COMP5048 – Week 1

Visual analytics is analytical reasoning process facilitated by interactive visualisation system.

Introduction to Visual Analytics

What Is Visual Analytics and Why It Is Needed

Visual Analytics

- Is the science of analytical reasoning ***facilitated by interactive visual interfaces***
- Has an analytical reasoning process carried out by human to derive a decision
- Involves **interaction** with **visual representation** of data that **changes the course of action**
- Aims to reach ***the best/a good decision fast***

Visual Analytics (cont.)

- Is needed in many areas such as:
  - Security (physical, cyber, bio, etc.)
  - Health
  - Financial
  - Environment
  - Education
- Is needed when the decision-makers need to make a good/the best decision fast

Visual Analytics Needs Interactive Visualisation

interact with data

Visualisation
- Converting data to pictures/images

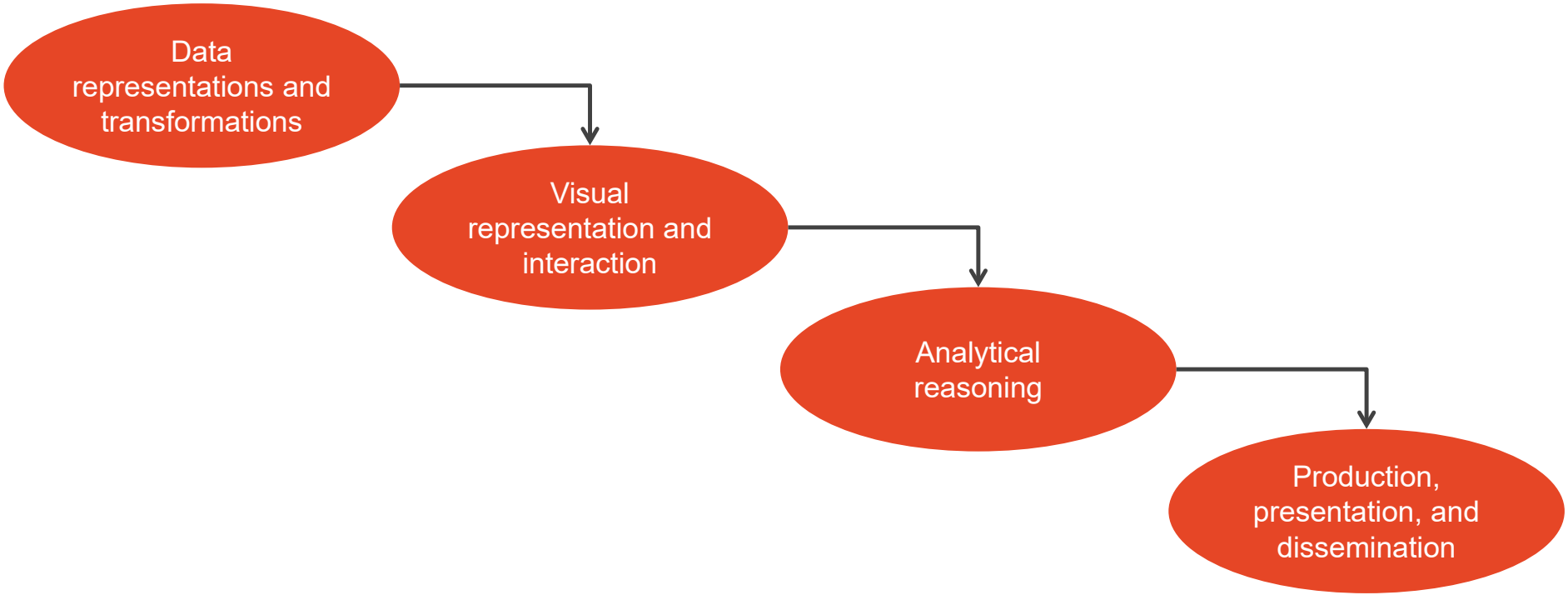
Interaction
- Methods to alter/enhance the visual representation based on a new query

Both need to be:
- Driven by theory-based computational tools
  - Data types, semiology of graphics
- Based on cognitive, design, and perceptual principles
  - Human visual systems, human-computer interaction, gestalt theory

Elements of Visual Analytics

- Analytical reasoning
- Visual representation and interaction
- Data representations and transformations
- Production, presentation, and dissemination

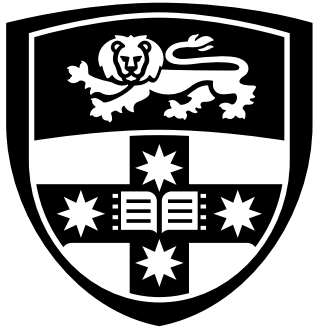
Visual Analytics Pipeline



Conclusion

Visual analytics

- Interactive visual interfaces guides analytical reasoning process
- Encompasses:
  - Analytical reasoning process
  - Visual representations and interactions
  - Data representations and transformations
  - Production, presentation, and dissemination



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Based on the data that you have, you want to understand the past and present by analysing the data.

Analytical Reasoning

Methods to Obtain Deep Insights

Analytical Tasks

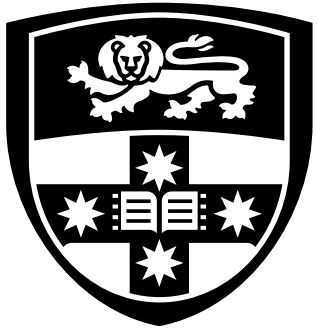
- Understand past and present situation (including trends/events leading to the current situation) ***quickly***
- Ascertain the sign of **alternative** futures and warning signs
- Monitoring of emerging events (including **unexpected** events)
- Etc. (other tasks which influence the decision-making process)

Role of Visualisation in Analytical Reasoning

- Increased resources
- Reduced search
- Enhanced recognition of patterns
- Perceptual inference
- Perceptual monitoring
- Manipulable medium

Conclusion

- Analytical reasoning
  - Assessment
  - Forecast
  - Develop hypotheses/options
- Visualisation facilitates the analytical reasoning process



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Visual Representation and Interaction

Allows to See/Explore/Understand a Lot at Once

Principles for Depicting Information

- Appropriateness principle
  - *The visual representation should provide neither more nor less information than that needed for the task at hand.*
- Naturalness principle
  - *Experiential cognition is most effective when the properties of the visual representation most closely match the information being represented.*
- Matching principle
  - *Effective visual representations should present affordances suggestive of the appropriate action.*
- Principle of congruence
  - *The visual representation should represent the important concepts in the domain of interest.*
- Principle of apprehension
  - *The structure and content of a visualisation should be readily and accurately perceived and comprehended.*

– when representing temperature on your viz, you should use blue for cooler temps and red for hotter temps

E.g. Governance should be visualised in a hierarchy

Designing Visualisation

- Bertin (French cartographer) developed a system for characterising visual representations (semiology of graphics)
- Semiology of graphics has been used to define various design spaces
  - Mackinlay (1986), MacEachren (1995), etc.
- Taxonomies of visual techniques
  - Shneiderman (1996), Spence (2000), Ware (2000)

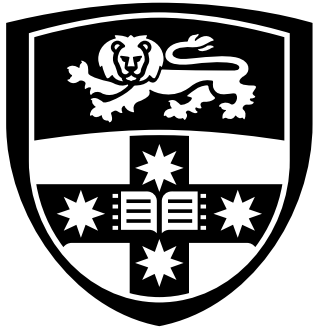
Interaction in Visualisation

- Filtering: modifying data transformation through interaction
- Visual mapping: modifying visual representation through interaction
- Navigation: moving through data space through interaction
  - Selection, panning, zooming, etc.
- Human-info discourse: analytical process through interaction
  - Interactions for comparing, categorising, extracting, and recombining data
  - Creating/testing hypotheses and annotating data

seen a lot in Tableau

Conclusion

Theoretically founded visual representation and interaction design leads to effective analysis. ✓✓



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Data Representations and Transformations

Convert Data Into Forms That Facilitate Analytical Process

Data Representations

Transform data you obtained into a visual representation.

