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Jacques Bertin:  
The Semiology of Graphics

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## Jacques Bertin (1918-2010)

- French cartographer
- *Semiolegie Graphique: Les Diagrammes, Les Reseaux, Les Cartes*, Mouton, 1967
- *Semiology of Graphics: Diagrams, Networks, Maps* (English translation by W.J.Borg), University of Wisconsin Press, 1983
- Mostly interested in the depiction of symbols on maps, but his framework also covers a range of diagrams, networks and data charts
- References
  - Monmonier, M. (1983) *Mapping It Out: Expository Cartography for the Humanities and Social Sciences*, Chicago Guides to Writing, Editing, and Publishing.
  - Roth, R.E. (2017) *Visual Variables*. The International Encyclopedia of Geography, John Wiley & Sons, Ltd.
  - Carpendale, M.S.T. (2001) *Considering Visual Variables as a Basis for Information Visualisation*. University of Calgary Technical Report, <https://prism.ucalgary.ca/handle/1880/45758>.
  - Treisman, A. (1985) *Preattentive processing in vision*, Computer Vision, Graphics, and Image Processing, 31(2), pp156-177

## Semiotics (in brief)

- Visualisation facilitates communication between people
- Visualisation therefore is a **visual language**
- Like all languages, it has **tokens** (words, signs) and **rules** describing how the tokens can legitimately be combined (syntax)

Semiotics is the study of signs and how they convey meaning

## The nature of signs

Signs can be:

- **symbols**: there is no perceptual relationship between the object and what it is meant to represent (arbitrary)
- **icons**: there is a clear perceptual relationship between the object and what it is meant to represent (non-arbitrary)



“An absolute boundary between symbols and icons is illusory because as soon as a symbol’s meaning has been learned it will become a meaningful image”

(Sutcliffe (2013), Human-Computer Interface Design, pg164)

- Bertin defined a set of “**visual variables**”
- The various ways a visual object can be displayed (and therefore perceived)
- Independent of each other
- Reducing the map/visualisation into its constituent graphical symbols, for critical analysis

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

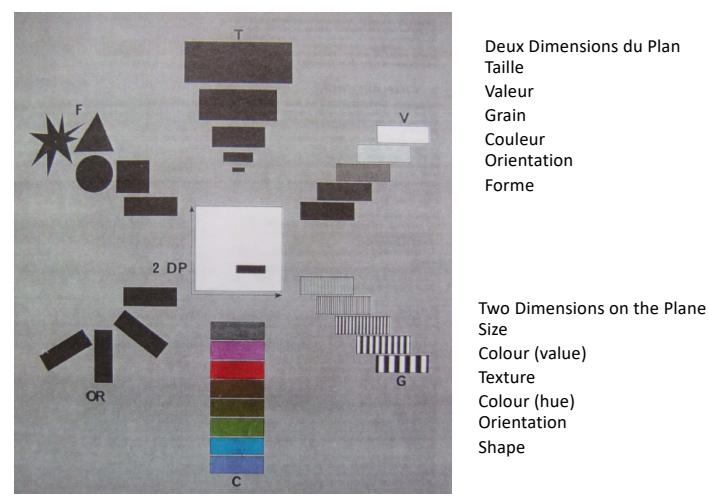
## Bertin's Visual Variables

- **Location variables** (position, relative to a coordinate frame)
  - e.g. horizontal and vertical axes on a scatterplot; longitude and latitude on a map
  - (so fundamental to presenting map information that these variables are often ignored in cartography)
- **Retinal variables** (perceptual properties)
  - ways of representing differences between objects
  - size, shape, colour (hue), colour (value), texture, orientation

*This separation makes clear the difference between the spatial relationships between symbols and the perceptual properties of the symbols themselves*

- Location variables
  - fix a 'graphic mark' (symbol, visual object) on to a position on the plane
- Retinal variables
  - 'elevate' that mark with a different 'pattern of light'

Mark Monmonier, *Mapping It Out* (1993)



Bertin, *Sémiologie Graphique* (1967)

