Human Visual System

Learning Objectives

- What are the stages of human visual systems?
- What are the key principles of Gestalt for visualisations?

Human Visual Information Processing stages

Human Perception

Interpretation of Sensory Inputs

- visual
- auditory
- tactile
- olfactory
- taste

Visualization ... just “Visual Sensory Inputs?”

Human visual information processing model

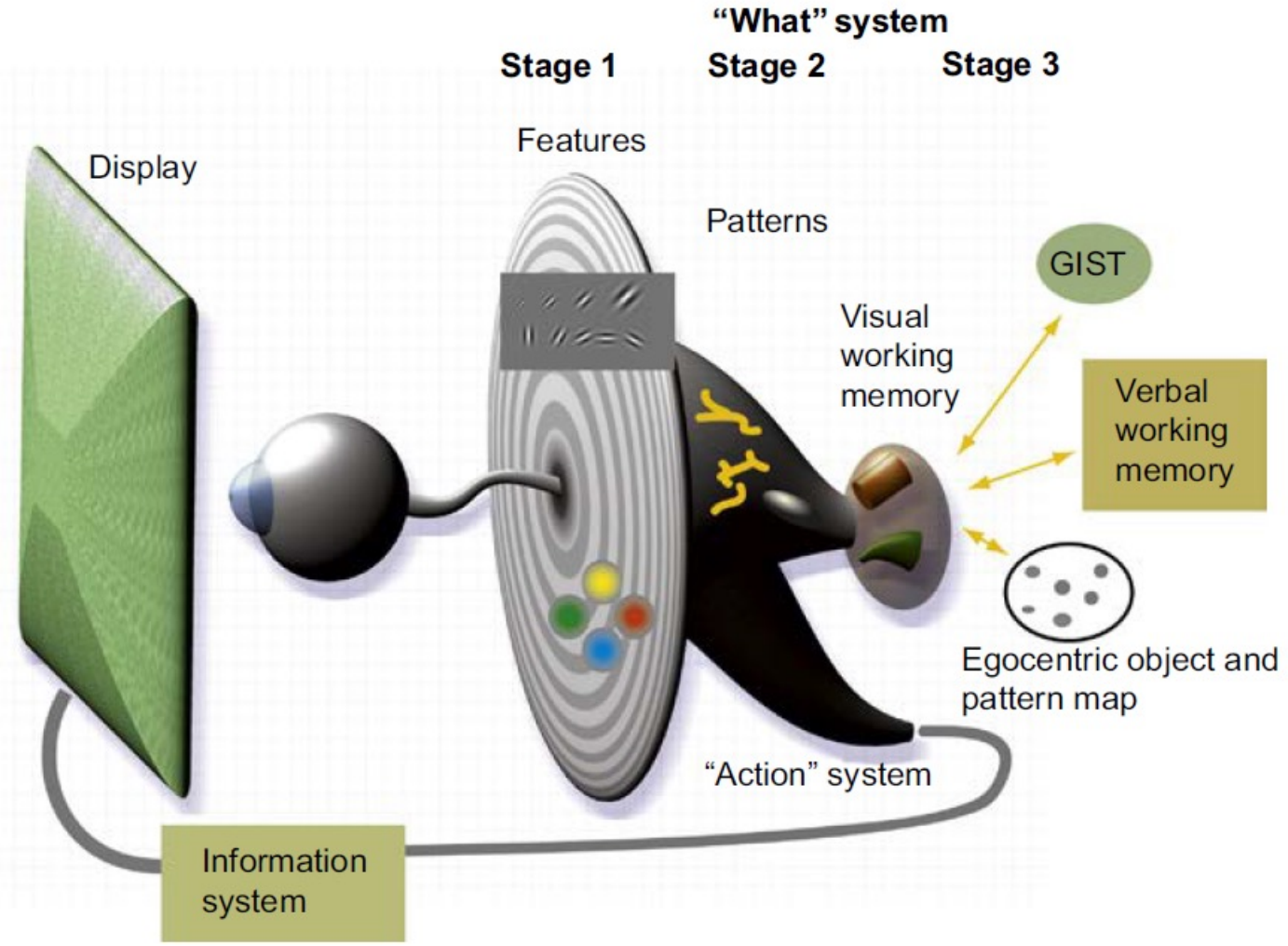
by Colin Ware

Stage 1: Parallel Processing to Extract Low-Level Properties

of the Visual Scene

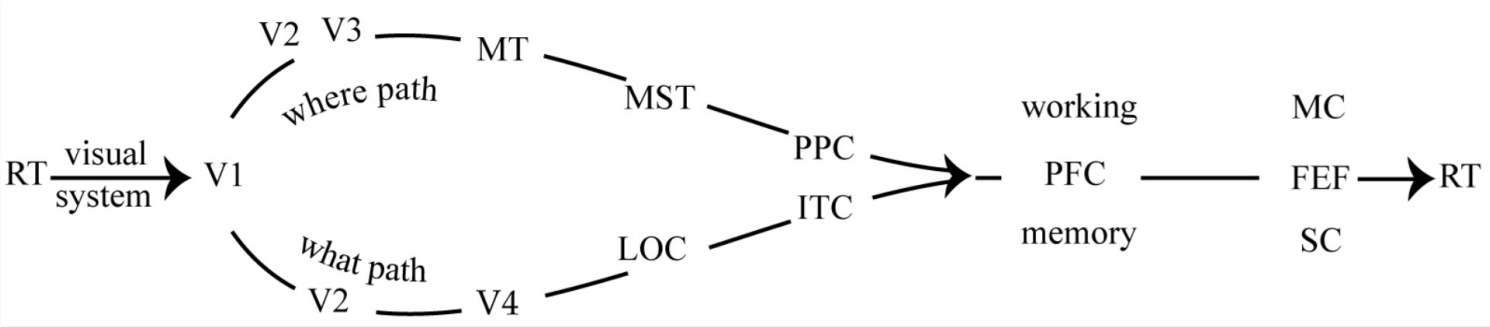
Stage 2: Pattern Perception

Stage 3: Visual Cognition



Ware, C. (2013). *Information Visualization: Perception for Design*. Elsevier Science. https://books.google.com.au/books?id=qFmS95vf6H8C

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		

- C.W. Eriksen and J. Hoffman, “The Extent Of Processing Noise Elements During Selective Encoding From Displays”, Perception and Psychophysics, vol. 14, pp. 155-160, 1973.
- A. Treisman and G. Gelade, “A Feature Integration Theory Of Visual Attention”, Cognitive Psychology, vol. 12, pp. 97-136, 1980.
- R.J. Allen, A.D. Baddeley and G.J. Hitch, “Is The Binding Of Visual Features In Working Memory Resource Demanding?” Journal of Experimental Psychology, vol. 135, pp. 298-313, 2006.
- L. Ungerleider and M. Mishkin, “Two cortical visual systems”, Analysis of Visual Behaviour, D.J. Ingle, M.A. Goodale and R.J.W. Mansfield, eds., Cambridge: MIT Press, pp. 549-586, 1982.
- M.A. Goodale and A.D. Milner, “Separate Visual Pathways For Perception And Action”, Trends Neuroscience, vol.15, pp. 20-25, 1992.
- M.J. Webster and L.G. Ungerleider, ”Neuroanatomy of visual attention”, The Attentive Brain, R.Parasuraman, ed., Cambridge: MIT Press, pp. 19-34, 2000

Variables vs Brain Areas

	Brain Areas									
Potential Ordered Variables	V1	V2	V3	V4	LOC	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

