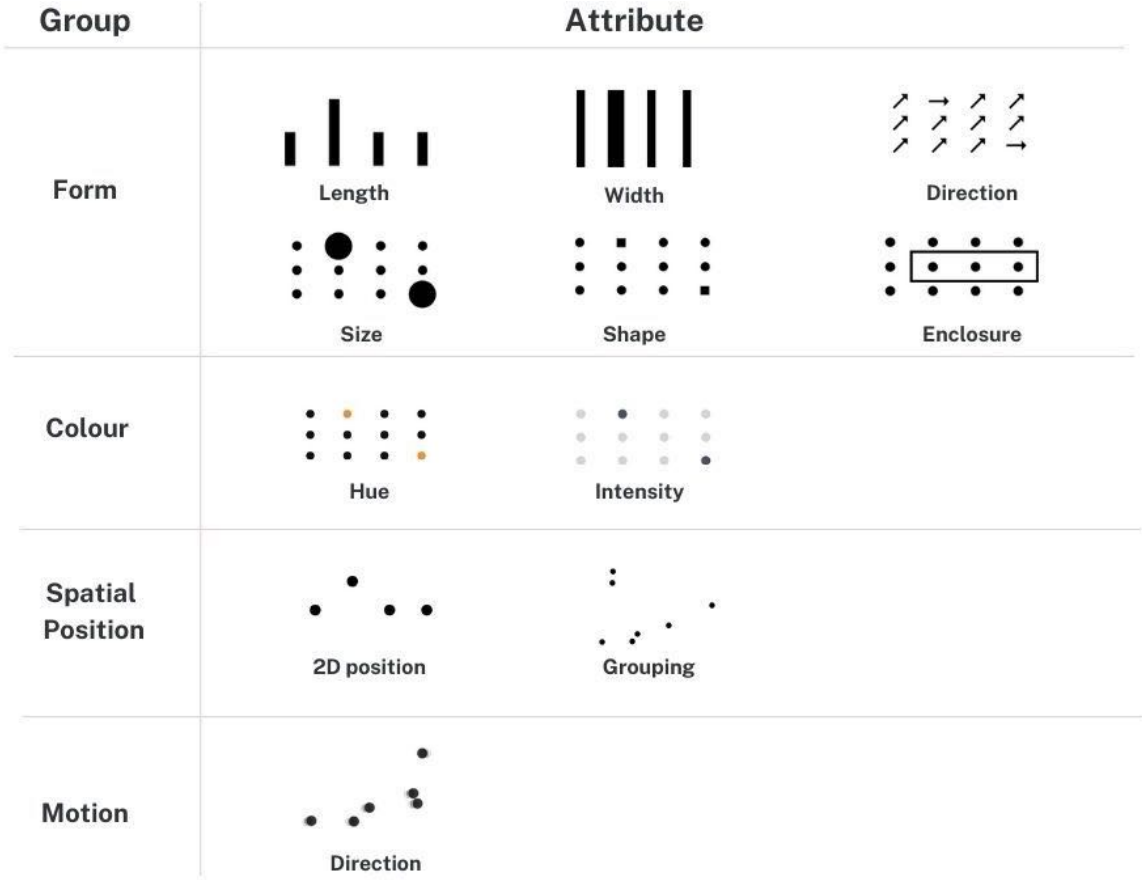
- **Visual** sensory memory register of the visual domain and a fast-decaying store of visual information.
- It involves the **brief** retention of a visual image **after the exposure to the actual visual stimulus has ended**
  - transferred to short-term memory or lost.
- Enables the brain to process visual information from the environment as a **continuous stream**, despite the rapid eye movements (**saccades**) and brief visual interruptions that occur
- Characteristics:
  - **Very brief (100-200 ms)**
  - **High-capacity**
  - Integration of sequential visual stimuli into a **coherent scene**
    - important for pattern recognition, reading, and the perception of motion
- Iconic memory assists in accounting for phenomena such as:
  - **Change blindness**

Change Blindness

- Inability to detect differences in two successive scenes separated by a very brief blank interval, or **interstimulus interval**
- Difficult to see visual changes when our vision is interrupted
  - Avoid abrupt changes in the interface (show animations, highlight changes)

