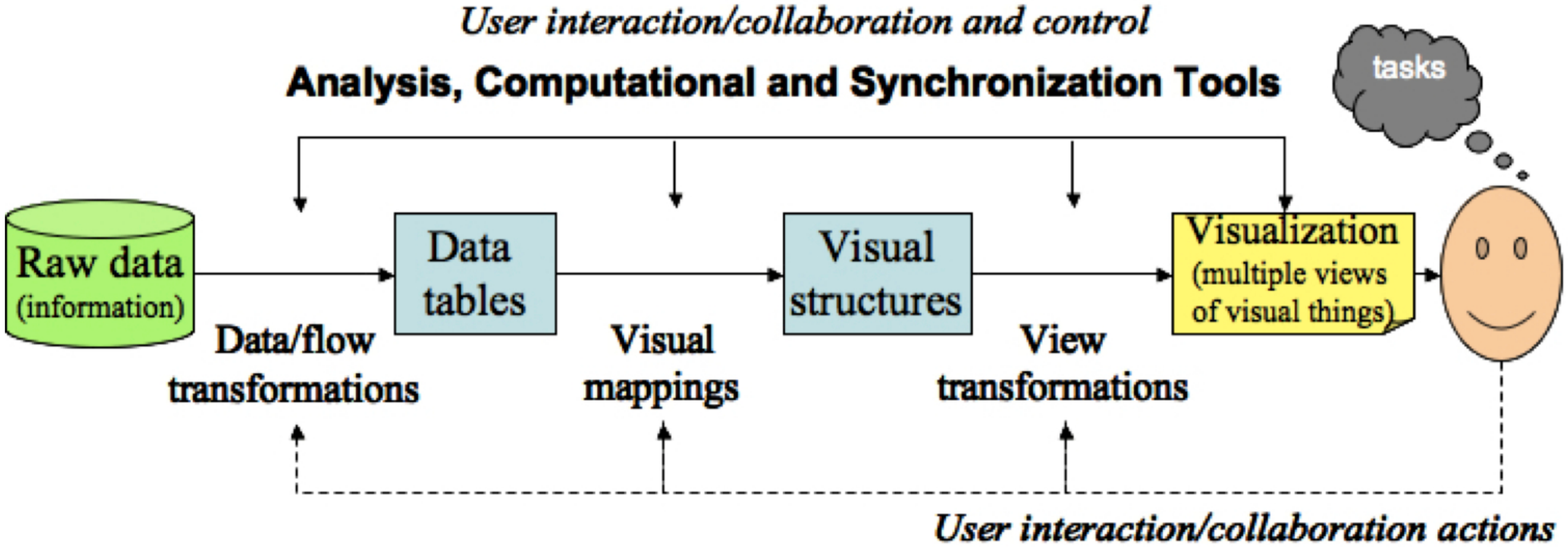

data
representation

(96% recovery)