- Structured forms suitable for computer-based transformations
  Data types etc...
- Original structures might not be easily mapped to visual representations
  - May require transformation ✓ Char to integer, one-hot encoding for e.g.
- Data representation may influence the design of interactive visualisation ✓

Characteristics of Data Representations

- Data type
  - Numeric (numbers) vs non-numeric (text/language)
- Levels of structure
  - Structured (easy to computationally represent) vs unstructured (human usually interpret)
  - Text, image, video
- Geospatial
  - Georeferenced numeric (physical measurement) vs non-numeric data (e.g. political boundaries)
- Temporal
  - Data may change over time

Data Transformations

- When the original data representation is not appropriate for visualisation
- Data may need to be converted into different representations
  - To structured
  - So that they are easily mapped to visual representations
  - Based on a mathematically defined conversion process
- Examples
  - High-dimensional data to low-dimensional data (easy to display on the screen/paper)
  - Derive statistical characteristics of the data
  - Applying computational linguistic analysis, etc.

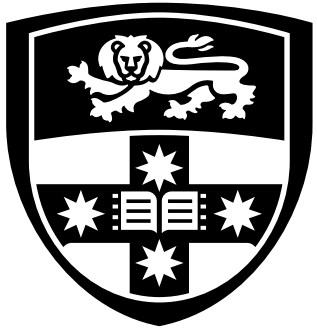
→ dimensionality reduction, PCA etc. Recall COMP9417

avg, median of large dataset.

Conclusion

If it’s necessary, the original data should be transformed into different representations so they are:

- Easily mapped to better visual representations
- Suitable to be manipulated through interactive interfaces



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Production, Presentation, and Dissemination

Present and Consume Visual Analytics Results

Production

- It is the process of summarising the results obtained through the analytical processes.
- All the processes and configuration of tools/applications are finalised.
  - You can repeatedly produce the same result by applying the same process.

Presentation

All the results produced by the “production” process are packaged together to form a contextualised artifact meaningful to the target audience.

Data story-telling...

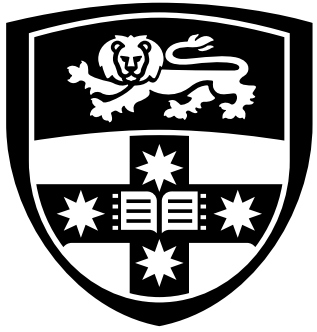
Dissemination

Packaged presentation needs to be efficiently shared and circulated among all the relevant parties.

Conclusion

Production, presentation, and dissemination aim to inform a wide variety of audiences (including decision-makers and even the public) about the analytical results in efficient manner.

key stakeholders



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Human Visual Information Processing Stages

Human Perception

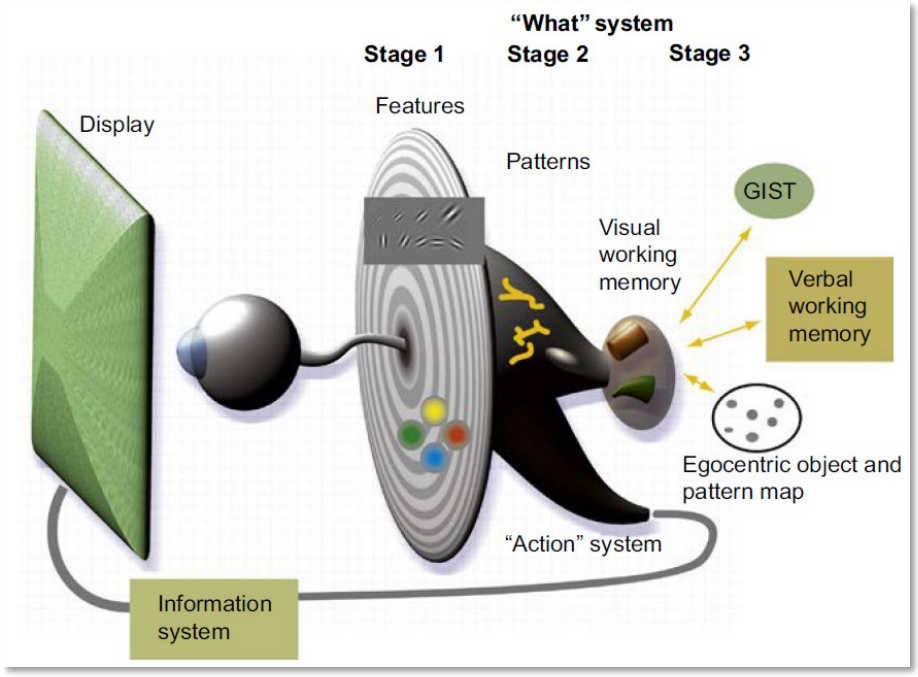
- Interpretation of sensory inputs
  - Visual
  - Auditory
  - Tactile
  - Olfactory
  - Taste
- Visualisation ... just “visual sensory inputs”?

In some occasions we do use other sensory inputs.

E.g. using tactile sensory inputs for visually-impaired people

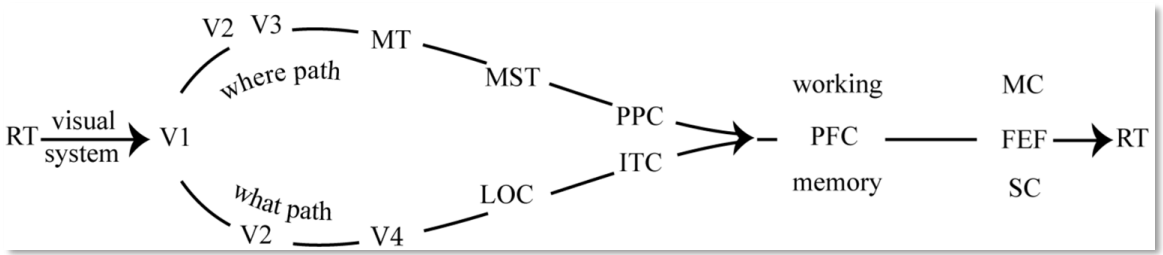
Human Visual Information Processing Model by Colin Ware

- Stage 1: parallel processing to extract low-level properties of the visual scene
- Stage 2: pattern perception
- Stage 3: visual cognition



Ware, C. (2013). *Information visualization: Perception for design*. Elsevier Science.

Basic Visual Information Processing Sequences

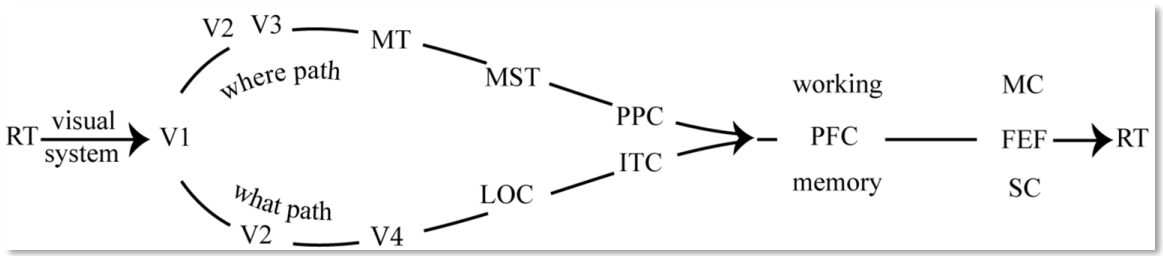


	Description		Description
RT	Retina	ITC	Inferotemporal cortex
V1-V4	Visual cortices	PFC	Prefrontal cortex
LOC	Lateral occipital complex	MC	Motor cortex
MT	Middle temporal area	FEF	Frontal-eye-field
MST	Medial superior temporal area	SC	Superior colliculus
PPC	Posterior parietal cortex		

- Eriksen, C.W., & Hoffman, J. (1973). The extent of processing noise elements during selective encoding from displays. *Perception and Psychophysics*, *14*, 155–160.
- Treisman, A., & Gelade, G. (1980). A feature integration theory of visual attention. *Cognitive Psychology*, *12*, 97–136.
- Allen, R. J., Baddeley, A. D., & Hitch, G. J. (2006). Is the binding of visual features in working memory resource demanding?" *Journal of Experimental Psychology*, *135*, 298–313.
- Ungerleider, L., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of visual behaviour* (pp. 549–586), MIT Press.

what we see ← The path ← Our brain has 2 paths when processing information

Basic Visual Information Processing Sequences (cont.)