Pre-attentive attributes

- Visual properties that are **detected very rapidly** and **accurately** by the low-level visual system **without conscious effort** in the very first stage of visual perception
- Four main categories:
  - **Form**
  - **Colour**
  - **Spatial Position**
  - **Motion**
- When mapping data to pre-attentive attributes, the designer must pay attention to **interferences**
  - Consider the short-term memory effect

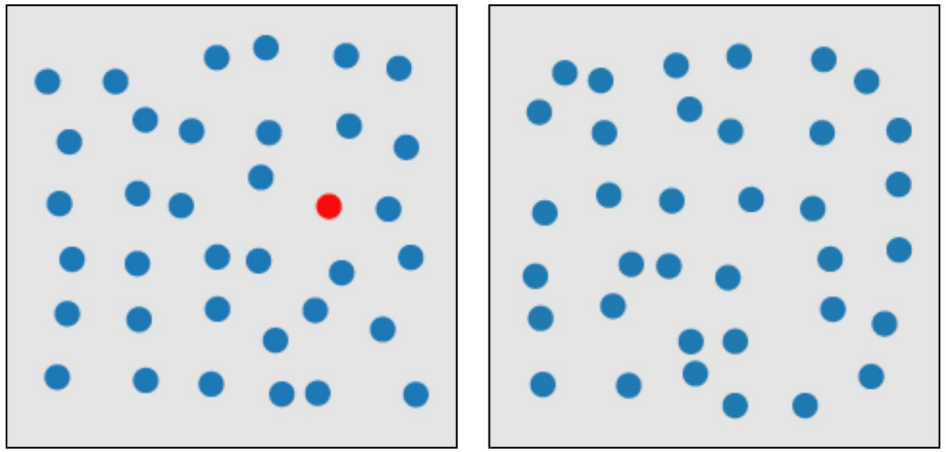


Pre-attentive Visual Tasks

- **target detection:** users rapidly and accurately detect the presence or absence of a **target** element with a unique visual feature within a field of distractor elements
- **boundary detection:** users rapidly and accurately **detect a texture boundary** between two groups of elements, where all of the elements in each group have a common visual property
- **region tracking:** users 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

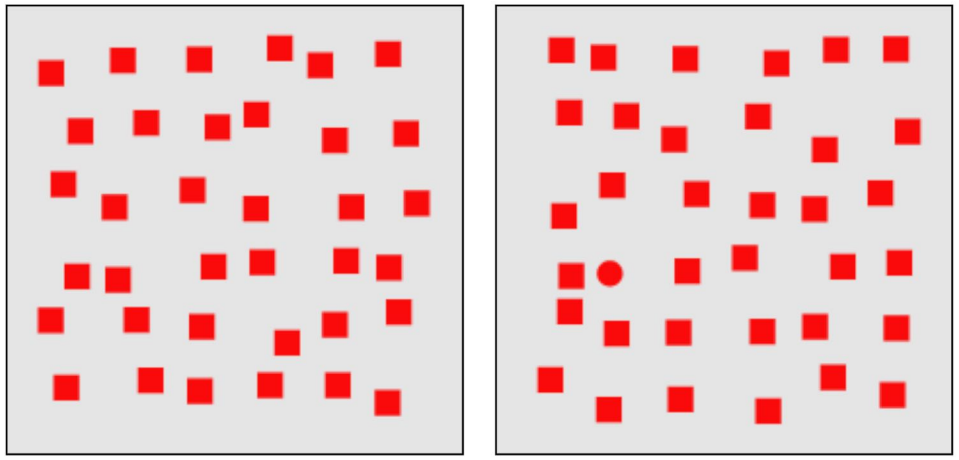
Target detection

- An example of searching for a **target red circle** based on a difference in hue
- The visual system identifies the target through a difference in hue, specifically, a red target in a sea of blue distractors.