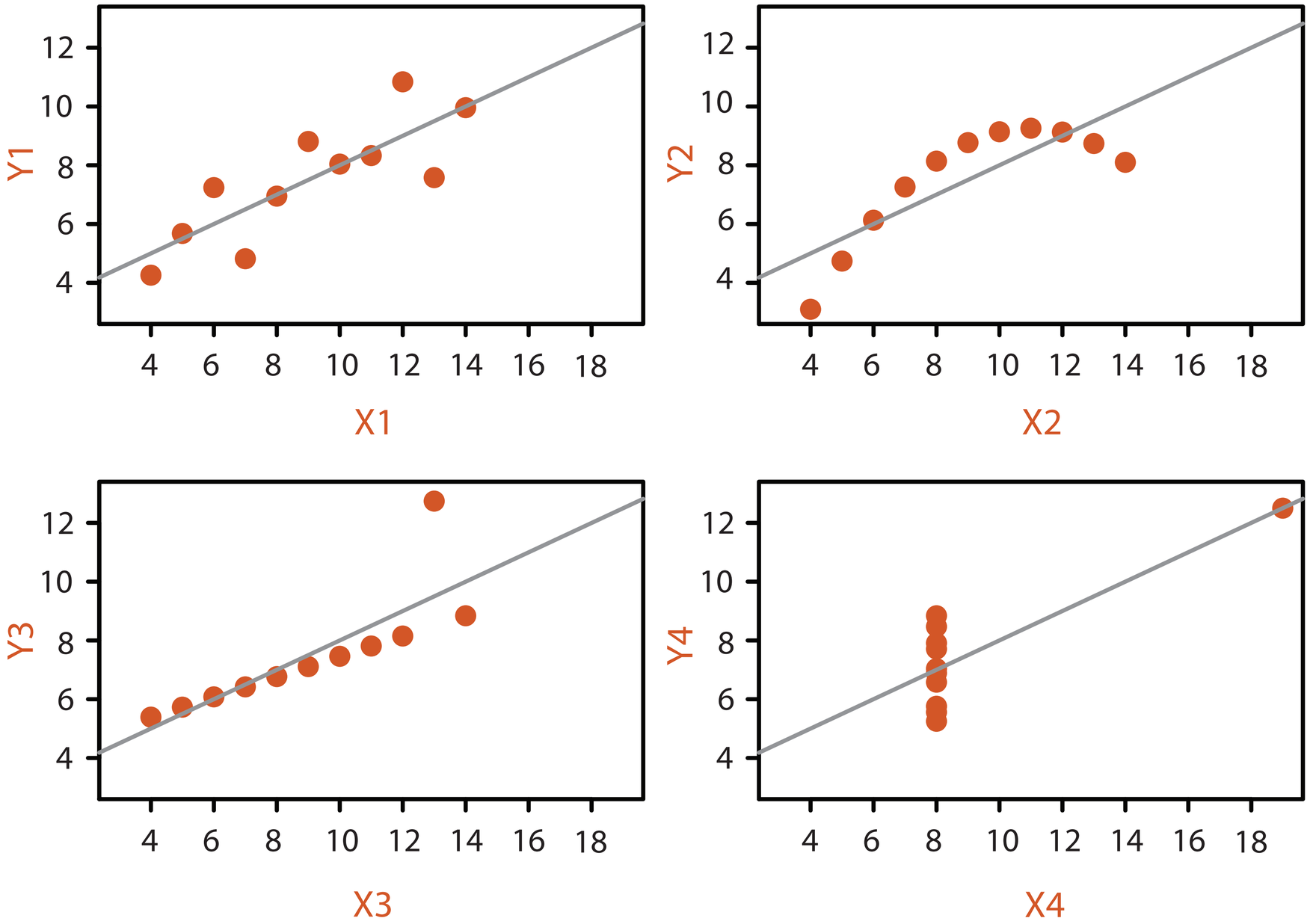

User interaction/collaboration and control
Analysis, Computational and Synchronization Tools
tasks
Raw data
(information)
Data
tables
Visual
structures
Visualization
(multiple views
of visual things)
Data/flow
transformations
Visual
mappings
View
transformations
User interaction/collaboration actions

10.0	8.04
8.0	6.95
13.0	7.58
9.0	8.81
11.0	8.33
14.0	9.96
6.0	7.24
4.0	4.26
12.0	10.84
7.0	4.82
5.0	5.68

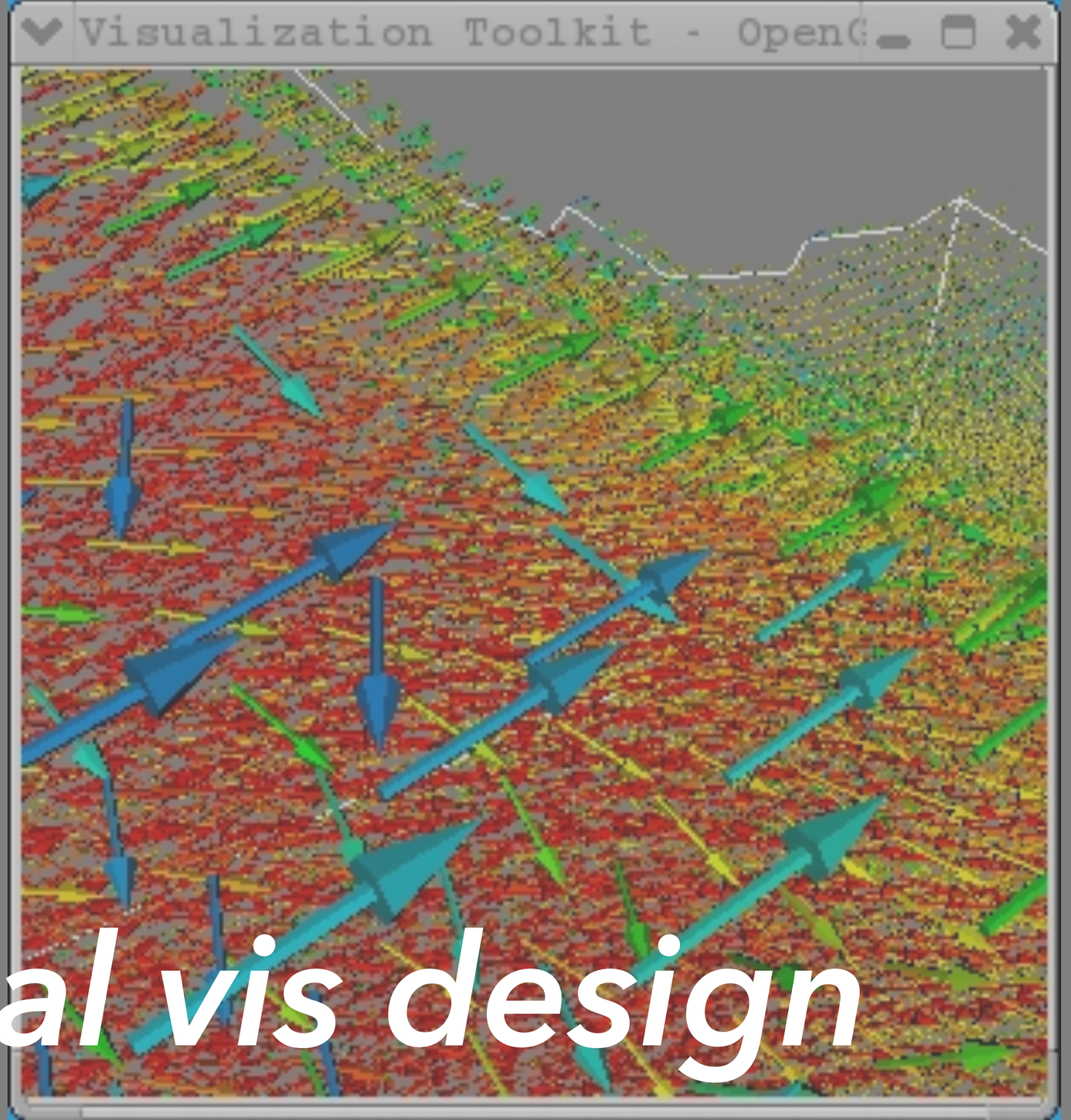
	10.0	8.04
	8.0	6.95
	13.0	7.58
	9.0	8.81
	11.0	8.33
	14.0	9.96
	6.0	7.24
	4.0	4.26
	12.0	10.84
	7.0	4.82
	5.0	5.68
Mean	9.0	7.5
Variance	10.0	3.75

	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
	10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
	8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
	13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
	9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
	11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
	14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
	6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
	4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
	12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
	7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
	5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89
Mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5
Variance	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75

	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
	10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
	8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
	13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
	9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
	11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
	14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
	6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
	4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
	12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
	7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
	5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89
Mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5
Variance	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75
Correlation	0.816		0.816		0.816		0.816	