## The Six Retinal Variables

- **Shape:** (e.g. square, circle, star)
- **Size:** (e.g. measured in mm or pixels)
- **Orientation:** angle of most prominent axis in the symbol to the coordinate axes (e.g.  $36^\circ, 218^\circ$ )
- **Texture:** spacing between repeated elements of a symbol (e.g. fine, coarse)
- **Hue:** colour, as associated with wavelength (e.g. blue, green, turquoise)
- **Value:** depth of colour, as associated ink density and represented by greyscale (e.g. red ink with low value will be perceived as pink)

Mark Monmonier, *Mapping It Out* (1993)

Bertin's Original Visual Variables	
<b>Position</b> changes in the x, y location	
<b>Size</b> change in length, area or repetition	
<b>Shape</b> infinite number of shapes	
<b>Value</b> changes from light to dark	
<b>Colour</b> changes in hue at a given value	
<b>Orientation</b> changes in alignment	
<b>Texture</b> variation in 'grain'	

Carpendale, M.S.T. (2001) Considering Visual Variables as a Basis for Information Visualisation.

## Pre-attentive processing

Visual variables are recognised immediately

- “pre-conceptually”
- at a sensory level (rather than cognitive level)
- “seen” rather than “understood”
- Often called “pop-out” (Treisman, 1985)
- Also, 4 categories of perception of visual variables:
  - Associative/dissociative, selective, ordered, and quantitative

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

Note that the categories can overlap

## Associative variable (Bertin)

All variations are perceived equally  
(e.g. location, shape, orientation, colour hue, texture)

No colour is seen as more prominent than another



No shape is seen as more prominent than another



Allows for other variations to be noticed (e.g. different colour values)

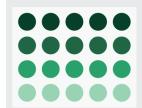
Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

Note that this kind of variable would be good for data that is *nominal*, with different values but no order

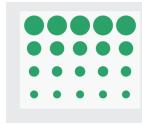
## Dissociative variable (Bertin)

One variable dominates others (size, colour value)

The eye is drawn to the darker colour values



Larger sizes are seen as more dominant than smaller ones



Variation in other variables is likely to be overlooked (e.g. different hues)

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

## Ordered variable (Bertin)

Variations are perceived as being ranked in order  
(e.g., colour value)

Green hue is not seen as 'more' than purple or red



Darker value circles are seen as 'more' than the lighter ones



Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

Note that this kind of variable would be good for data that is *ordinal*, with different ordered values... but no metric of distance between them

## Quantitative variable (Bertin)

*(an extension of ordered perception)*

The variation can be quantitatively estimated  
(location, size)

Darker circles are seen as 'more' than the lighter ones,  
but it is difficult to estimate how much more



It is possible to estimate how much more the larger  
circles represent, compared to the smaller ones



Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

Note that this kind of variable would be good for data that is *numerical* (or *quantitative*), with different ordered values... and also a metric of distance between them

## Using the variables

### **Unordered** (*colour hue, orientation, shape, texture*)

for **nominal** information: apples, oranges, pears

### **Ordered, non-quantitative** (*colour value*)

for **ordinal** information: rainfall map of low/medium/high

### **Ordered, quantitative** (*location, size*)

for **numerical** information: electricity usage

(also good for non-quantitative and nominal information given their visual dominance)

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

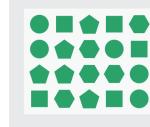
## Also: Selective perception (Bertin)

It is possible to focus on the variations of the variable,  
despite variations in other variables  
(only shape is not selective)

Easy to see the distribution of red circles, despite  
location changes



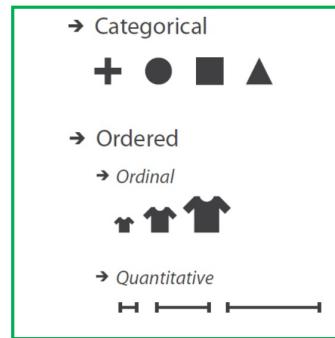
Not so easy to see the distribution of hexagons, even though  
they are distributed in the same way as the red circles above



Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

This is a different issue or categorization than (dis)associative/ordered/quantitative