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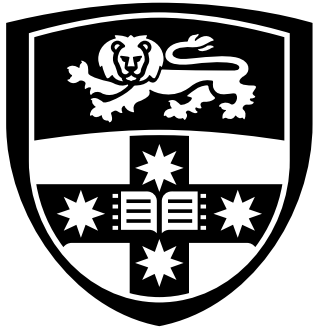
- Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends Neuroscience*, *15*, 20–25.
- Webster, M. J., & Ungerleider, L. G. (2000). Neuroanatomy of visual attention. In R. Parasuraman (Ed.), *The attentive brain* (pp. 19–34), MIT Press.

Variables vs Brain Areas

Potential ordered variables	V1	V2	V3	V4	Brain LOC	Areas MT	MST	ITC	PPC	PFC
Size			X							
Texture				x						
Value		X								
Contour (width)	X	X		X						
Resolution (blur)	x									
Crispness (blur)	x									
Transparency (blur)	x									
Colour saturation			X			X				
Colour hue		X	X	X						
Orientation			X	x		x				
Shape		x		x	x			x		
Flicker (motion)		x								
Velocity (motion)						x	x			
Direction (motion)			x			x	x			
Rotation (motion)							x			
Radial flow (motion)							x			
Contraction (motion)							x			
Implied motion		x					x			
High-level functions										
Configures spatial relations						x			x	
Shifts attention									x	
Omits visual distractors								x	x	
Filters information								X	X	
Initiates visual motor tasks									x	
Represents salient cues				x				X	X	
Tunes contour features				x						
Orientates angles, curves				x						
Distinguishes between objects				x				x		
Segregates figure from ground	X	X		X					X	
Recognises patterns			x					x		
Recognises shapes				x				x		
Recognises objects				x				x		
Updates information in WM								x		x
Stores information in WM								x		x
Selects information from WM										X
Monitors motor-output in WM										X



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Data-Driven vs Concept-Driven Stages

Data-Driven

“Template” scheme

- From given data, try to find a known template.

Concept-Driven

Conceptually-driven process

- Start with a given concept.
- Try to make sense of data based on the concept.

Competing Organisation:
Data-Driven to Concept-Driven, Example I

Even though we might not concretely know what this image is... our brain will still try to interpret it.

Gregory, R. L. (1970). *The intelligent eye.* Weidenfeld & Nicolson.

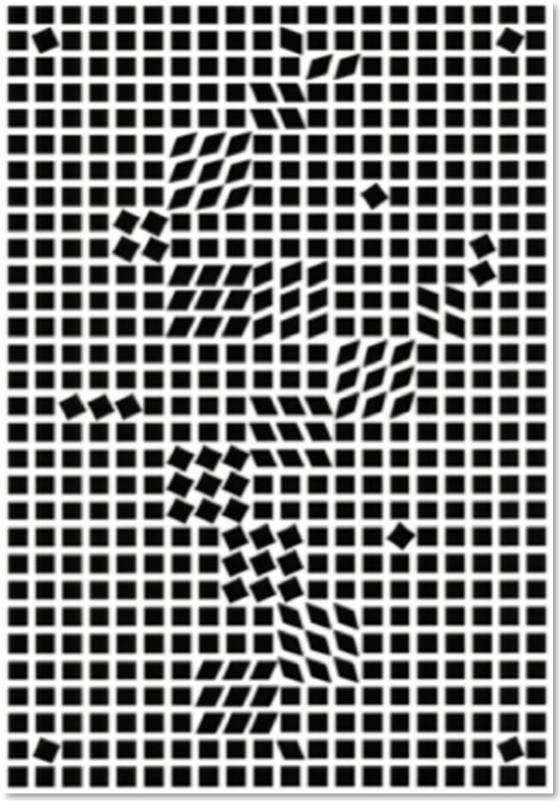
Competing Organisation:
Data-Driven to Concept-Driven, Example II

My Wife and My Mother-in-Law (1915) by William Ely Hill

Competing Organisation:
Data-Driven to Concept-Driven, Example III

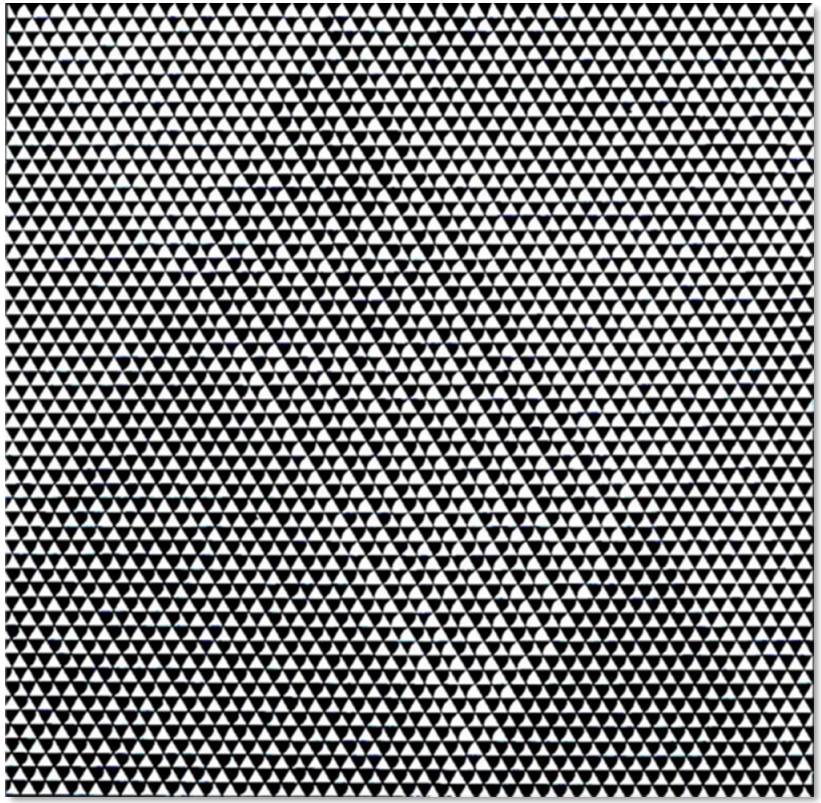
Slave Market With the Disappearing Bust of Voltaire (1940) by Salvador Dalí

Data-Driven: No Meaning Attached, Example I



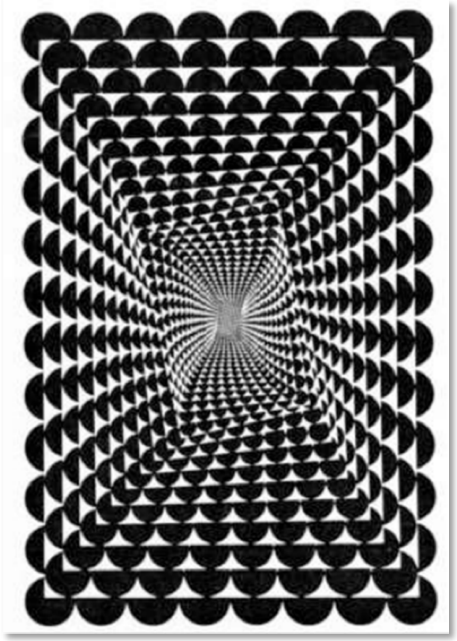
Tlinko, C.1955. Serigraph by Victor Vasarely