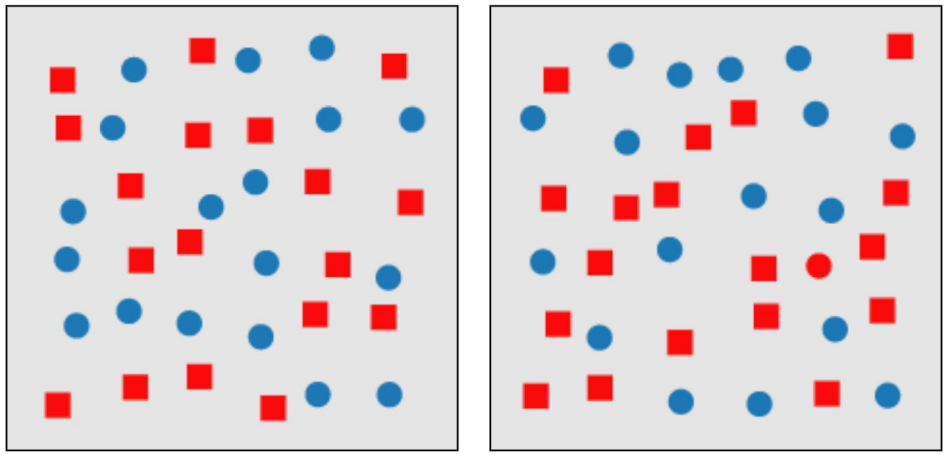
Target detection

- An example of searching for a **target red circle** based on a difference in shape
- In this case, the **distractors are the red squares**
- A viewer can rapidly and accurately determine whether the target is present or absent.
- The visual system identifies the target through a **curvature** (or form) difference.



Target detection

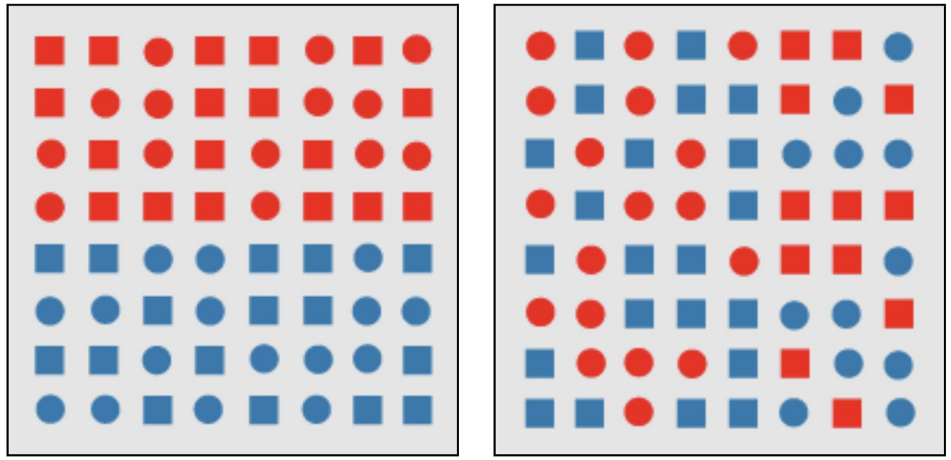
- Example of **conjunction search**
  - The target is made up of **two features**: **red** and **circular**.
- In this case, the **distractors are the red squares**
- One of these features is present in each of the distractor objects (red squares and blue circles)
  - **no unique visual property to search for when trying to locate the target**
- **No pre-attentive detection possible** (interference)



(a) (b)

Boundary detection

- **Figure (a):** a boundary defined by a **unique feature hue** (red circles and red squares on the top, blue circles and blue squares on the bottom)
  - **Preattentively classified as horizontal**
- **Figure (b):** a boundary defined by a **conjunction** of features (red circles and blue squares on the left, blue circles and red squares on the right)
  - **Cannot be preattentively classified as vertical**