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

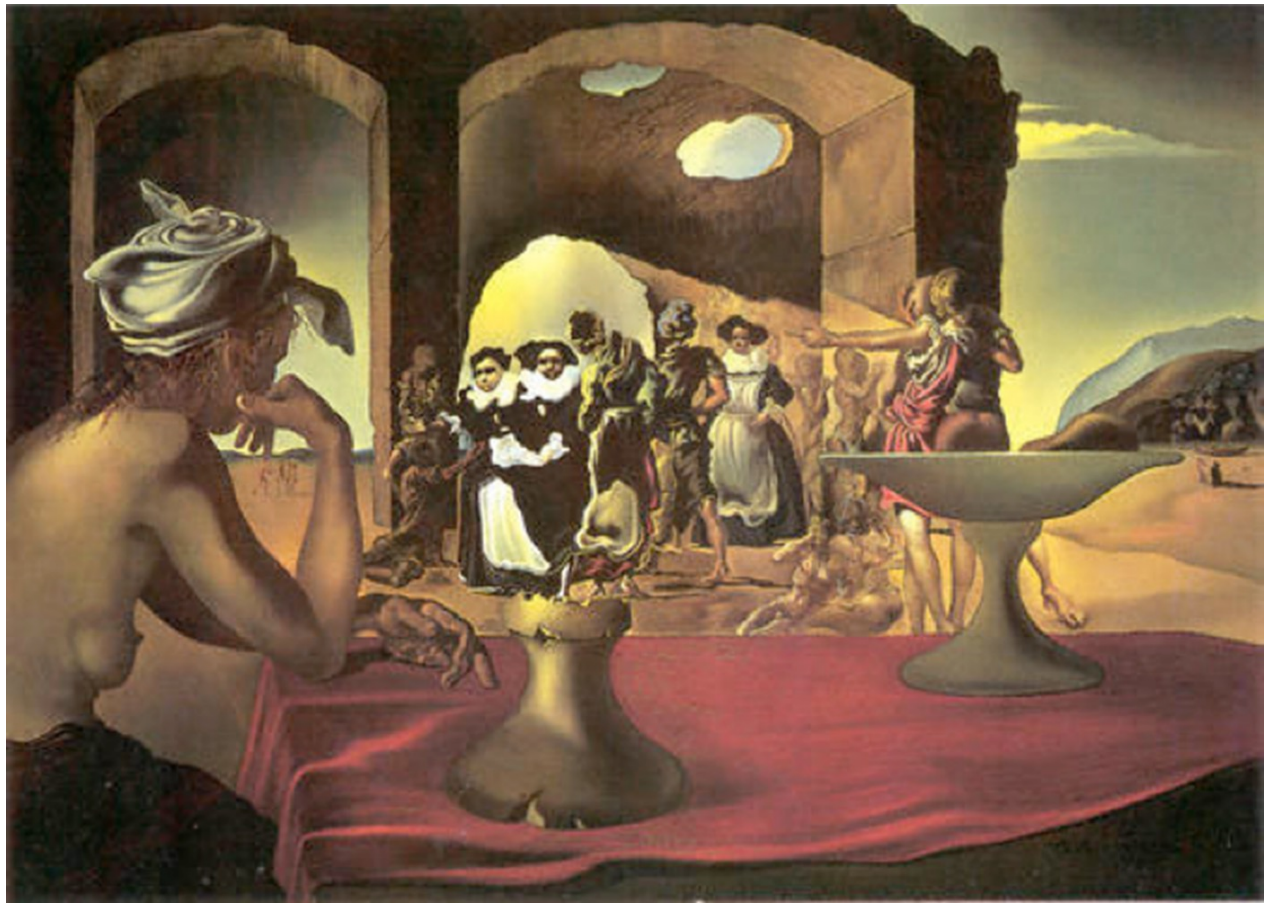
Competing Organisation:
Data-driven to concept-driven, Example I

Gregory, R. L. (1970). *The Intelligent Eye*. Weidenfeld & Nicolson.

Competing Organisation:
Data-driven to concept-driven, Example II

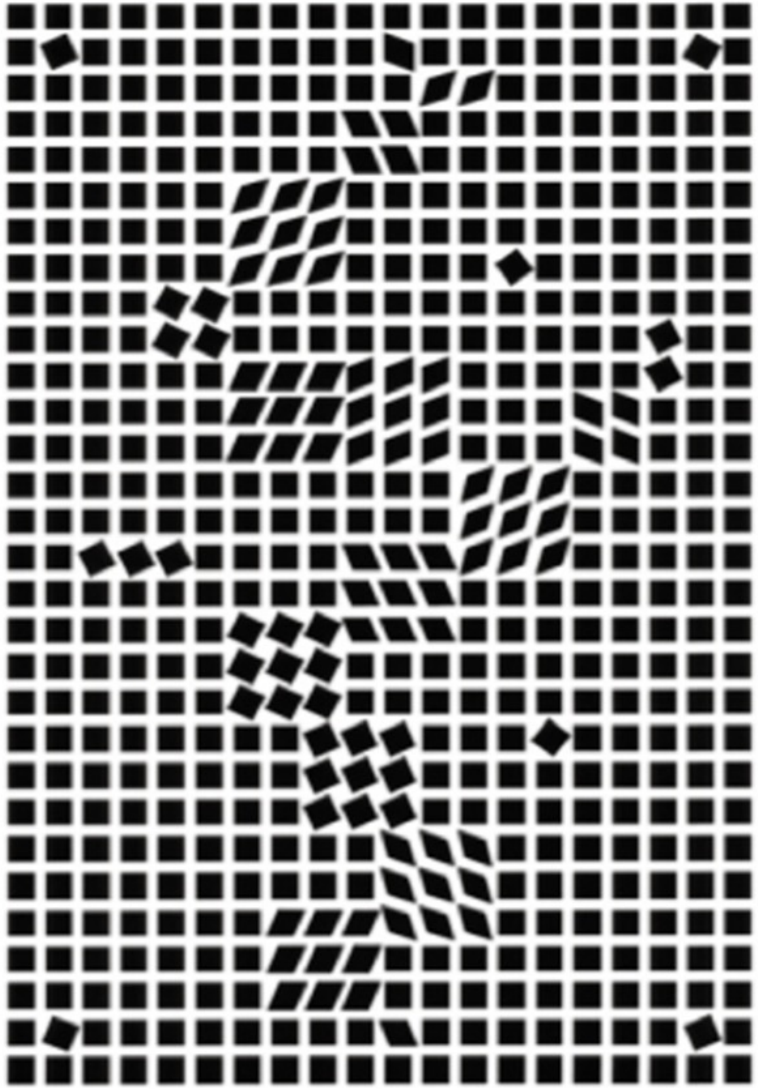
My Wife and My Mother-in-Law (1915) by William Ely Hill

Competing Organisation:
Data-driven to concept-driven, Example III



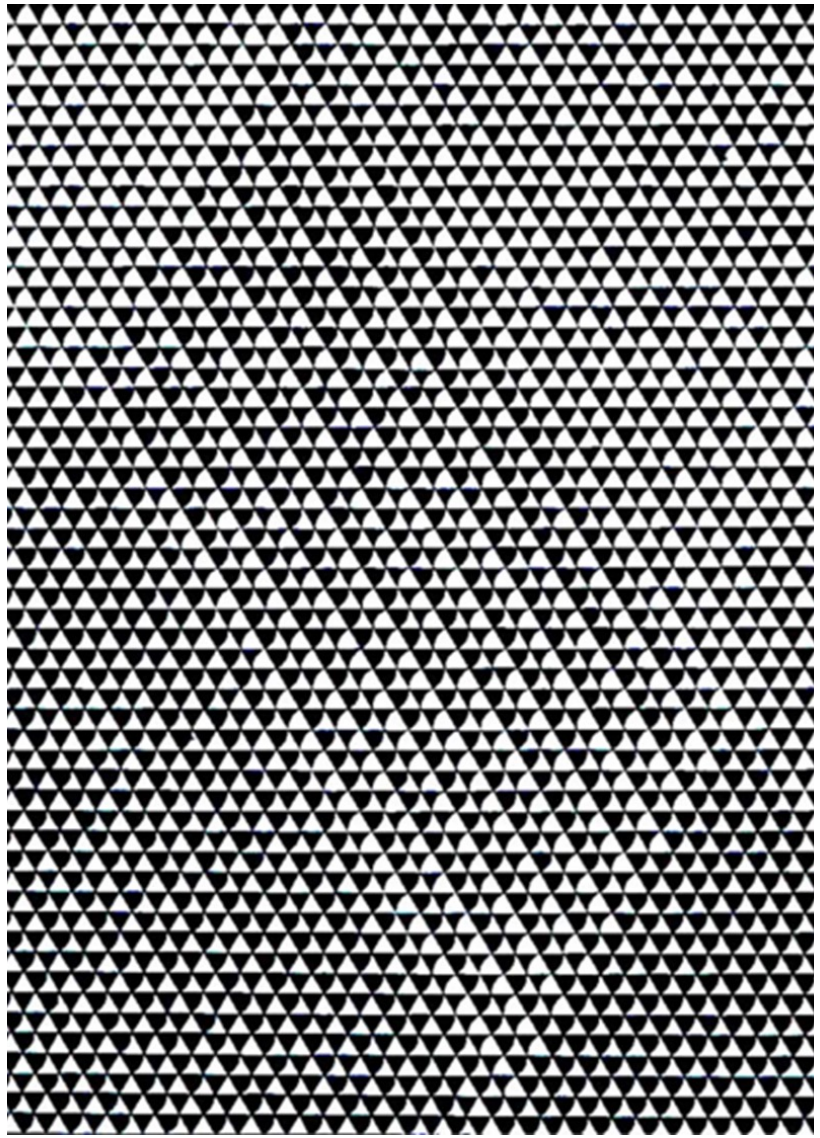
Slave Market with the Disappearing Bust of Voltaire(1940)
by Salvador Dalí