Data-Driven: No Meaning Attached, Example II



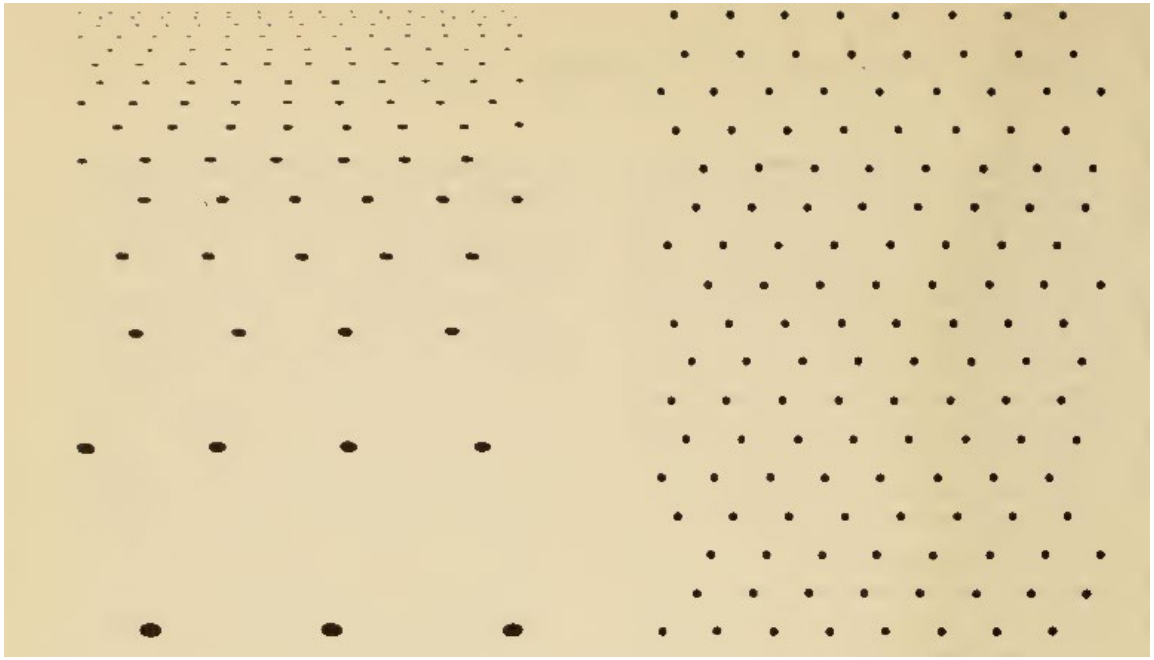
Tremor (1962) by Bridget Riley

Concept-Driven: Spatial Awareness, Example I



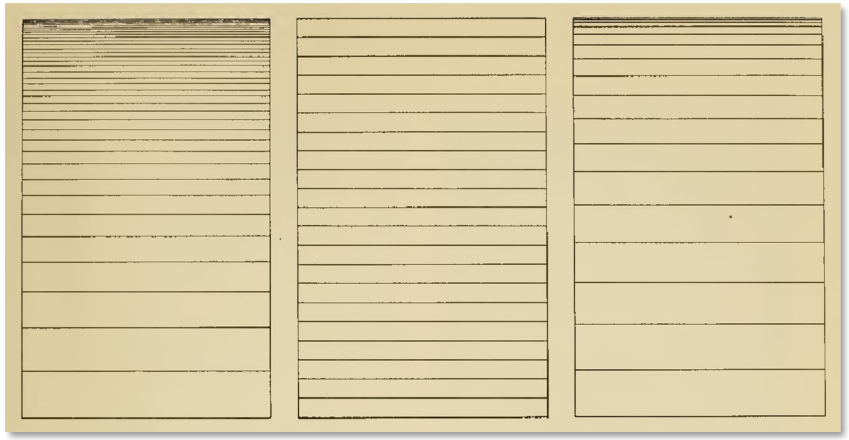
Baroque Experiment - Fred Maddox
(1962/63) by Jeffrey Steele

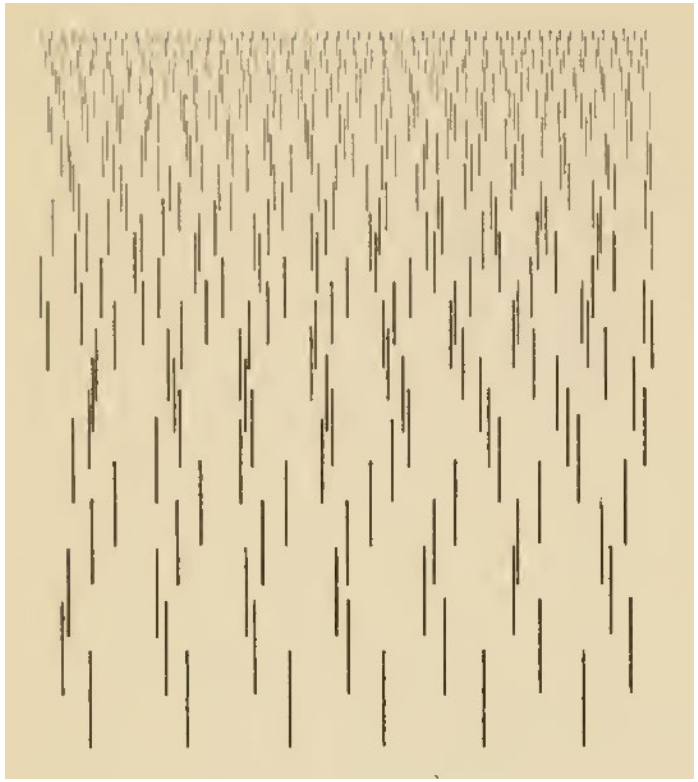
Concept-Driven: Spatial Awareness, Example II



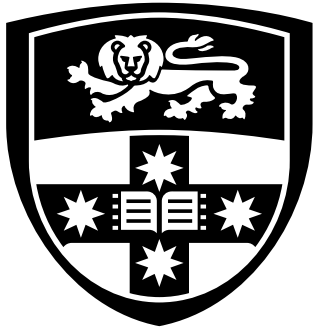
The Perception of the Visual World (1950) by James J. Gibson