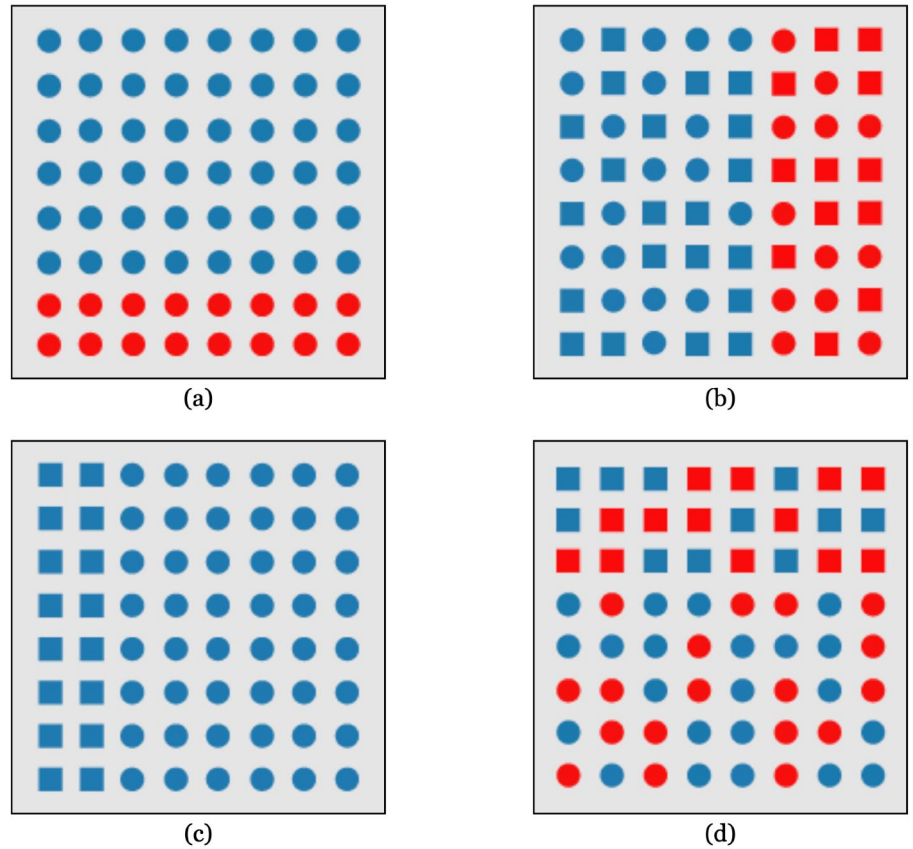


(a) (b)

Boundary detection

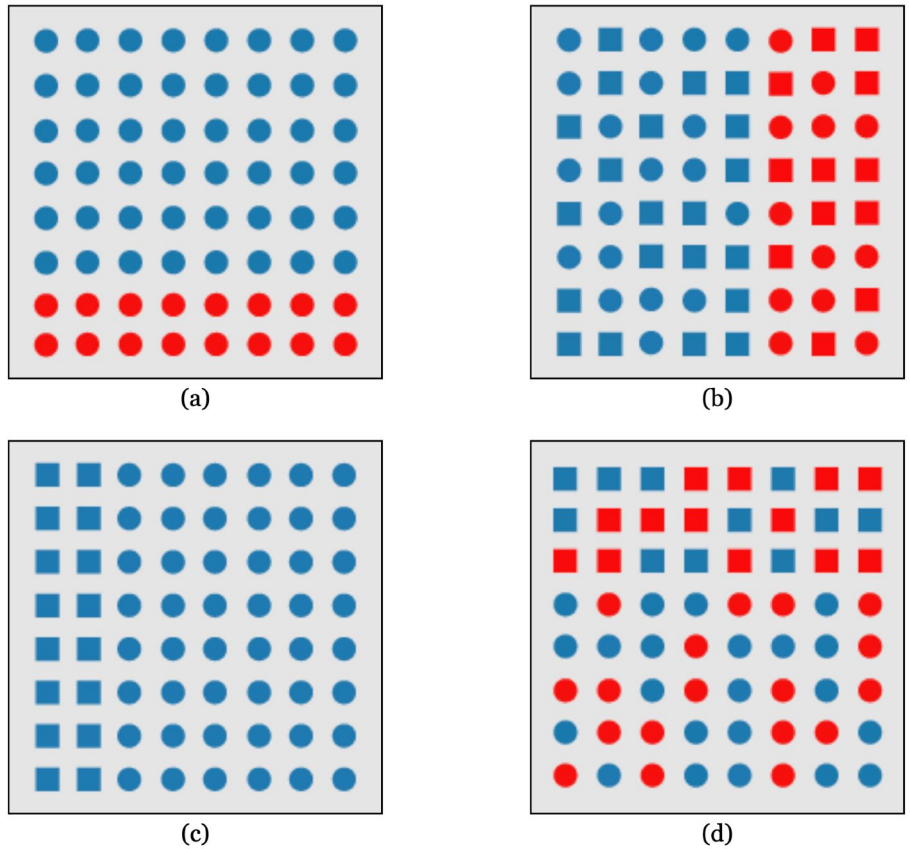
Feature hierarchy

- For certain tasks the visual system seems to **favour one type of visual feature over another**
- For example, during **boundary detection** researchers have shown that the **visual system favours colour over shape**