Data-driven: No meaning attached, Example I



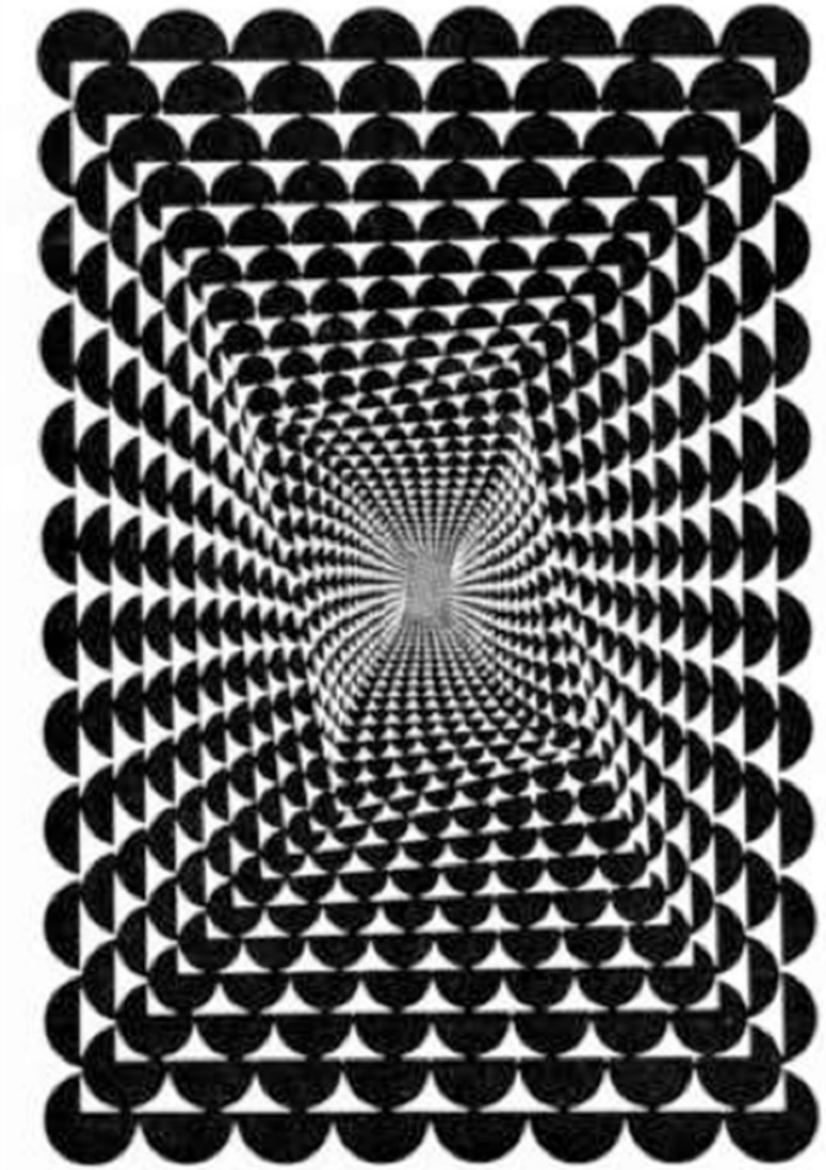
“Tlinko, C.1955” Serigraph by Victor Vasarely

Data-driven: No meaning attached, Example II



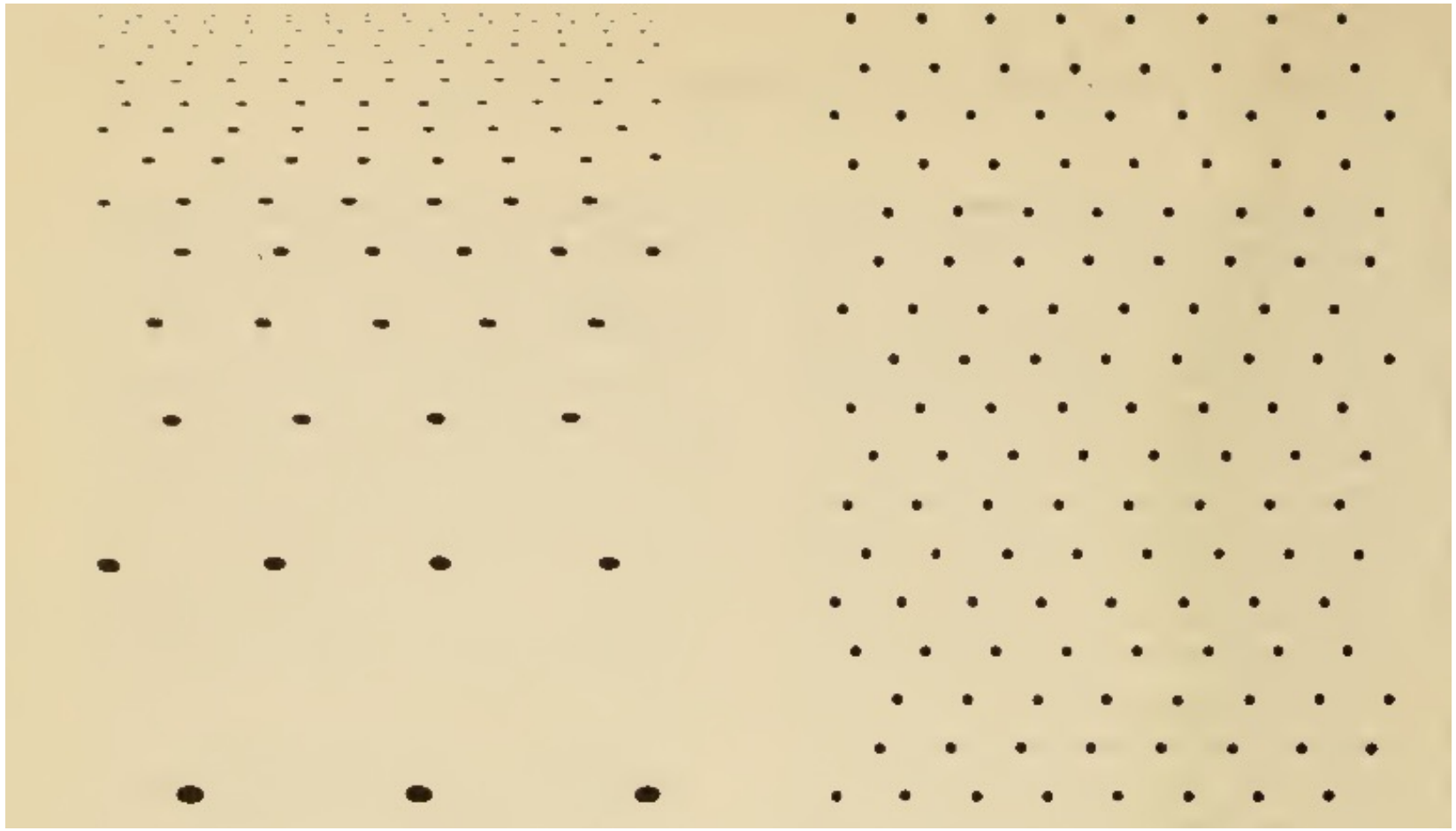
Tremor (1962) by Bridget Riley

Concept-driven: Spatial Awareness, Example I



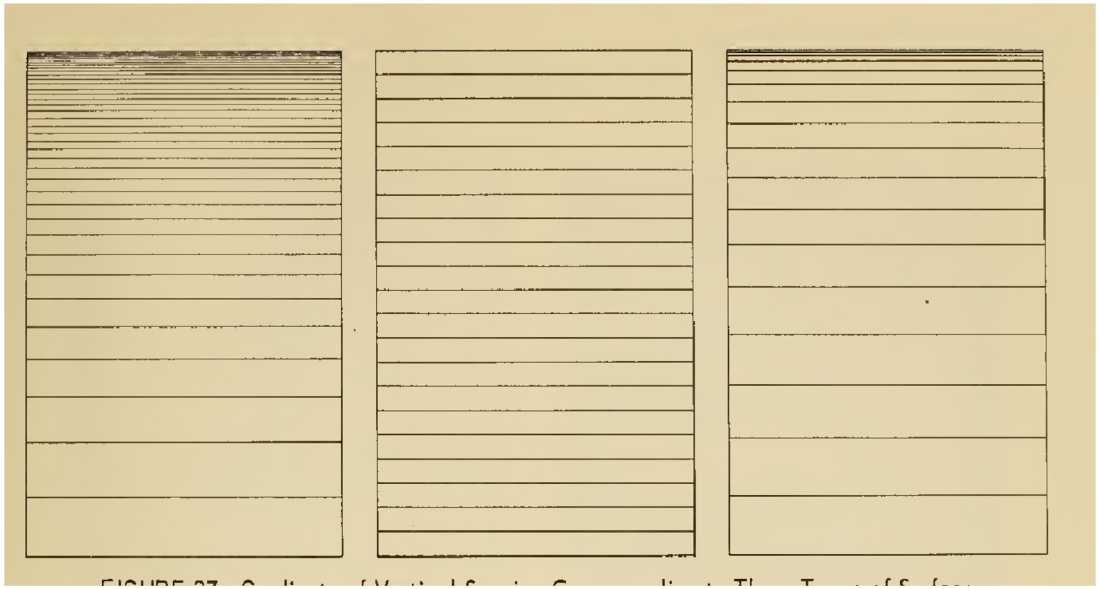
Baroque Experiment - Fred Maddox (1962/63) by Jeffrey Steele