Concept-Driven: Spatial Awareness, Example III





The Perception of the Visual World (1950) by James J. Gibson



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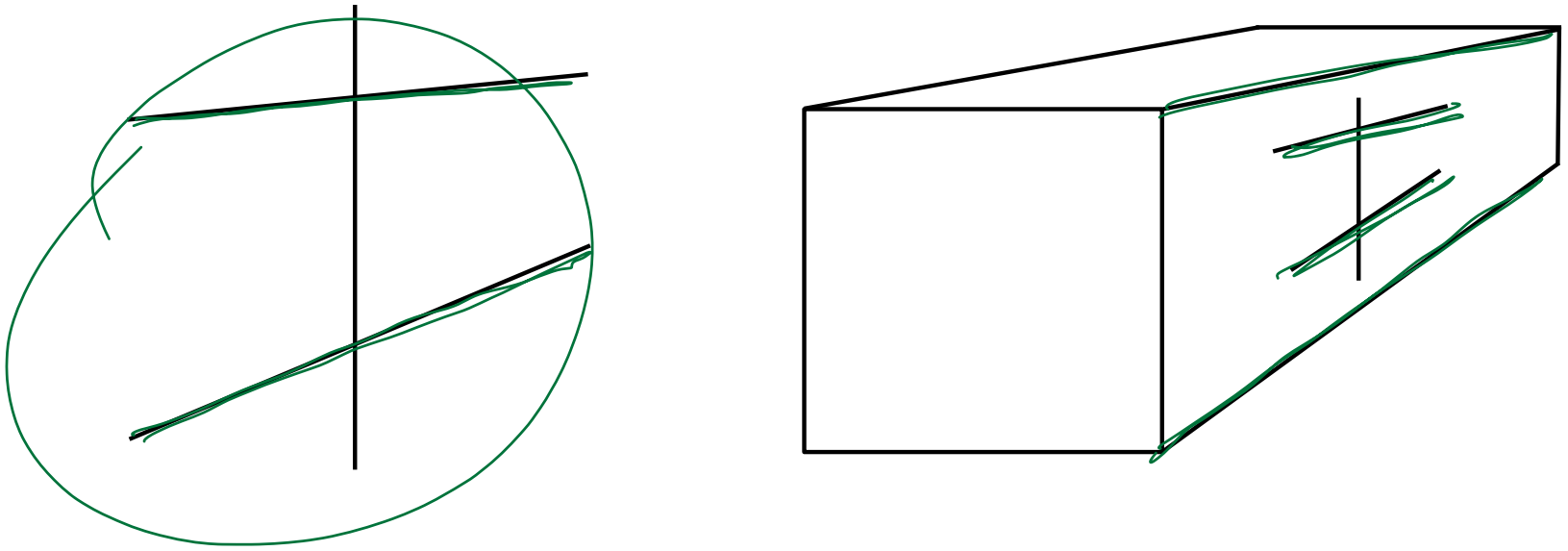
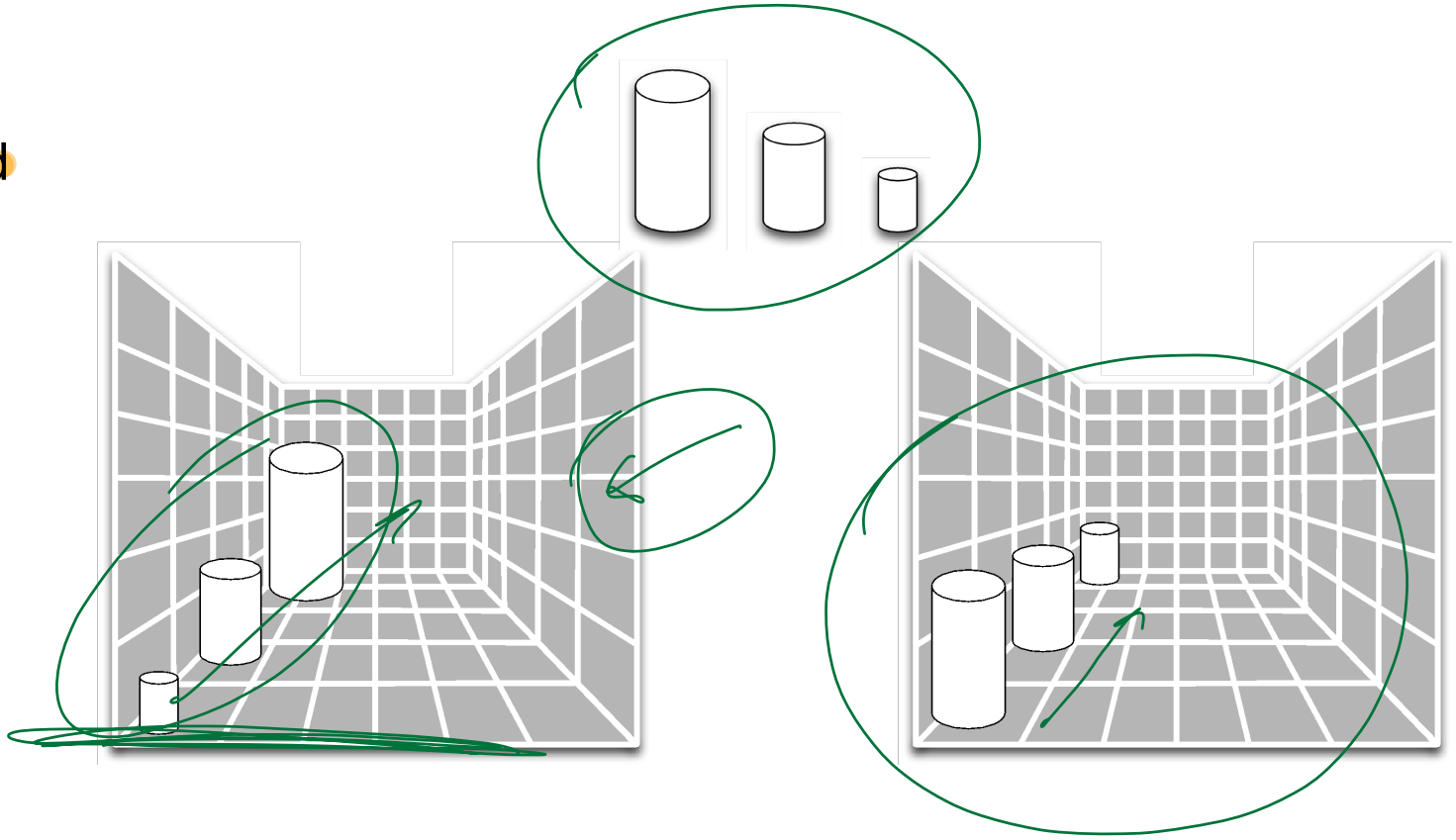
Influence of Context

Context-Induced Optical Illusion, Example I

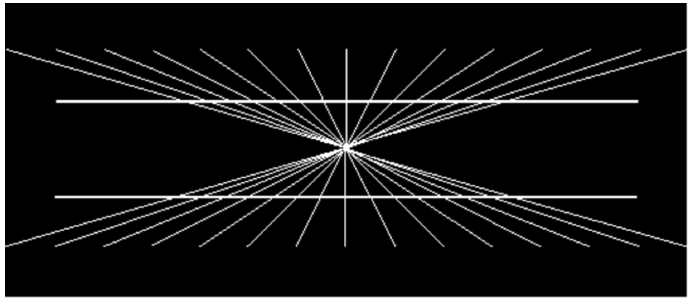


Context-Induced Optical Illusion, Example II

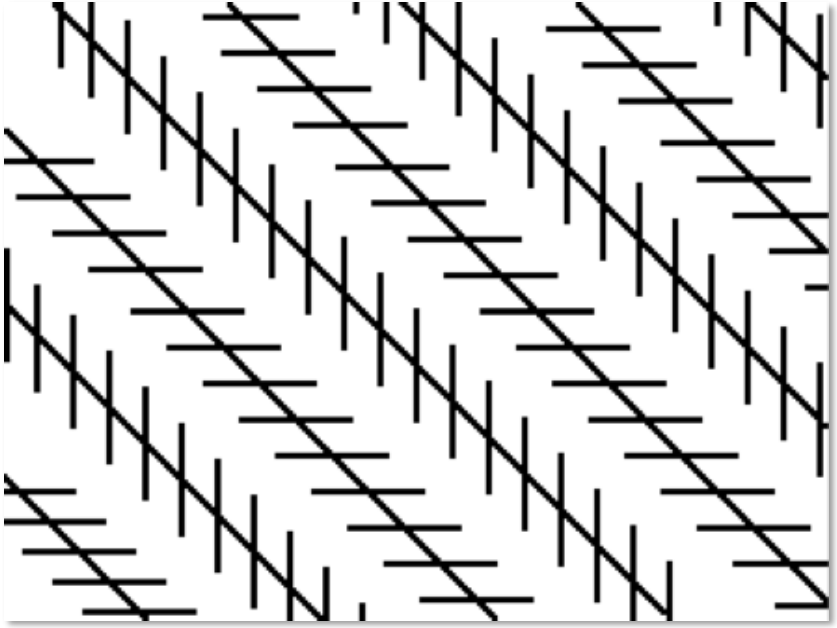
Perceptual size can be controlled with context