Boundary detection

- **Figure (a):** a horizontal hue boundary is preattentive identified when form is held constant
- **Figure (b):** a vertical hue boundary is preattentively identified when form varies randomly in the background
- **Figure (c):** a vertical form boundary is preattentively identified when hue is held constant
- **Figure (d):** a horizontal form boundary **cannot** be preattentively identified when hue varies randomly in the background



Counting

How many 3 are present in this sequence?

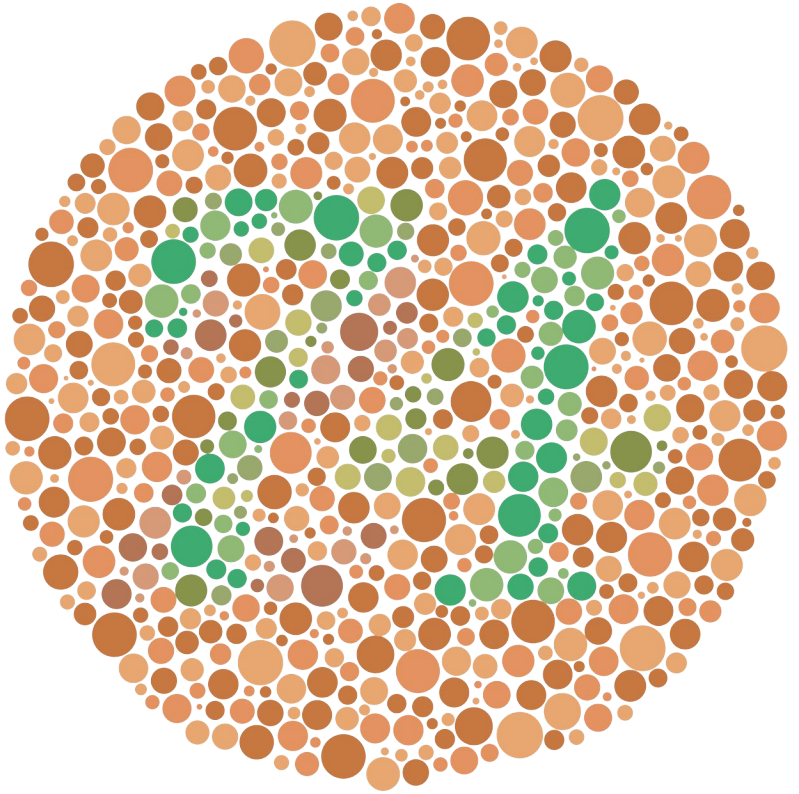
2481348118711671554138819844377134791564153184530584864123475789411484122
2347578941148412223881469161354804840789087707867875121186584234018874276

A different hue helps in identifying the 3 pre-attentively

2481348118711671554138819844377134791564153184530584864123475789411484122
2347578941148412223881469161354804840789087707867875121186584234018874276

Visual Perception and Colour

- Red-green color blindness (daltonism) is very common (8% of adult males)
  - Don’t use only color to highlight differences, or choose colors that are difficult to confuse
  - Ishihara's test
- Colors of different wavelengths are hard to tell apart
  - Don’t use red text on a blue background
- With age, blue becomes harder to read



Gestalt Principles

- Gestalt is German for **unified whole**. German psychologists Max Wertheimer, Kurt Koffka, and Wolfgang Kohler created the **Gestalt Principles** in the 1920s.
- A theory claiming that the perception processing and the mental/cognitive representation of information, process spontaneously (**pre-attentively**) the surrounding phenomena as **groups of structures** (forms), and **not as several discrete elements**
- Gestaltism's philosophy is not the same as Aristotle's saying, *"the whole is greater than the sum of the parts."* In Gestaltism, the whole is **different** and may even be **completely unrelated** to its parts.
- **Laws of Perception (examples)**
  - **Continuity**, **Proximity**, **Similarity**, **Symmetry**, **Closure**, **Good Figure or Pragnanz**
- These laws act at the same time and can be occasionally contradictory

Gestalt laws of perception

Good Figure

Objects groupped together tend to be perceived as a single figure. Tendency to simplify.