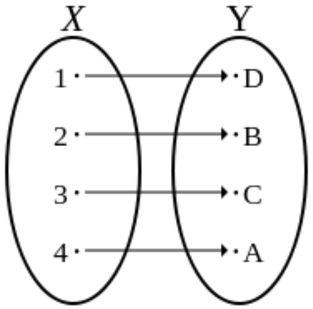

Y1
X1
Y2
X2
Y3
X3
Y4
X4
4
6
8
10
12
14
16
18

Tableau

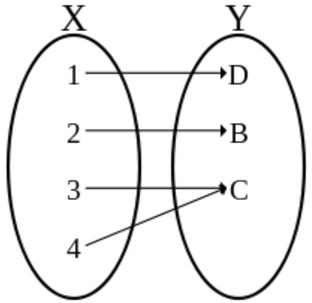


typical vis design

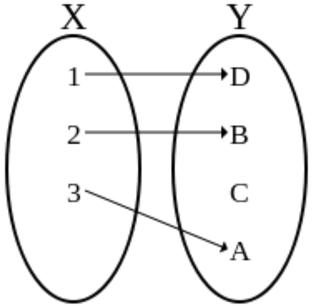
Key question: how to map data to visuals?



Bijection (one visual attribute, one data attribute)



Surjection (multiple visual attribute to one data attribute)



Injection (One to one mapping, but not all data elements are mapped)

Set Theory

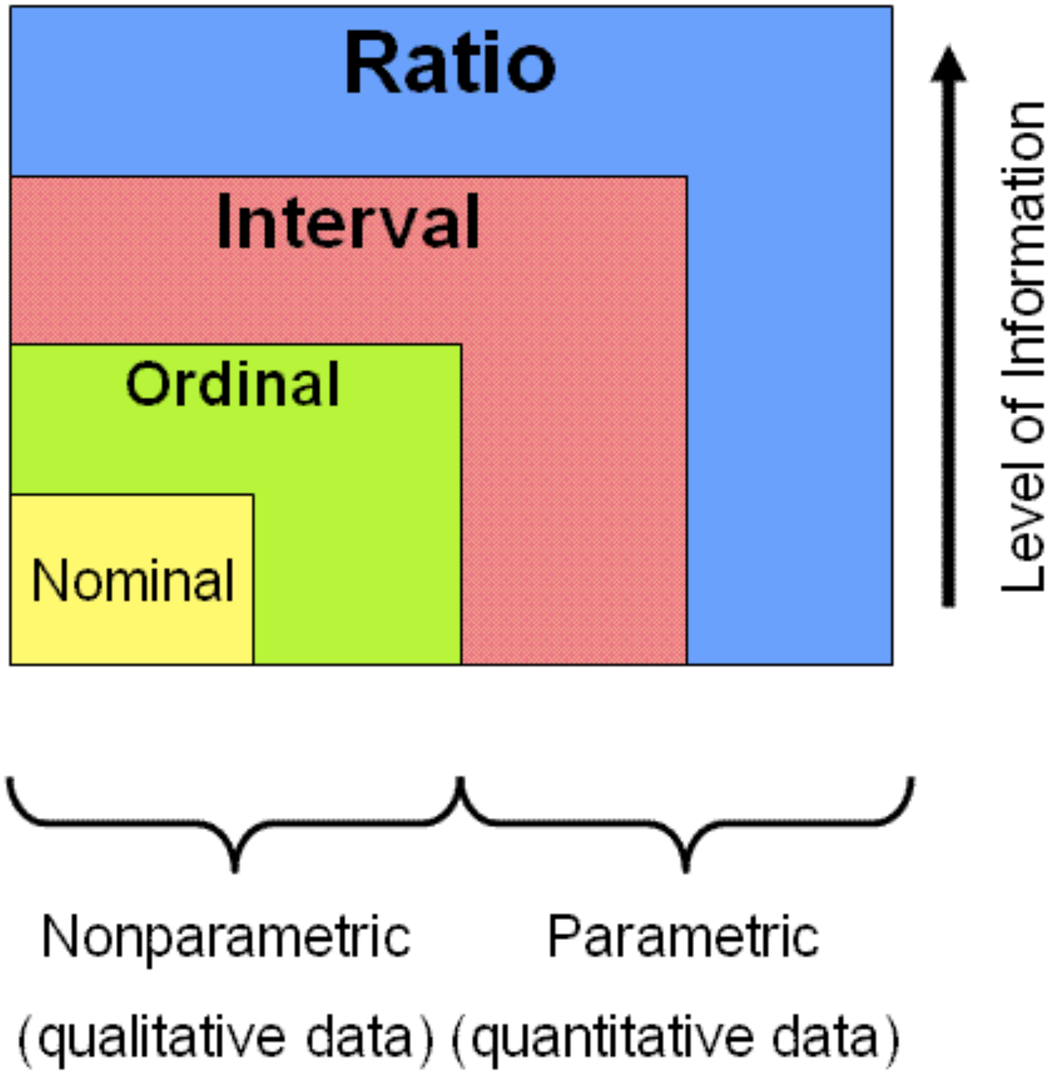
What happens when

Data Vars > Visual Vars ?

What happens when

Visual Vars > Data Vars ?

Data Attributes


Ratio
Interval
Ordinal
Nominal
Level of Information
Nonparametric
(qualitative data)
Parametric
(quantitative data)

Non-ordered and non-numeric

AKA categorical data

[‘apple’, ‘pear’, ‘banana’]

nominal

Ordered, not necessarily numeric

[1st, 3rd, 5th, 7th] 1st -> 3rd

[‘G’, ‘PG’, ‘PG-13’, ‘R’] PG -> R

ordinal

Ordered, not necessarily numeric

[1st, 3rd, 5th, 7th] 1st -> 3rd

[‘G’, ‘PG’, ‘PG-13’, ‘R’] PG -> R

length is not meaningful

ordinal

Ordered, numeric, not ratio-able

[‘Jan 12’, ‘Jan 20’]

Jan 12/Jan 20 = ???