## Data attributes



- Categorical/ “nominal”
  - no implicit order
  - **Names of fruit**
- Ordinal
  - implicit order
  - non-numerical
  - **Low/medium/high rainfall**
- Quantitative
  - implicit order
  - numerical
  - **Electricity usage**

From “Visualization Analysis & Design”, T. Munzner, , CRC Press, 2015, (Chapter 2)

## Visual variables and data attributes

	Ground	Figure	Associative	Selective	Normal (non-ordered)	Ordinal (ordered)	Numerical (quantitative)
Location	Y	Y	G	G	G		
Size	N	Y	G	G	G		
Shape	Y	N	G	P	P		
Orientation	Y	Y	G	M	M		
Color hue	Y	Y	G	M	M		
Color value	N	Y	P	G	M		
Texture	Y	Y	G	M	M		

Y=yes

N=no

G=good

M=marginal

P=poor

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)  
derived from Bertin (1967/1983), MacEachren (1995), and MacEachren *et al.* (2012).

'Figure' refers to the variation that stands out most; ground refers to the variation that recedes. (I assume this is empirically based, not speculative)

Associative: all variations perceived equally

Selective: can focus on variation, despite changes in other variables

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## Aside: “pop-out”

Is there an order for which some variables are pre-attentively more prominent than others?

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based on: A. Treisman, *Preattentive processing in vision*, 1985.

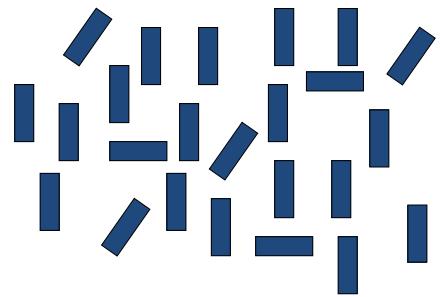
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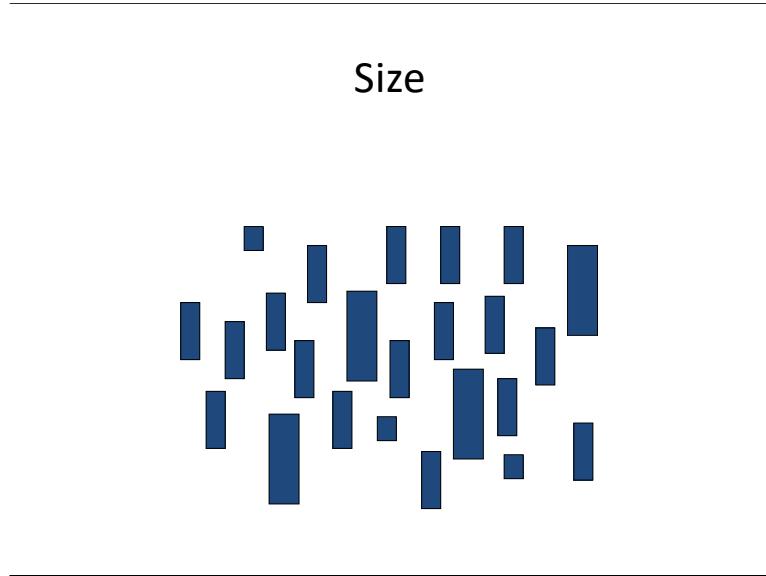
Pop-out examples follow...

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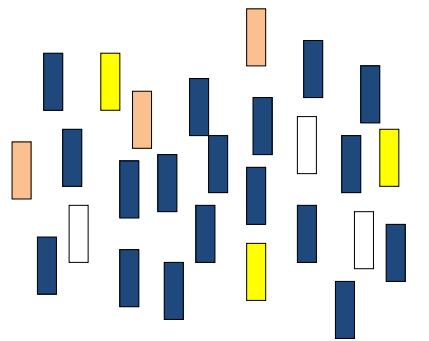
## Orientation