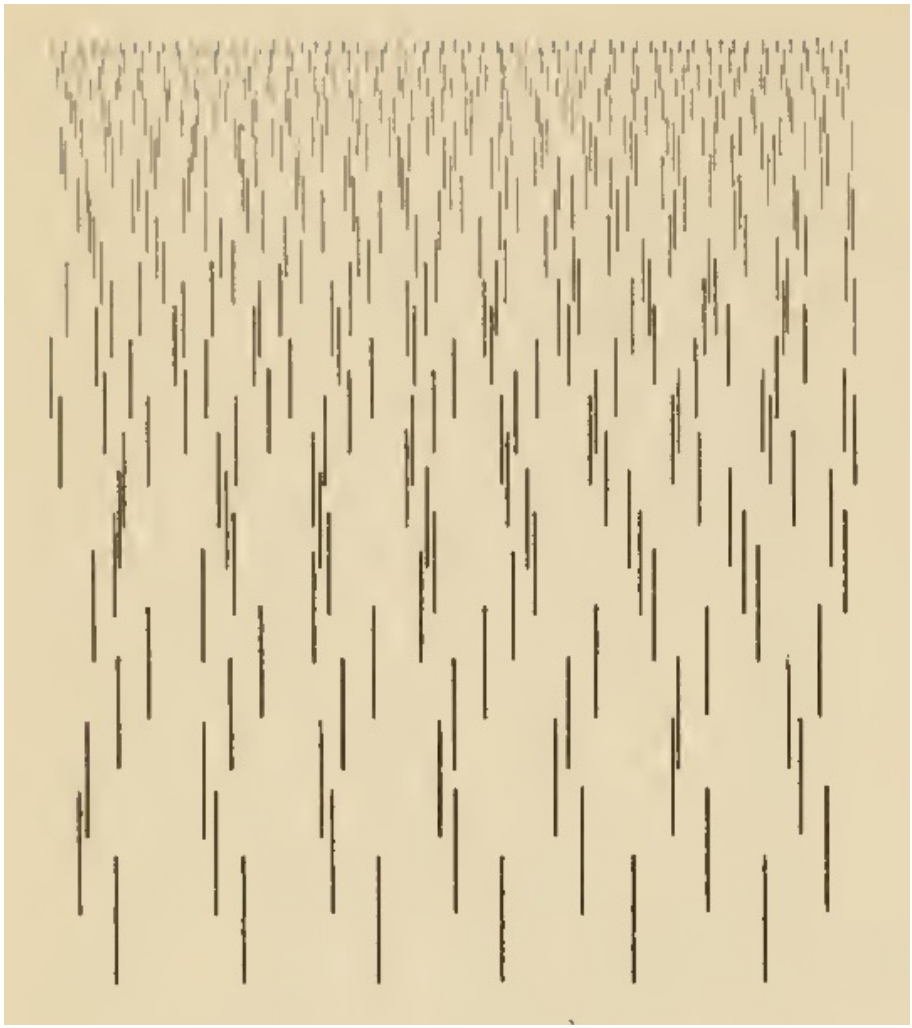
Concept-driven: Spatial Awareness, Example II



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

Concept-driven: Spatial Awareness, Example III





The Perception of the Visual World (1950)
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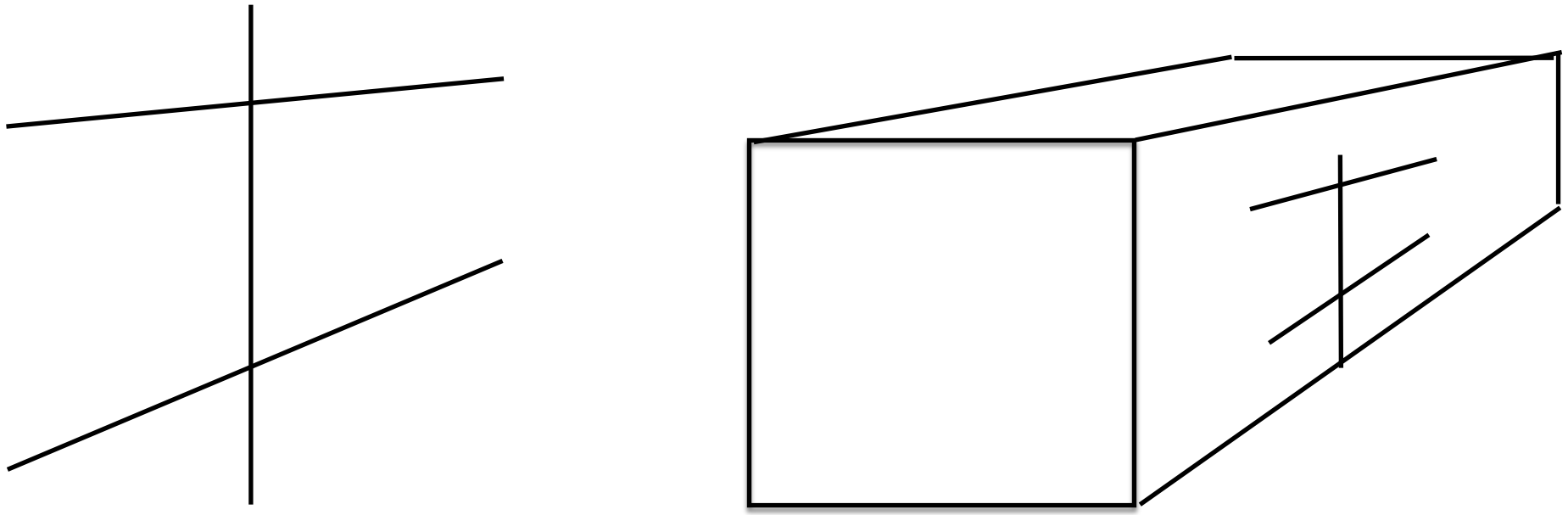
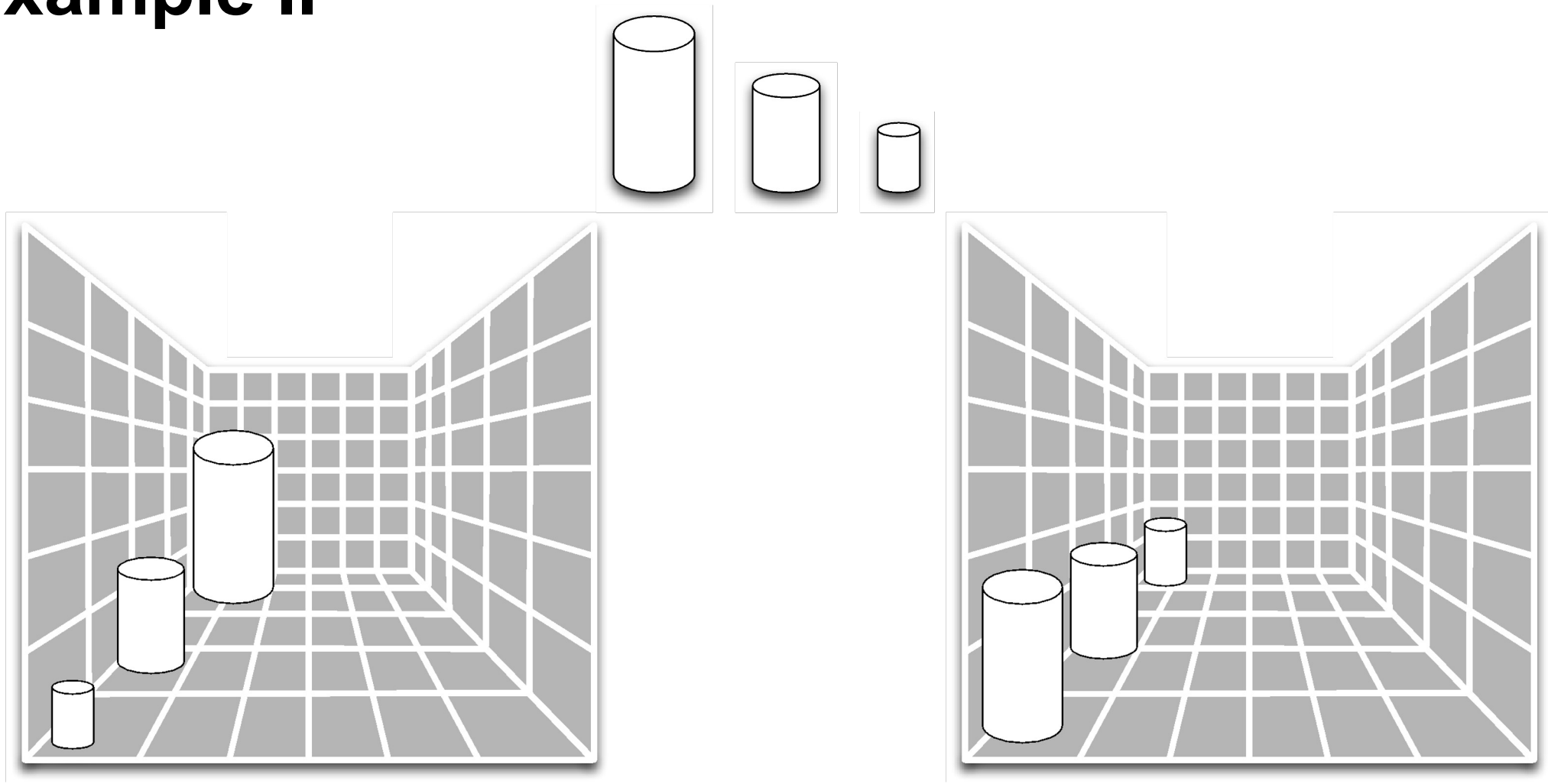
Influence of context