[’17°’, ‘44°’, ‘23°’, ‘30°’]

23° / 30° = ???

interval

Ordered, numeric, ratio-able (has a “true” 0)

[1, 3, 5, 7]

[5’8”, 6’1”, 5’4”]

ratio

Q -> O
[0-100] —> [A, B, C, D, F]

Ratio /
Interval (Q)

Ordinal

Nominal

transforms

Q -> O

[0-100] —> [A, B, C, D, F]

Ratio /
Interval (Q)

O -> N

[A, B, C, D, F] -> [B, C, F, D, A]

Ordinal

Nominal

transforms

Q -> O

[0-100] —> [A, B, C, D, F]

Ratio / Interval (Q)

O -> N

[A, B, C, D, F] -> [B, C, F, D, A]

Ordinal

N -> O

[“Jack”, “Alex”] -> [“Alex”, “Jack”]

Nominal

transforms

Q -> O

[0-100] —> [A, B, C, D, F]

Ratio / Interval (Q)

O -> N

[A, B, C, D, F] -> [B, C, F, D, A]

Ordinal

N -> O

[“Jack”, “Alex”] -> [“Alex”, “Jack”]

Nominal

O -> Q

“Alex”+”Jack” -> 7 ???

transforms

Nominal

== !=

Ordinal

> < <= >=

Interval

+ -

Ratio

/ *

operations

Nominal

== !=

Ordinal

> < <= >=

consider a
distance function...

Interval

+ -

Ratio

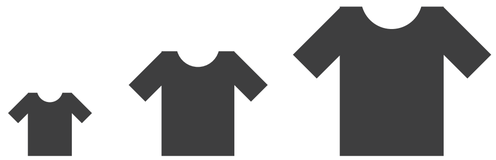
/ *

operations

Attribute Types

- Categorical

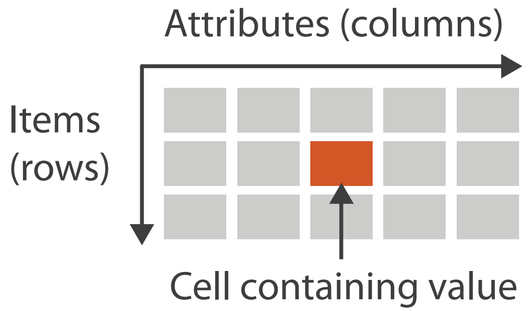
- Ordered
  - *Ordinal*



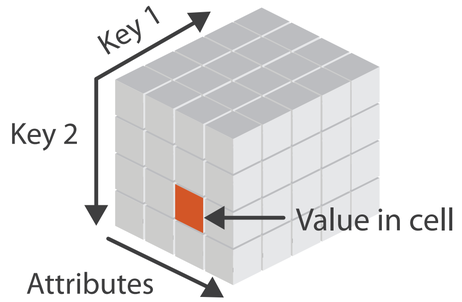
  - *Quantitative*

structure

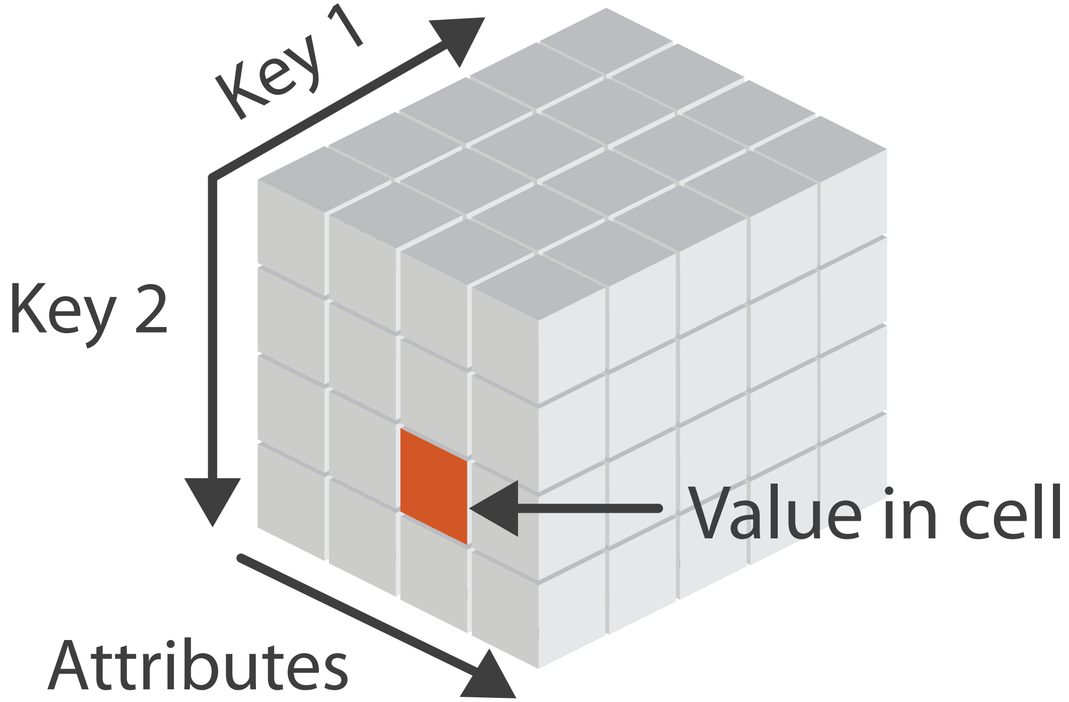
➔ Tables



➔ *Multidimensional Table*



➔ *Multidimensional Table*



Datasets

Data Types

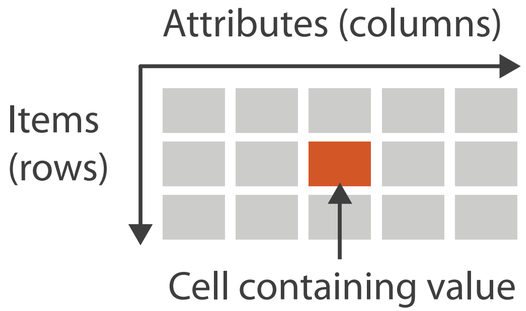
➔ Items ➔ Attributes ➔ Links ➔ Positions ➔ Grids