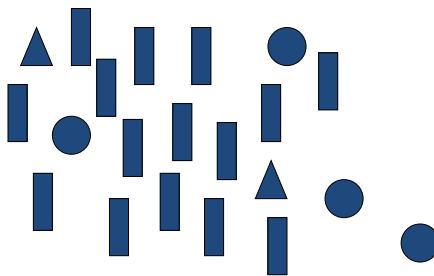
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## Colour



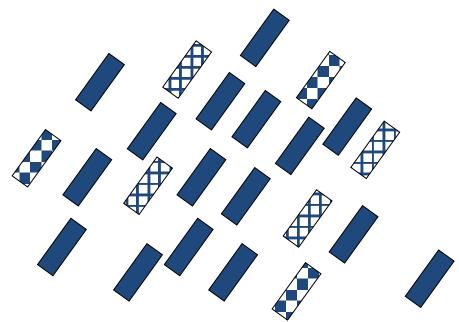
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## Shape



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## Texture



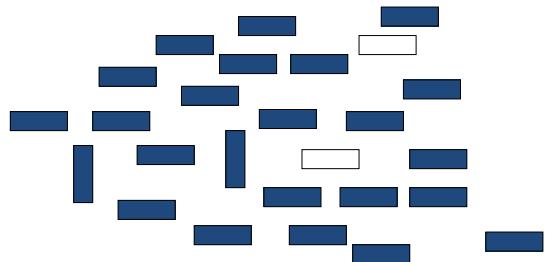
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What if there are two variations?

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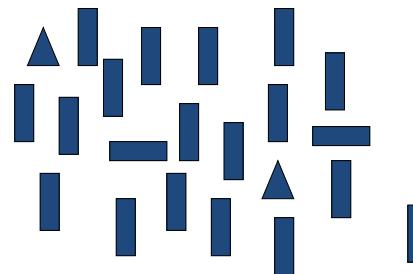
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## Colour vs orientation



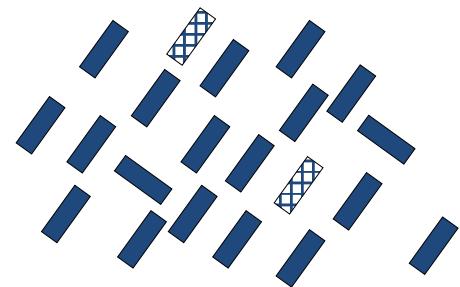
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## Shape vs orientation



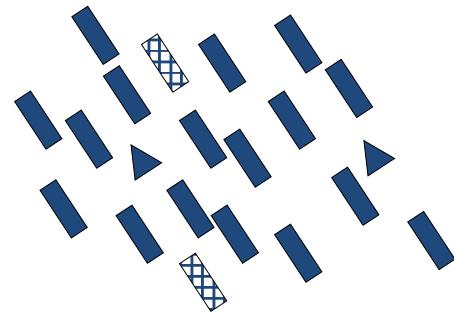
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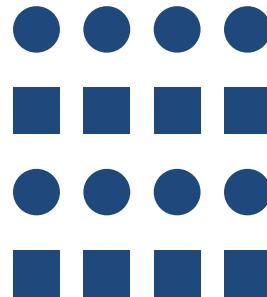
## Texture vs orientation

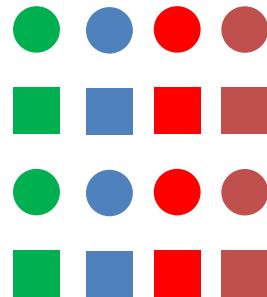


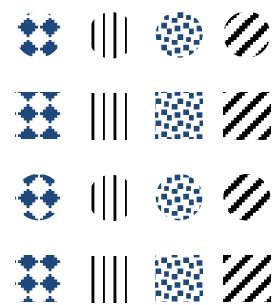
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## Texture vs shape









## Extensions to Bertin's Visual Variables

- Morrison (1974)
    - colour saturation, arrangement
    - particularly for cartographic purposes
  - MacEachren (1995)
    - crispness, resolution, transparency
    - variations enabled by digital manipulation
- (see Roth for details)

Robert E. Roth, *Visual Variables*, The International Encyclopedia of Geography (2017)

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