Context-induced Optical Illusion, Example I

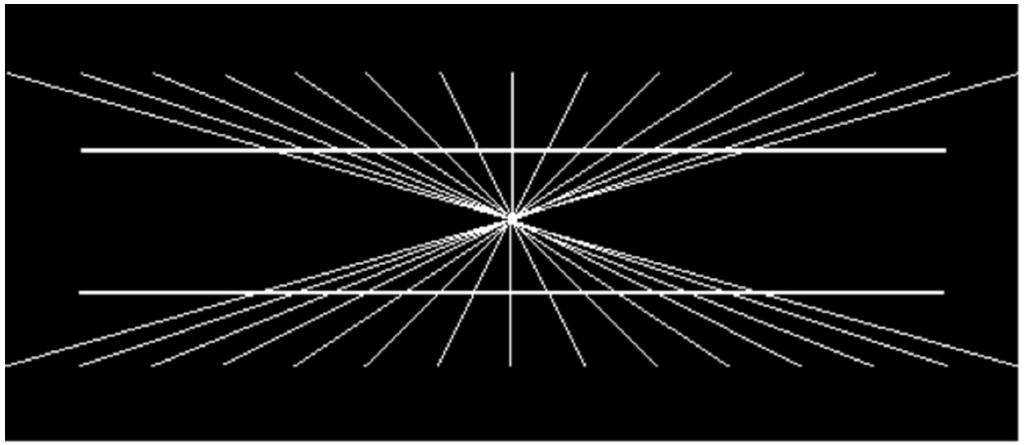


Context-induced Optical Illusion, Example II

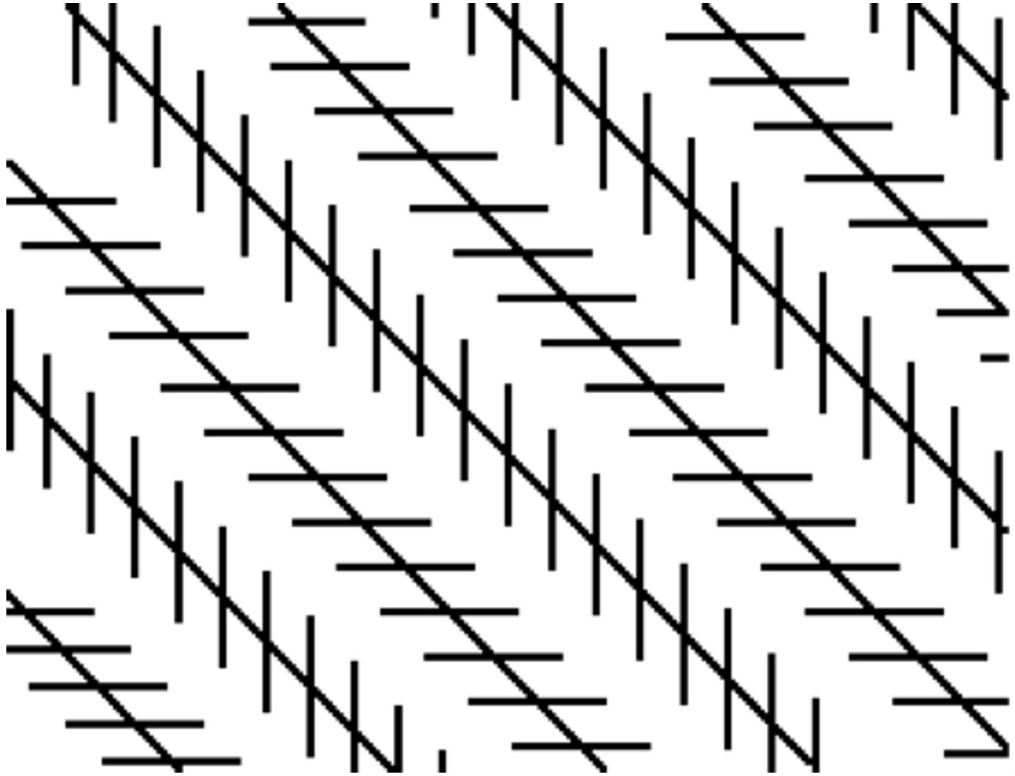


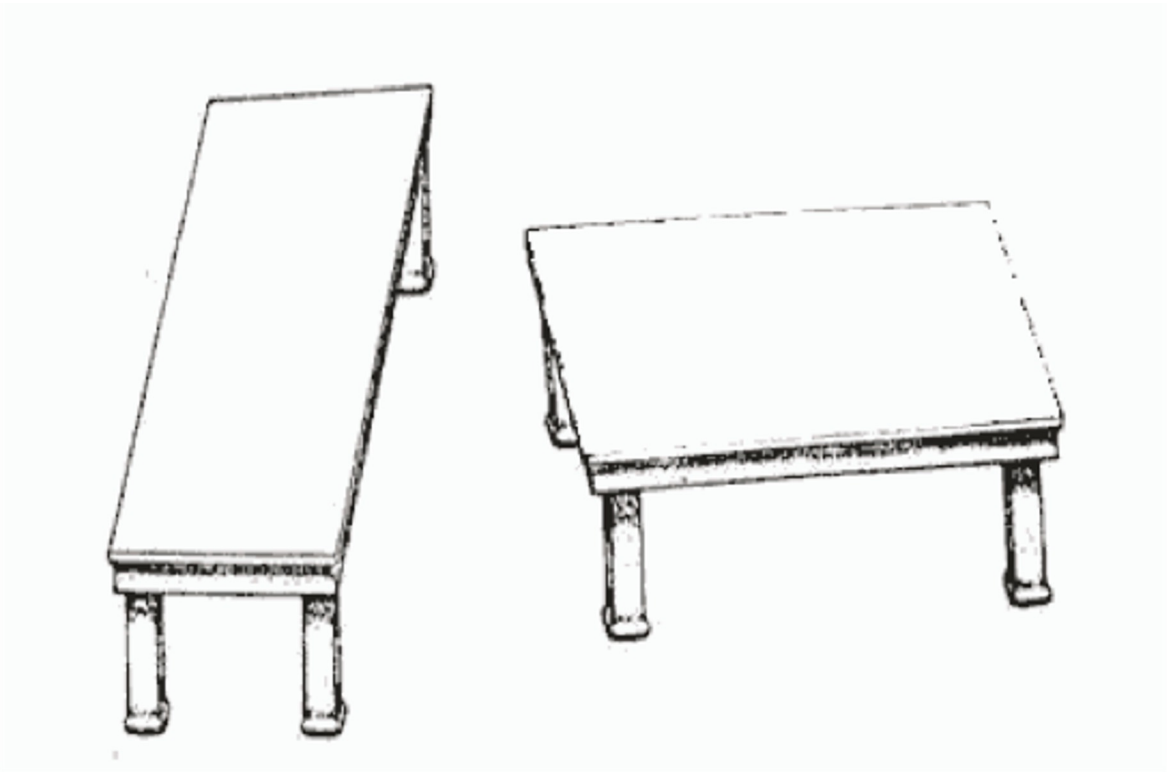
- Perceptual size can be controlled with context