Proximity

Objects tend to be grouped together if they are close to each other.

Similarity

Objects tend to be grouped together if they are similar.

Continuation

When there is an intersection between two or more objects, people tend to perceive each object as a single uninterrupted object.

Closure

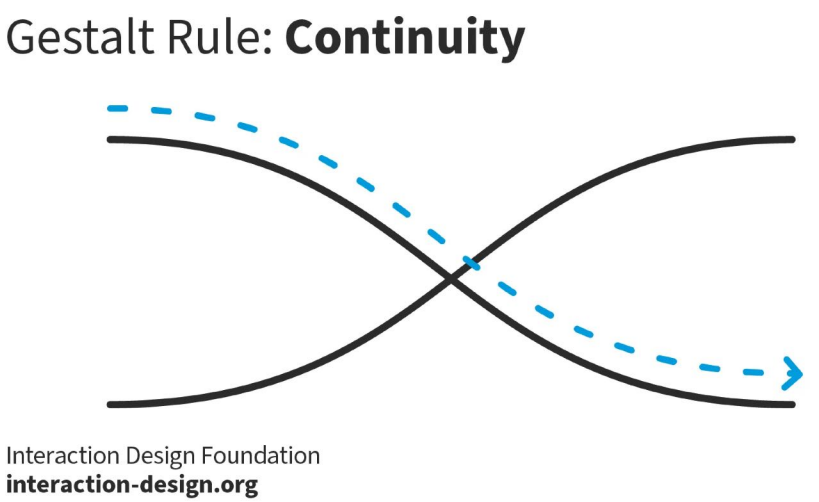
Visual connection or continuity between sets of elements which do not actually touch each other in a composition.

Symmetry

The object tend to be perceived as symmetrical shapes that form around their center.

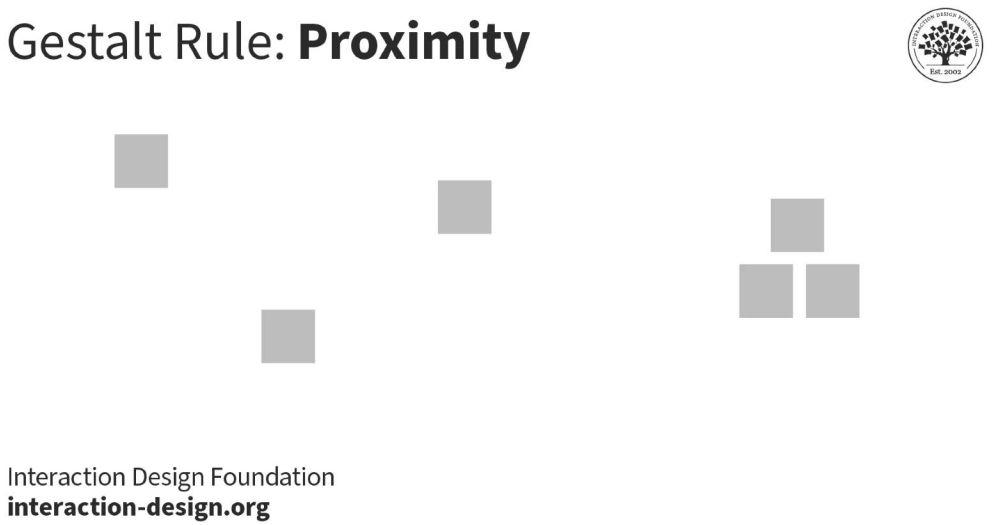
Continuity or Continuation

- We group elements that seem to follow a **continuous path** in a particular direction
- The human eye follows the paths, lines, and curves of a design and prefers to see a continuous flow of visual elements rather than separated objects.
- The human eye continues to follow the path even if an obstacle hides it or its flow is "broken" by interlinking or bisecting visual elements.
- Example:



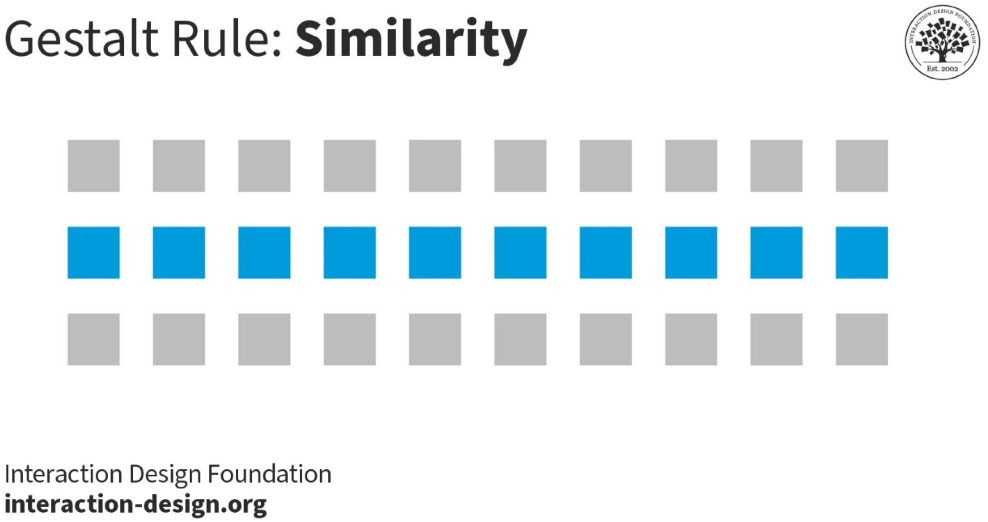
Proximity

- We **group objects first by their proximity** between them
- We group **closer-together** elements, separating them from those farther apart. When you group elements in your design, users will see it as one distinct entity on the screen.



Similarity

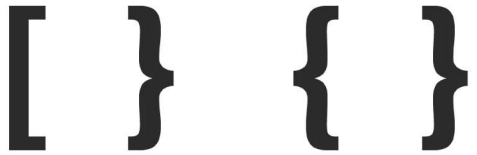
- If distance (proximity) does not allow grouping, we tend to group objects based on their **perceived similarity** in form
- When items, objects or elements **share superficial characteristics**, we perceive them as grouped.
- We can see the similarity principle in branding and design system guidelines.



Simmetry

- Humans tend to see visual elements as **grouped when they are arranged symmetrically**.
- The **natural world is filled with symmetry** (or near symmetry), and our brains favor symmetrical forms (symmetries are aesthetically pleasing).
- Grid systems that evenly divide the space help designers implement symmetry and order in user interfaces.

Gestalt Rule: **Symmetry**



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Closure

- We perceive objects, such as shapes, letters, and pictures, as being **whole** even when they are not complete
- We prefer complete shapes, so we automatically **fill the gaps between elements to perceive a complete image**.
- Example:

Gestalt Rule: **Closure**

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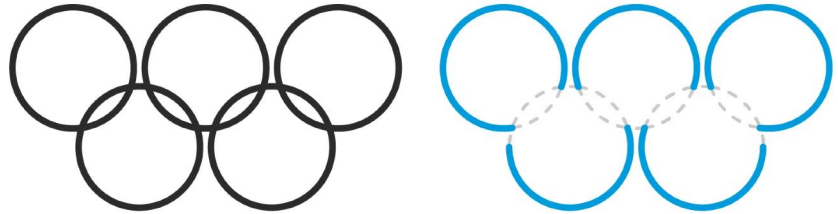
Good Figure or Pragnanz

- Pragnanz describes the human **tendency to simplify complexity**.
- Our environment constantly bombards our senses with stimuli, while we have limited attention and processing capacity to handle all the complexity.
- Pragnanz helps us see order and regularity in a world of visual competition

Gestalt Rule: **Pragnanz**



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Pareidolia

- A psychological phenomenon involving a stimulus (an image or a sound) wherein the mind perceives a **familiar pattern of something where none exists**
- Common examples are perceived images of animals, faces, or objects in cloud formations, the "man in the moon", the "moon rabbit"
- **Not limited to visual stimuli**, it can also occur with auditory stimuli
    - e.g., perceive sounds as familiar, such as hearing voices in random noise or music.
- Often present in **art**
- A subcase of the **apophenia** related to the sensory perception of patterns

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Q&A