Data and Dataset Types

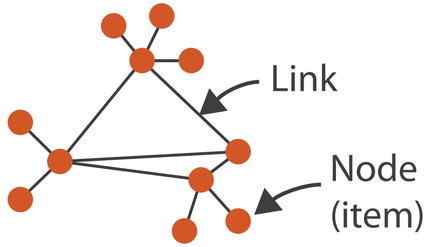
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

Dataset Types

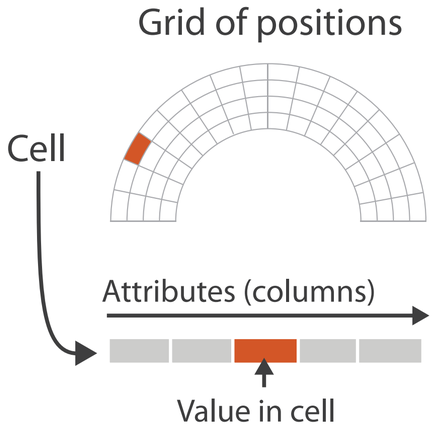
Tables



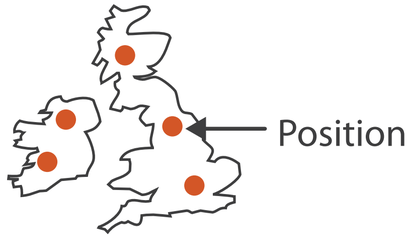
Networks



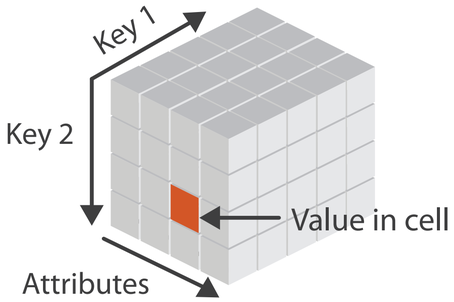
Fields (Continuous)



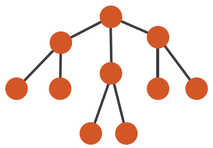
Geometry (Spatial)