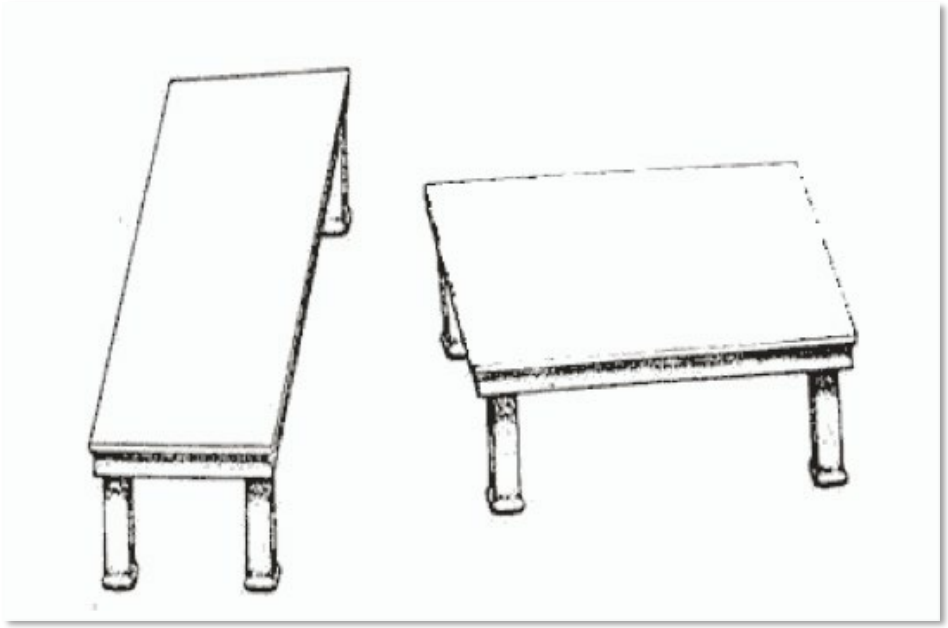


Context-Induced Optical Illusion, Example III

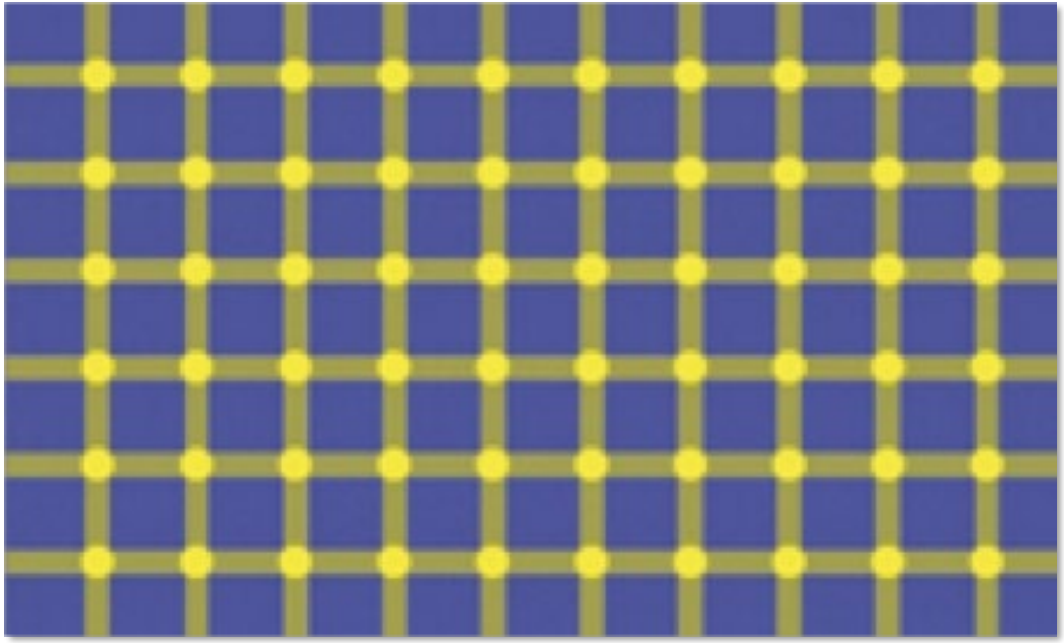


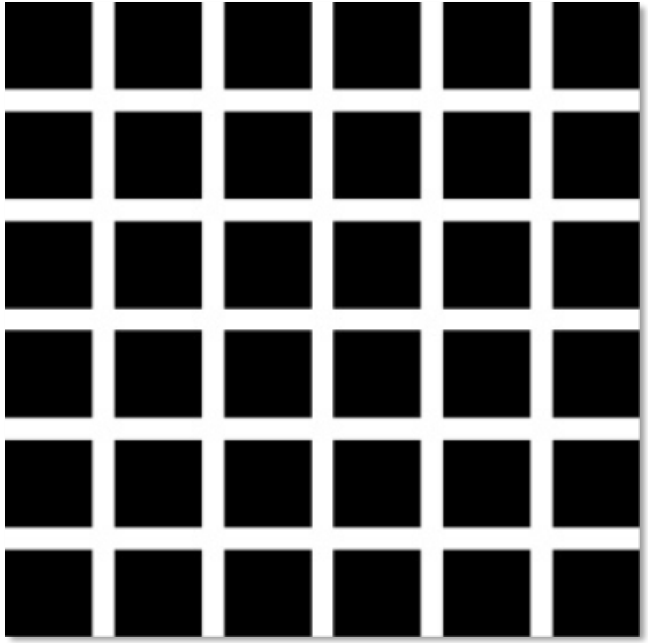
Context-Induced Optical Illusion, Example IV





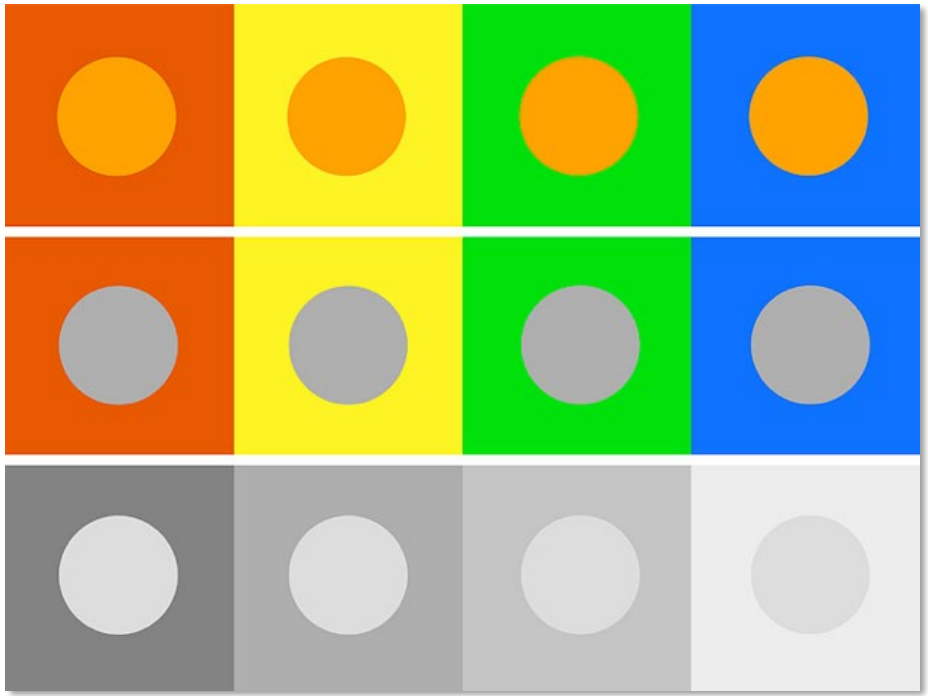
Feature Analyses Lateral Interaction



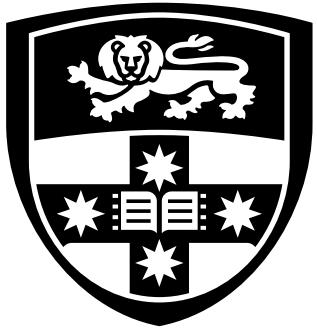


Grid illusion (1870) by Ludimar Herman

Simultaneous Contrast



Gage, J. (1993). *Colours of the mind in colour and culture: Practice and meaning from antiquity to abstraction* (pp.191–212). Thames and Hudson.



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Perception for Design

The Basics of Gestalt Principles

Gestalt Laws

- From gestalt psychology
- Laws of how humans:
  - Group similar entities ✓
  - Recognise patterns ✓
  - Simplify complex entities ✓
- They are in the mind, not the eye