Context-induced Optical Illusion, Example III

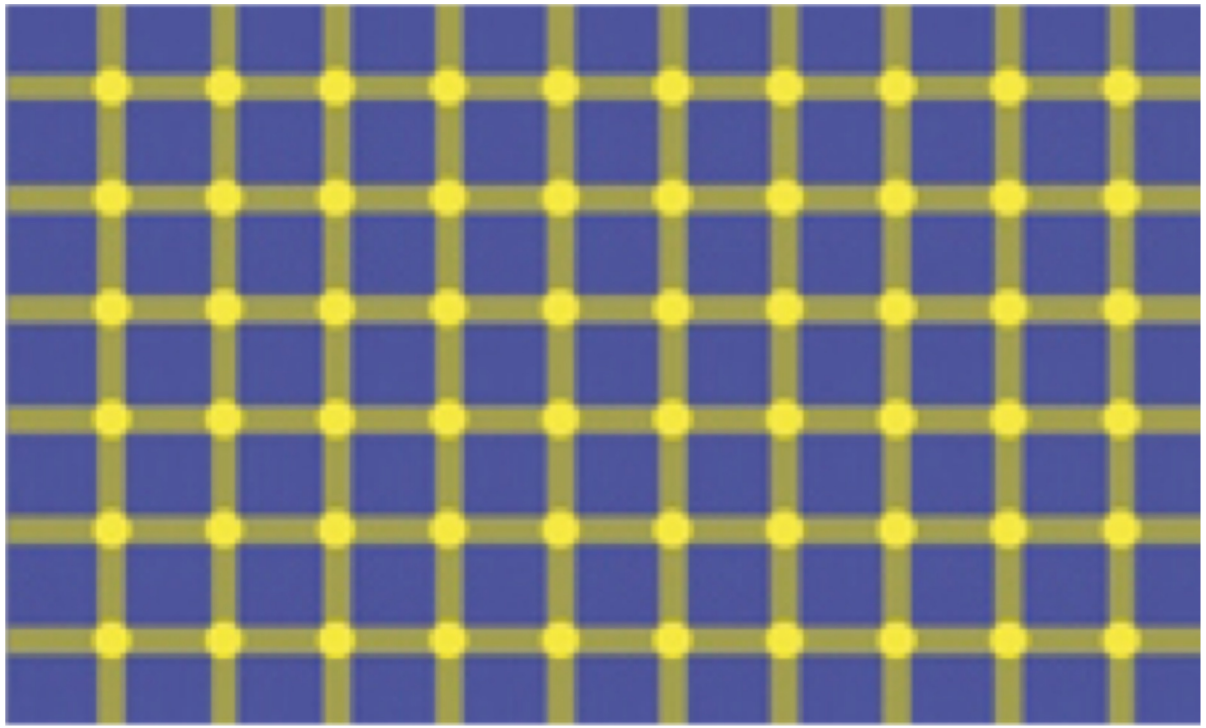


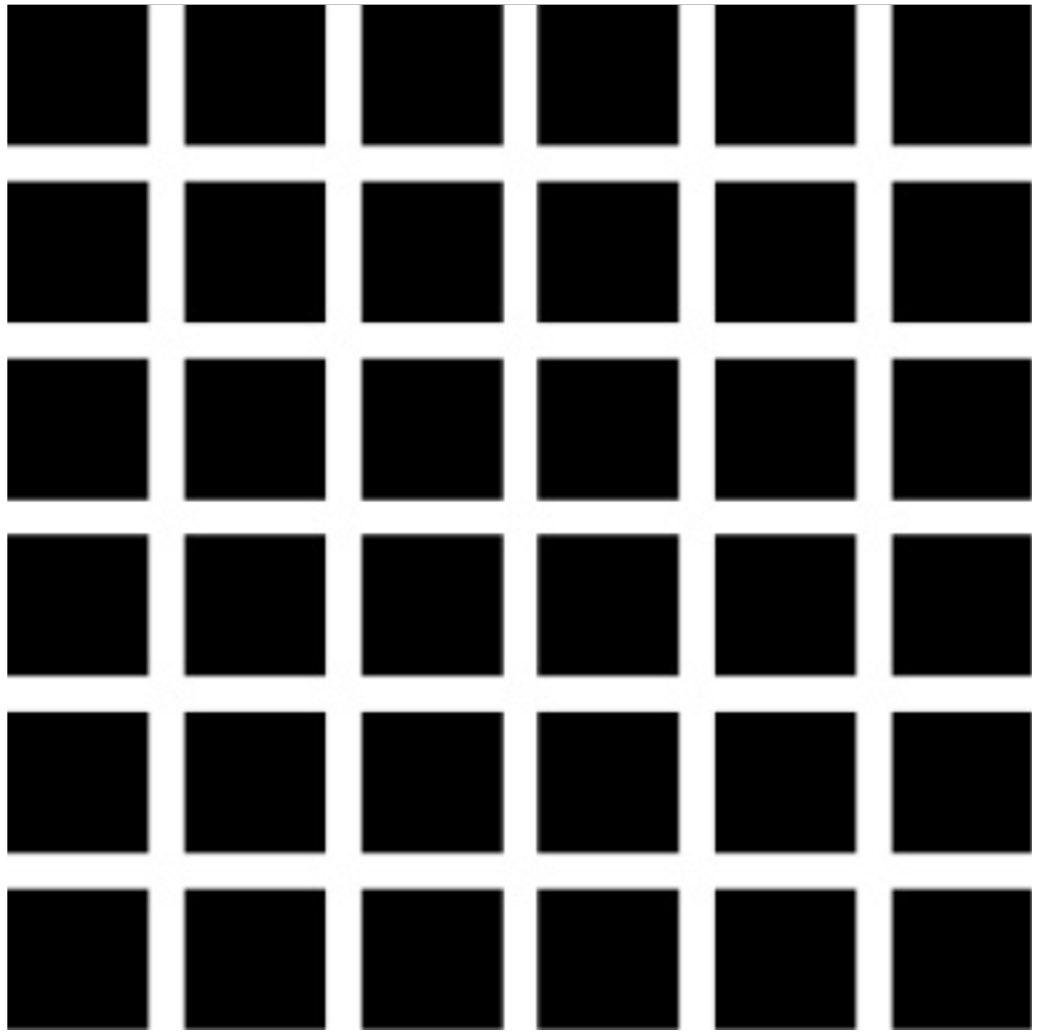
Context-induced Optical Illusion, Example IV