Multidimensional Table



Trees



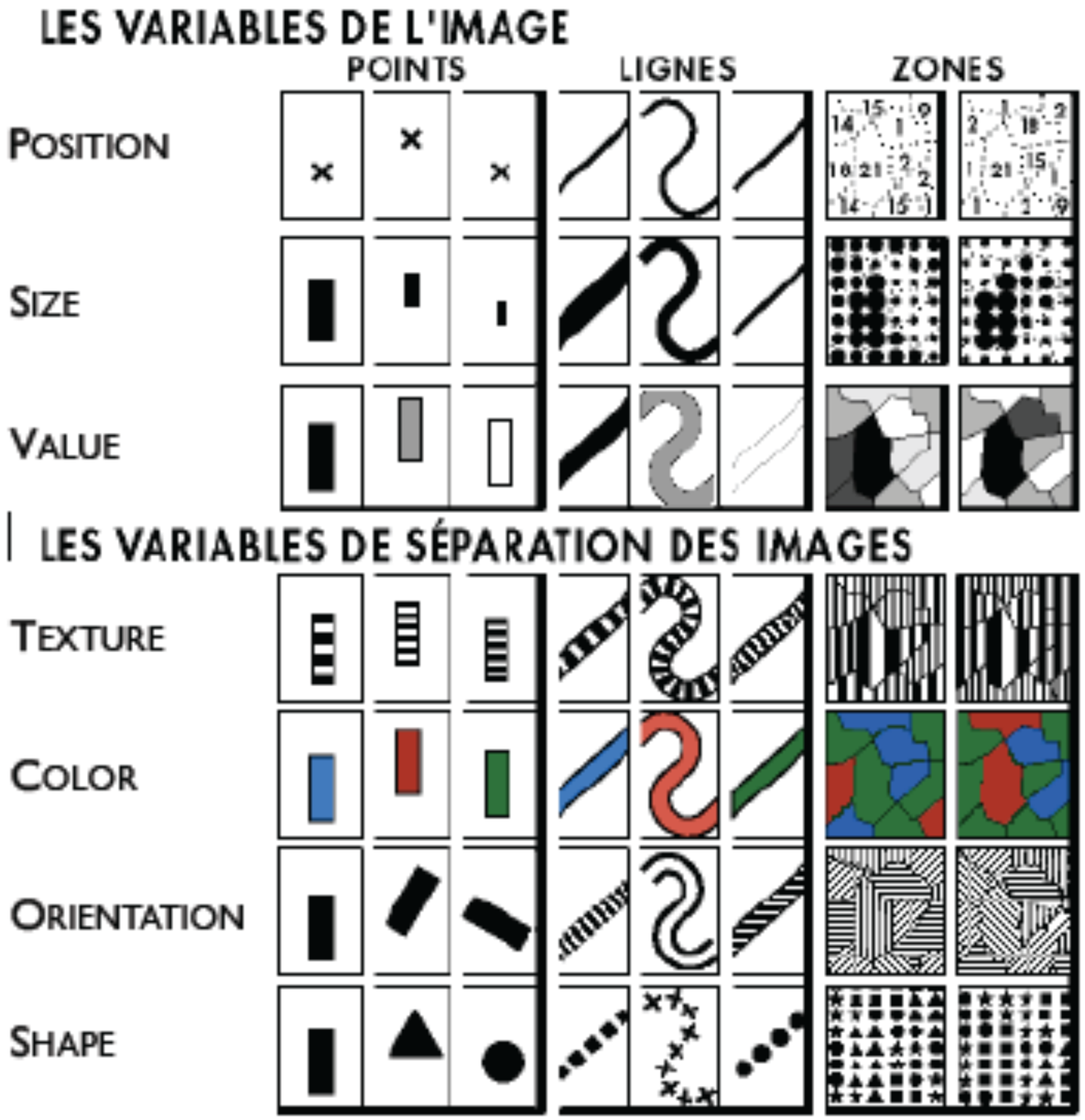
data shapes the algorithm space

data shapes the visual space

Further Reading

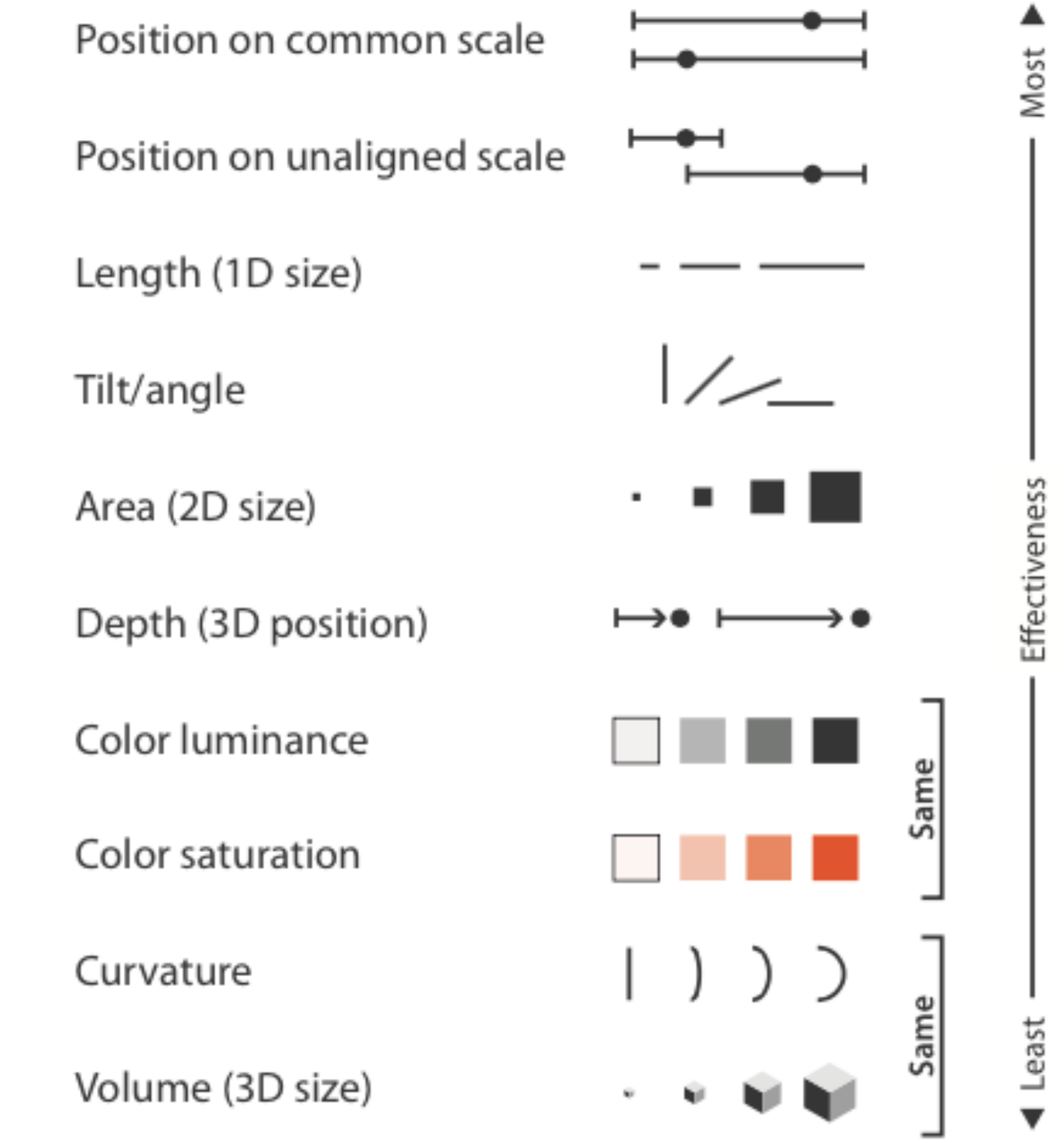
Stevens, Stanley Smith. "On the theory of scales of measurement." (1946).

Visual Attributes



Bertin, Semiologie Graphique, ‘67

Magnitude Channels: Ordered Attributes



(pay attention to your how you judge these differences)

Position (Common Scale)

-scatterplots
-bar charts
-line charts
-???

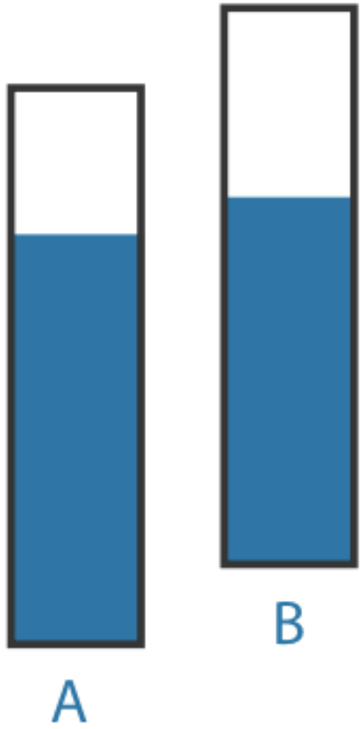
Position (Un-aligned Scale)

-stacked bars

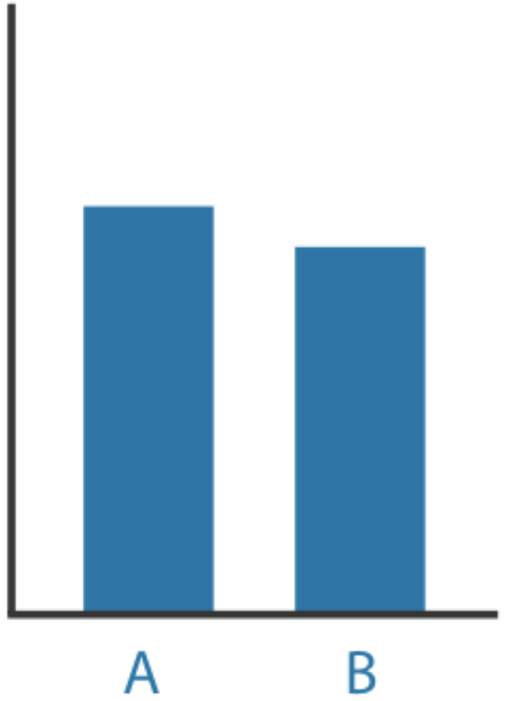
-stacked area

-???