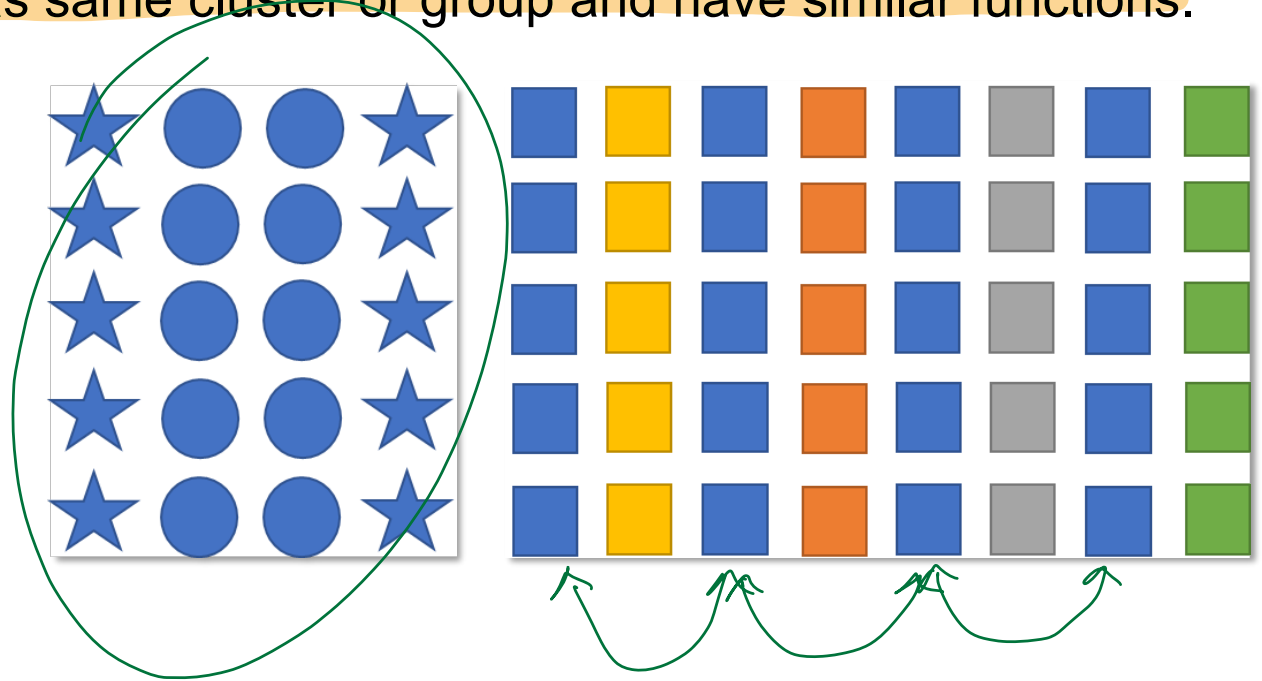
Key Principles for Visualisation

- Similarity
- Proximity
- Common region
- Closure
- Continuity
- Connection

SPCCC

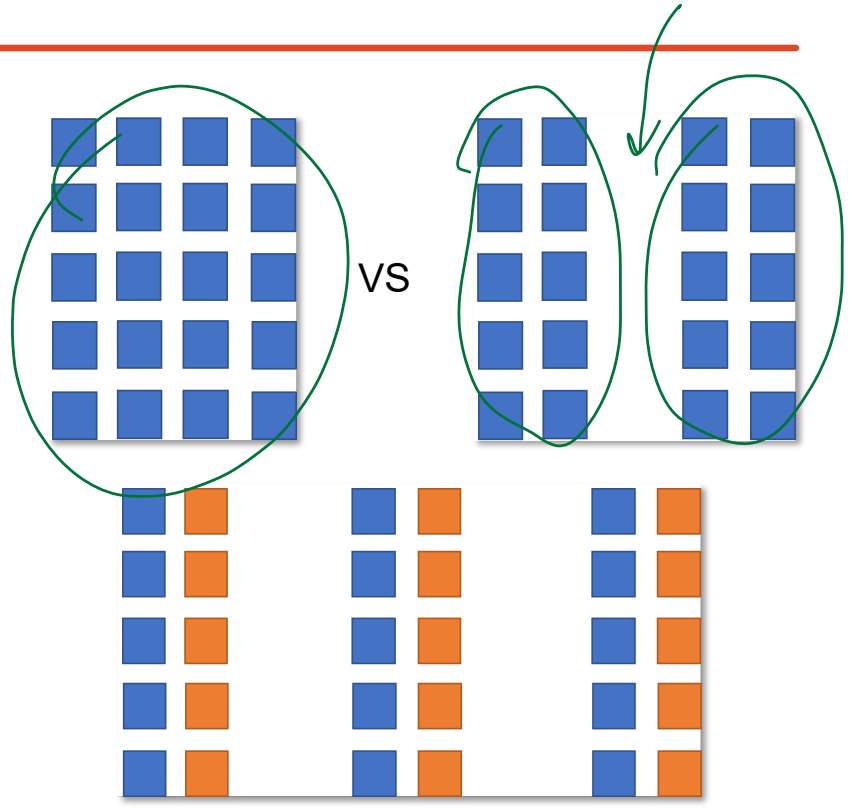
Similarity

Entities which have similar visual attributes (such as shape and colour) are perceived as same cluster or group and have similar functions.



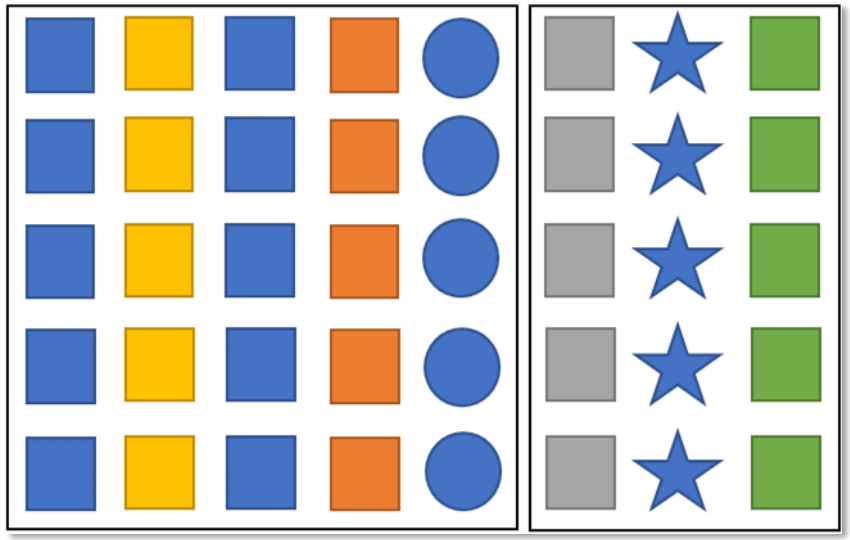
Proximity

- Entities which are close to each other can be seen as they belong to the same group
- Powerful: overrides similarity of colour, shape, and other factors that might differentiate a group of objects

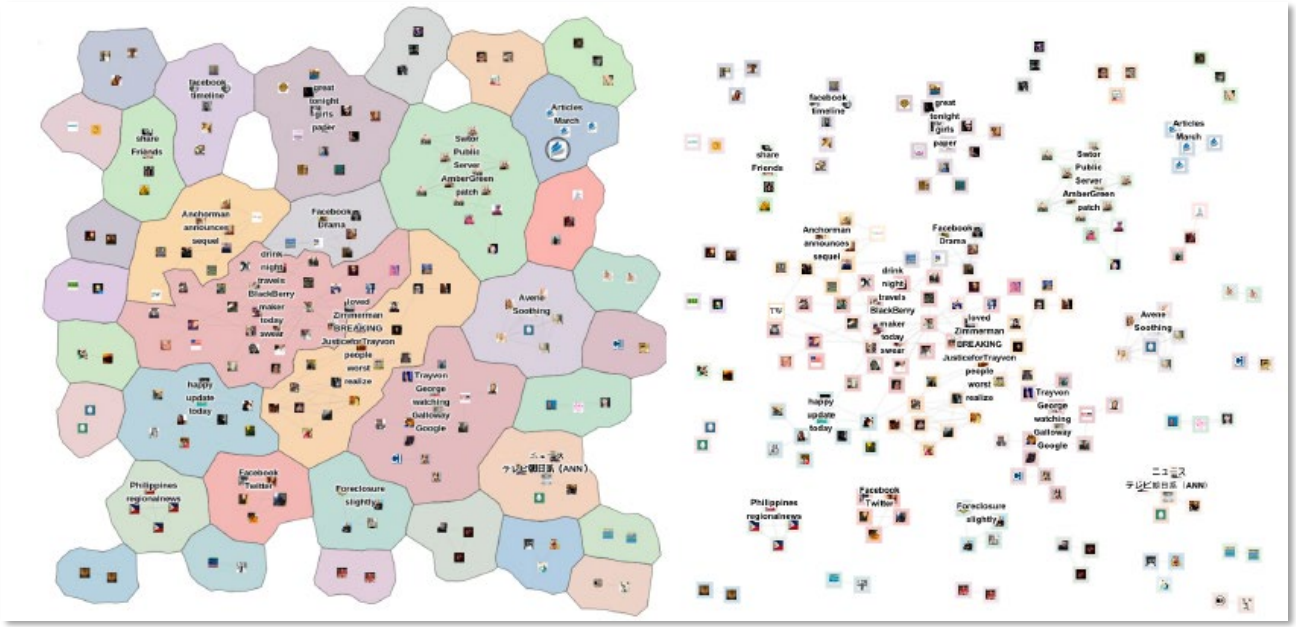


Common Region

Entities which are surrounded by a same closed region can be seen as they belong to the same group despite the differences in visual attributes.