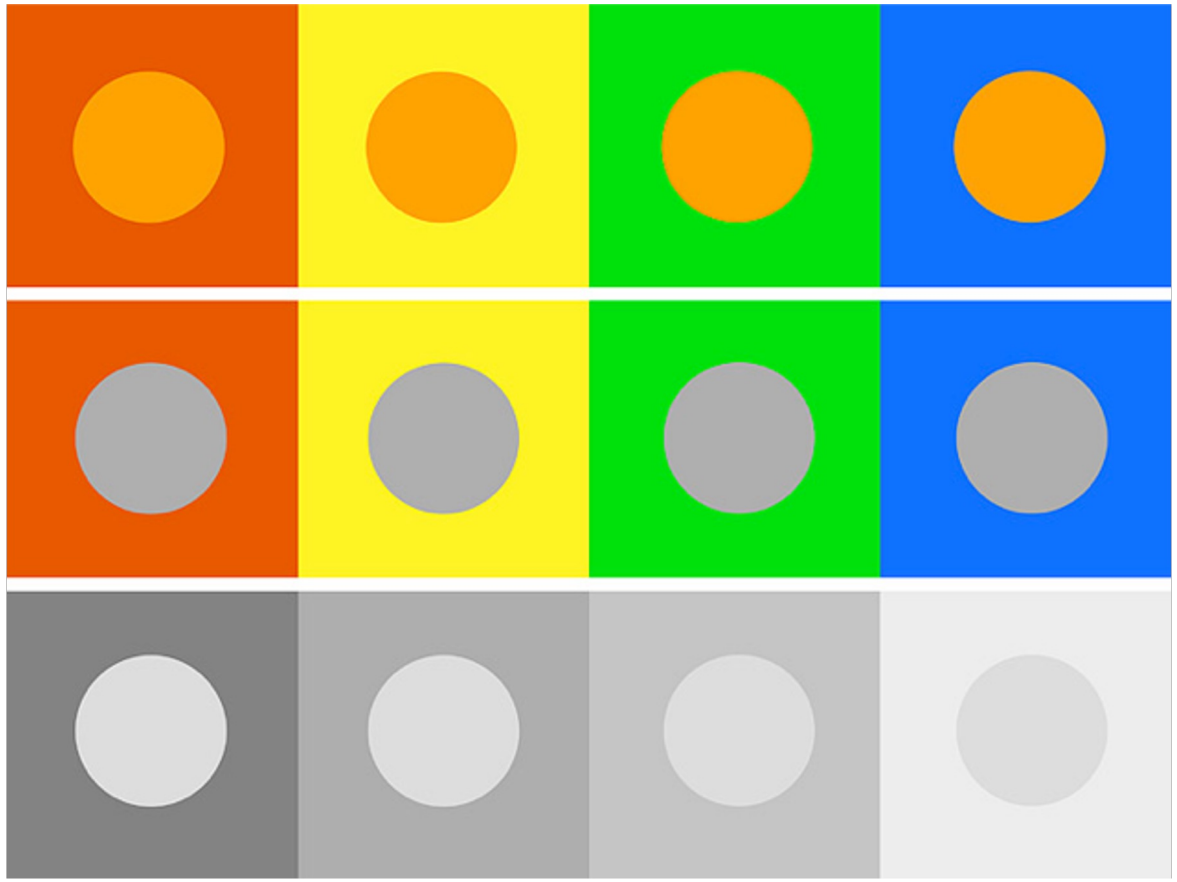
Feature Analyses
Lateral interaction





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). New York: Thames and Hudson

Perception for Design: The Basic of Gestalt Principles

Gestalt Laws

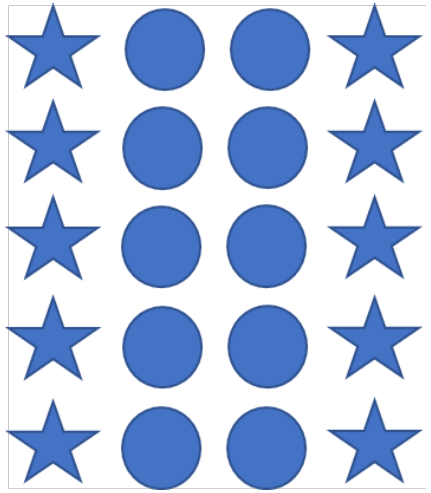
- From Gestalt Psychology
- Laws of how human
  - Group similar entities
  - Recognise patterns
  - Simplify complex entities
- They are in the mind, not the eye

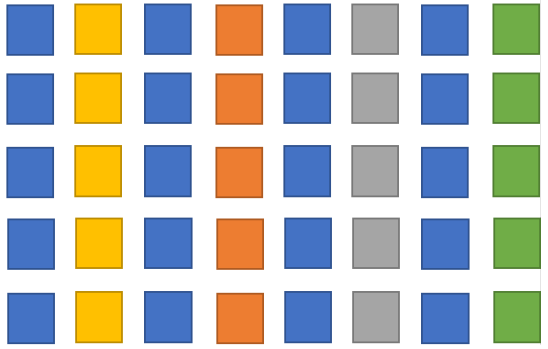
Key principles for Visualisation

- Similarity
- Proximity
- Common Region
- Closure
- Continuity
- Connection

Similarity

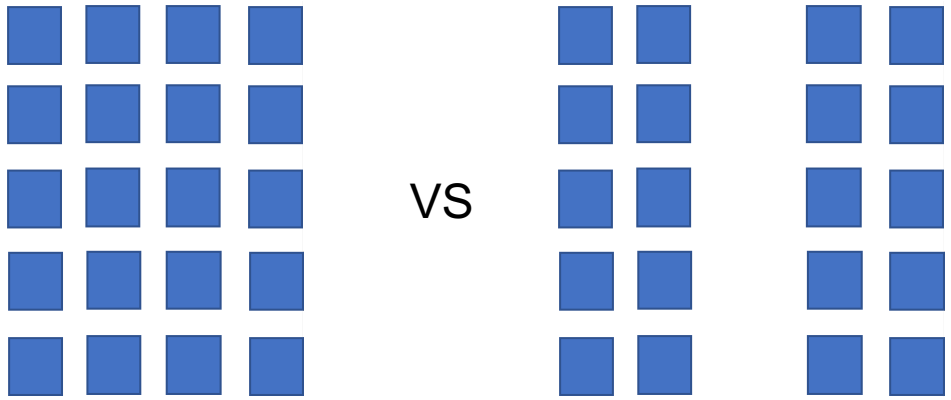
- Entities which have similar visual attributes (such as shape and colour) are perceived as same cluster or group and have similar functions.

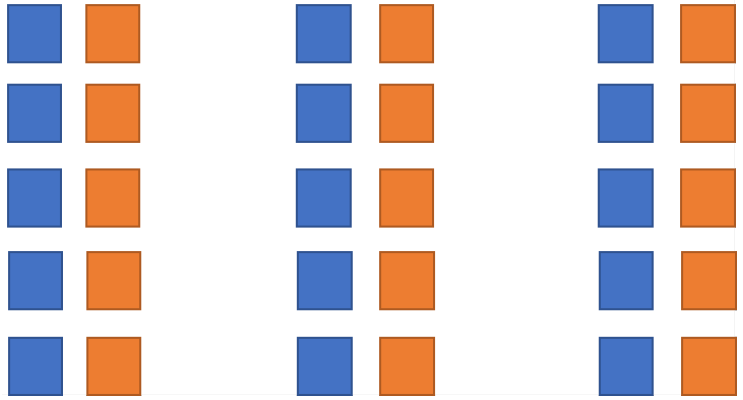




Proximity

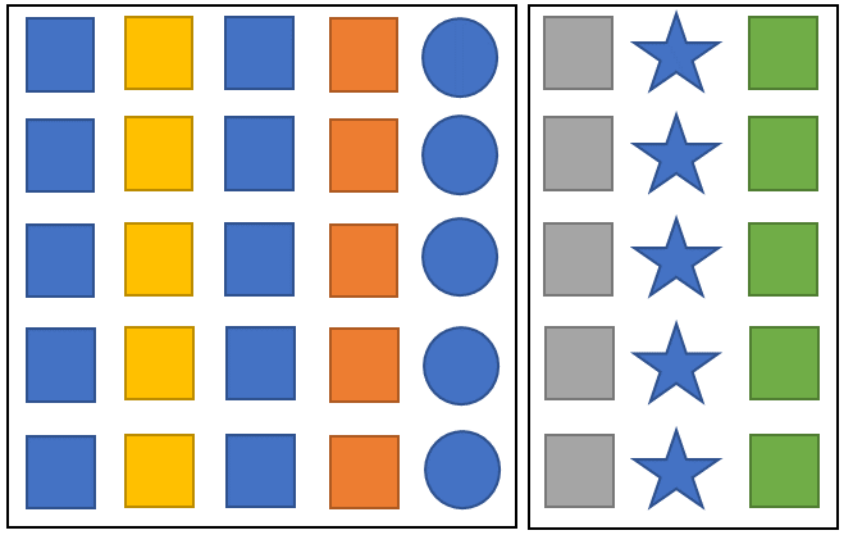
- Entities which are close to each other can be seen as they belong to the same group
- powerful – overrides similarity of color, shape, and other factors that might differentiate a group of objects