Common Region (cont.)

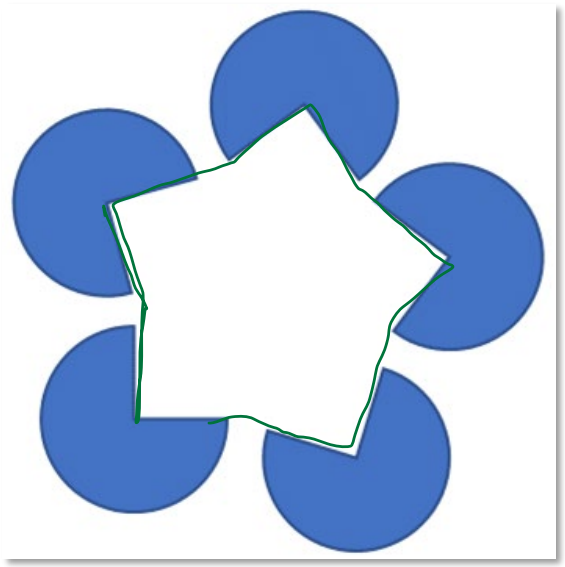


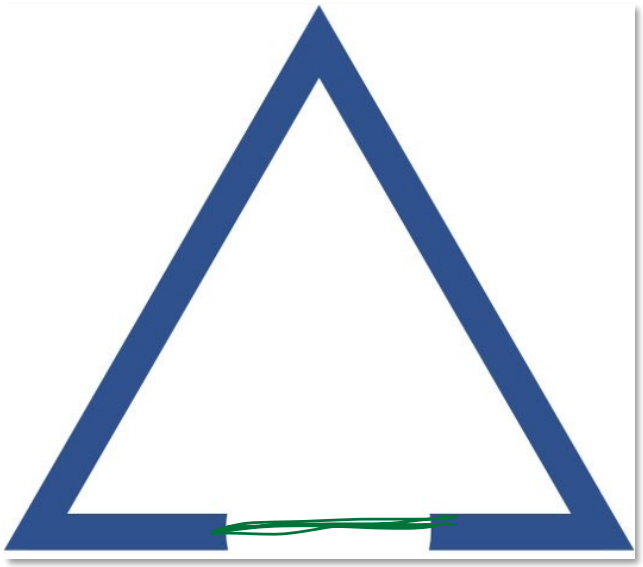
A map metaphor visualisation (left) seems more appealing than a plain graph layout (right), and clusters seem easier to identify.

Gansner, E. R., Hu, Y., & North, S. C. (2013). Interactive visualization of streaming text data with dynamic maps. *J. Graph Algorithms Appl., 17*(4), 515–540.

Closure

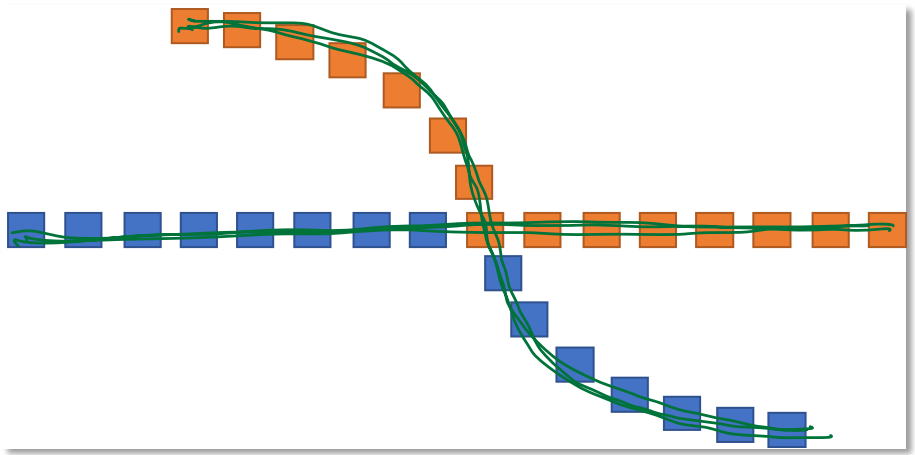
An entity, which looks like its part is missing, can be mentally filled in.





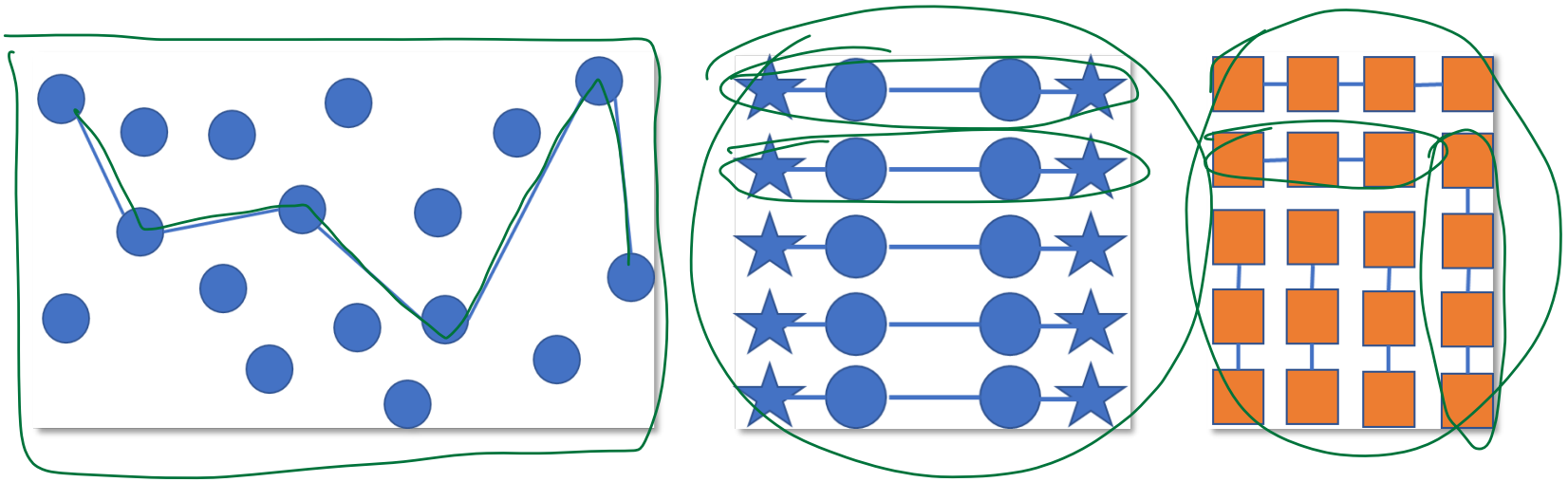
Continuity

Entities that are arranged on a line or curve are perceived to be more related than elements not on the line or curve.



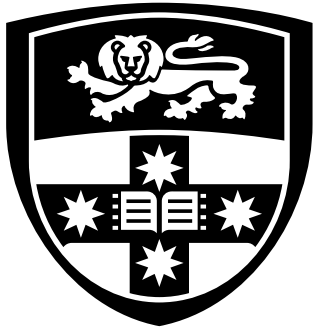
Connection/Connectedness

- Connected entities are perceived as a group or a chunk
- Powerful: stronger than proximity and similarity



Summary

- What are the stages of human visual systems?
  - Visual information processing stages
  - Data-driven vs concept-driven stages
- What are the key principles of gestalt for visualisations?
  - Similarity
  - Proximity
  - Common region
  - Closure
  - Continuity
  - Connection



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