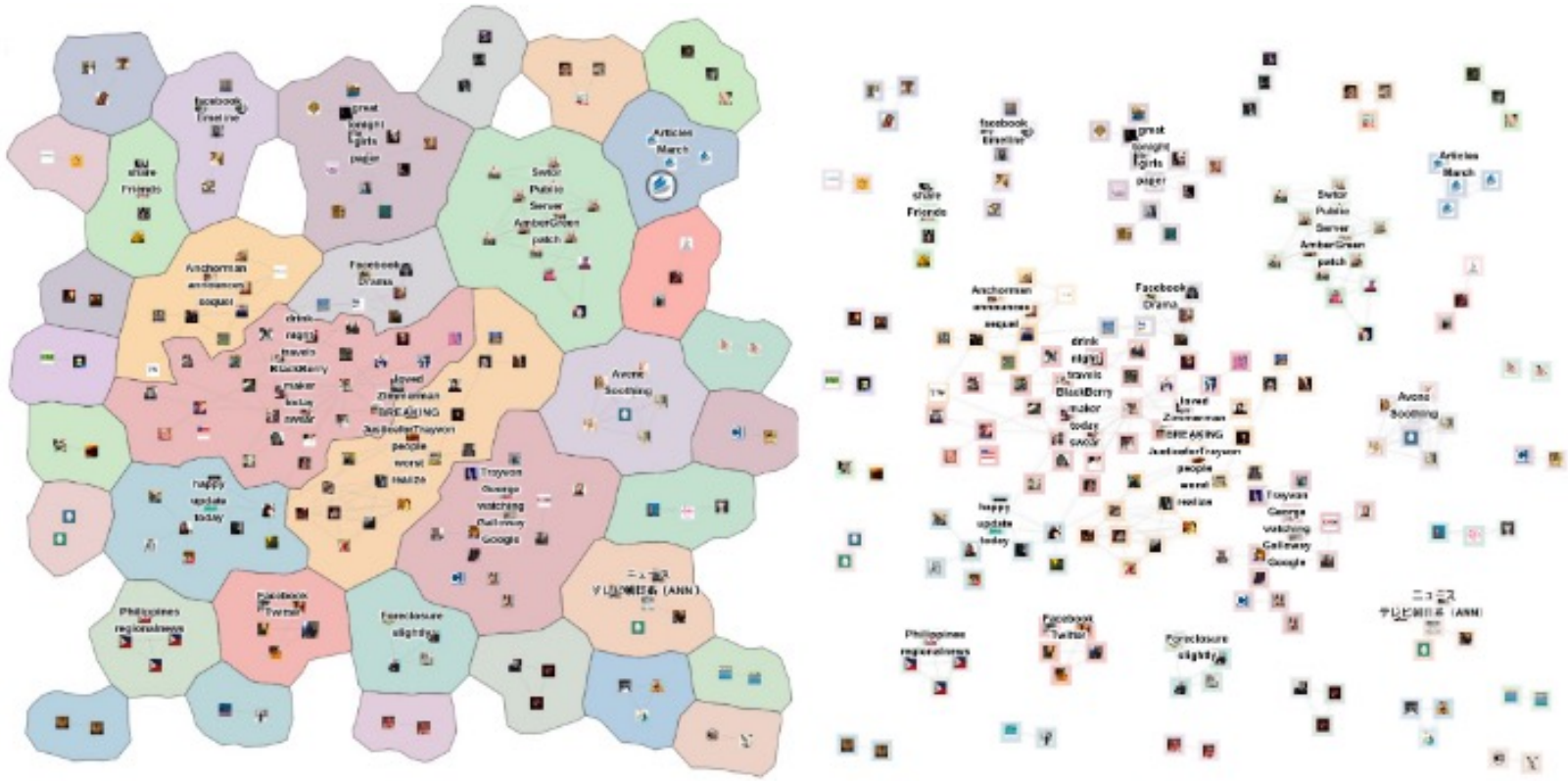


Common Region

- 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.

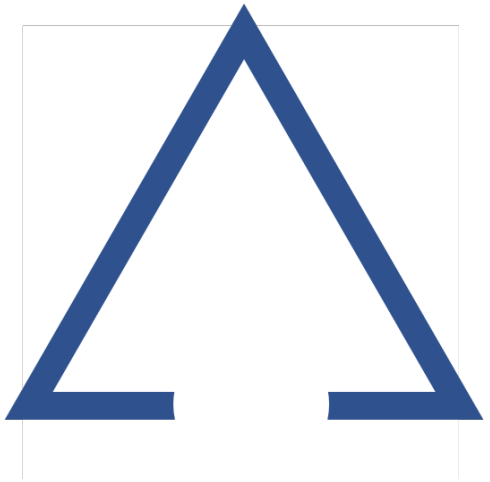


A map metaphor visualization (left) seems more appealing than a plain graph layout (right), and clusters seem easier to identify.

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.

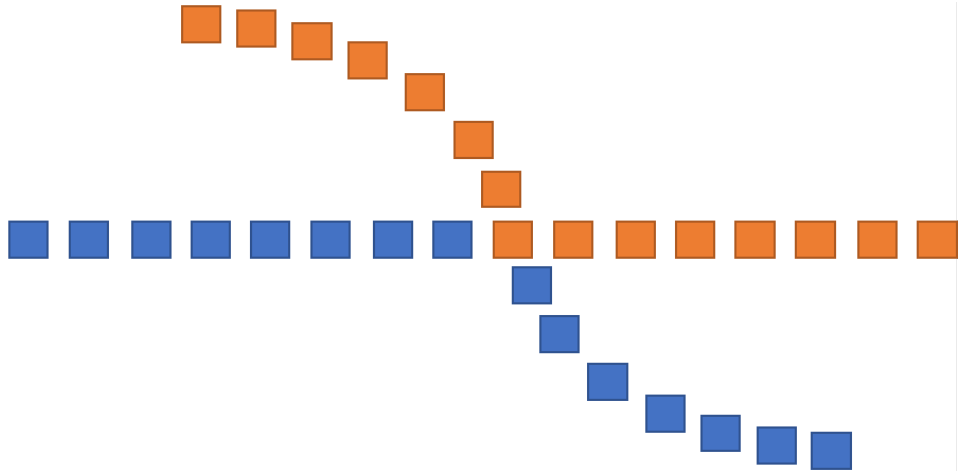
Closure

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



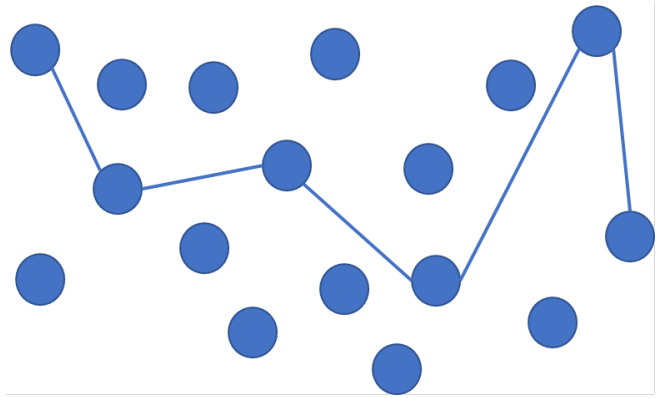
Continuity

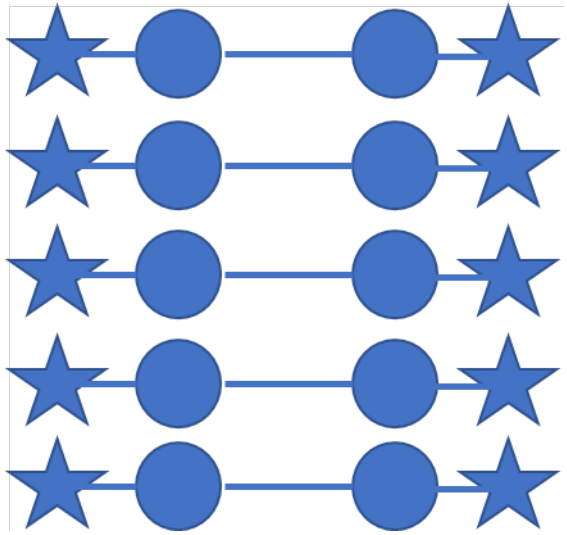
- Entities that are arranged on a line or curve are perceived to be more related than elements not on the line or curve

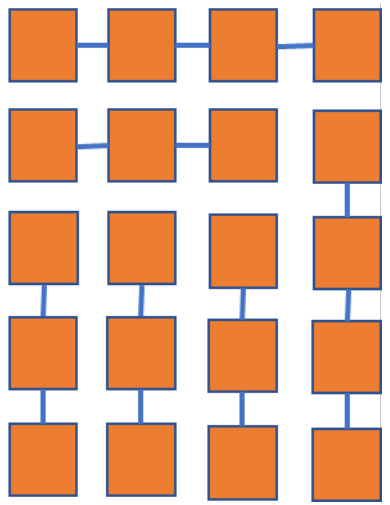


Connection / Connectedness

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

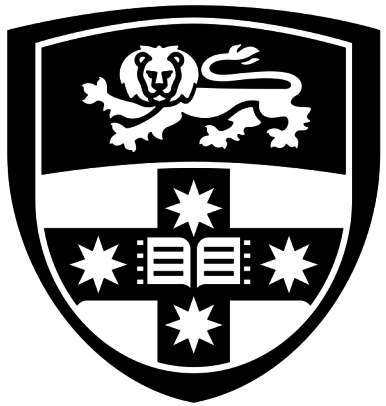






Summary

- 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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