Unframed
Unaligned

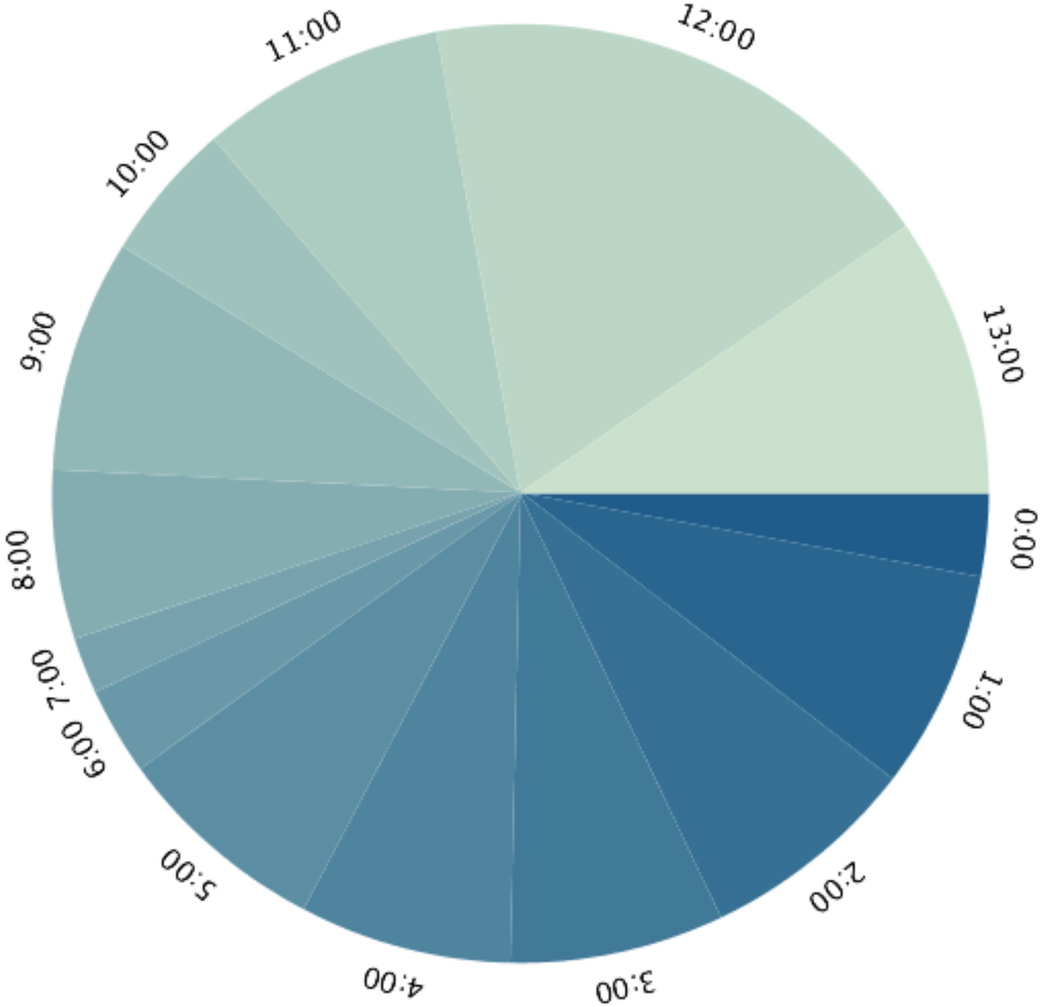


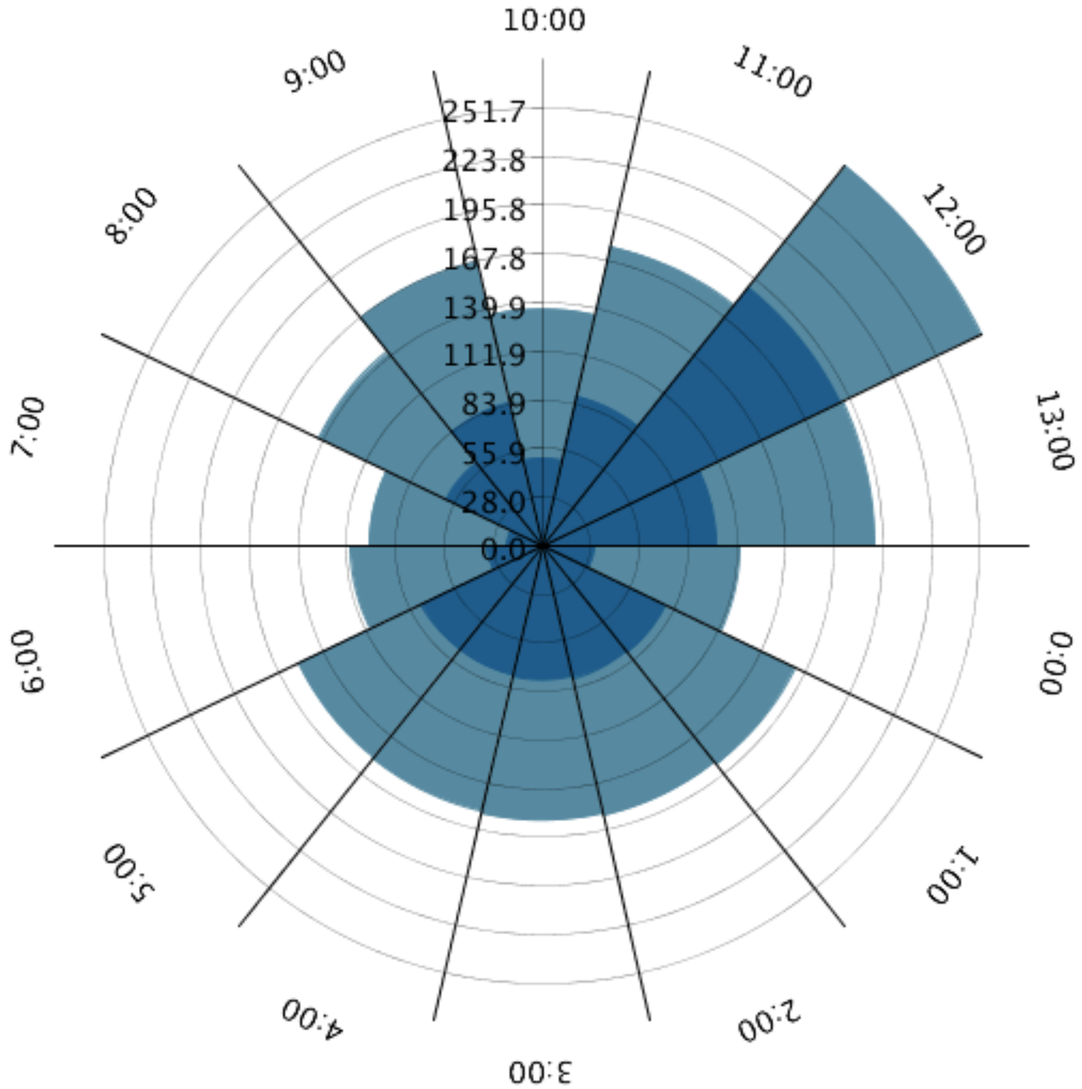
Framed
Unaligned



Unframed
Aligned

Use design elements to compensate!

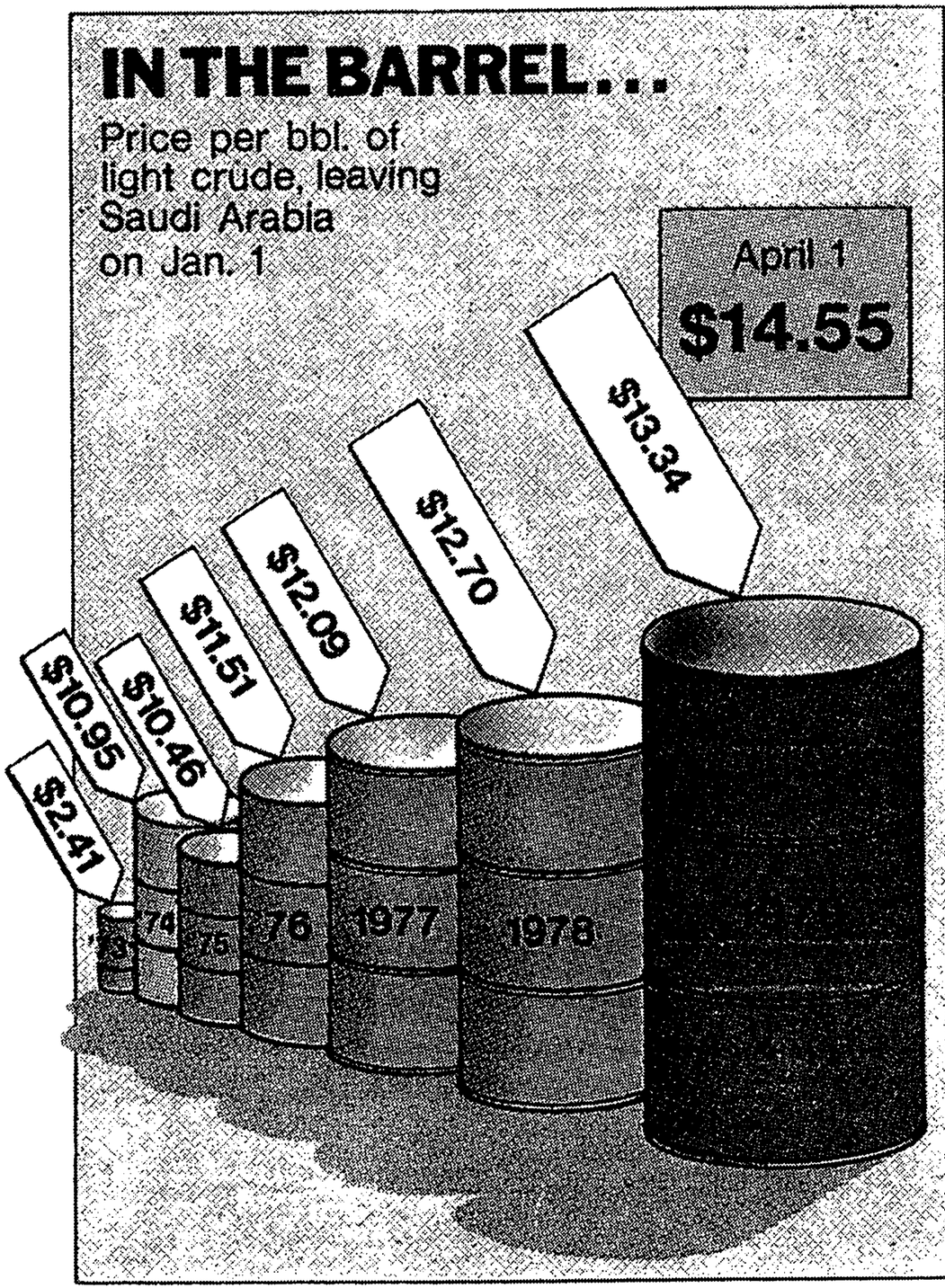

12:00
11:00
10:00
9:00
13:00
8:00
0:00
7:00
1:00
6:00
2:00
5:00
3:00
4:00


10:00
11:00
9:00
12:00
8:00
13:00
7:00
0:00
6:00
1:00
5:00
2:00
4:00
3:00
251.7
223.8
195.8
167.8
139.9
111.9
83.9
55.9
28.0
0.0

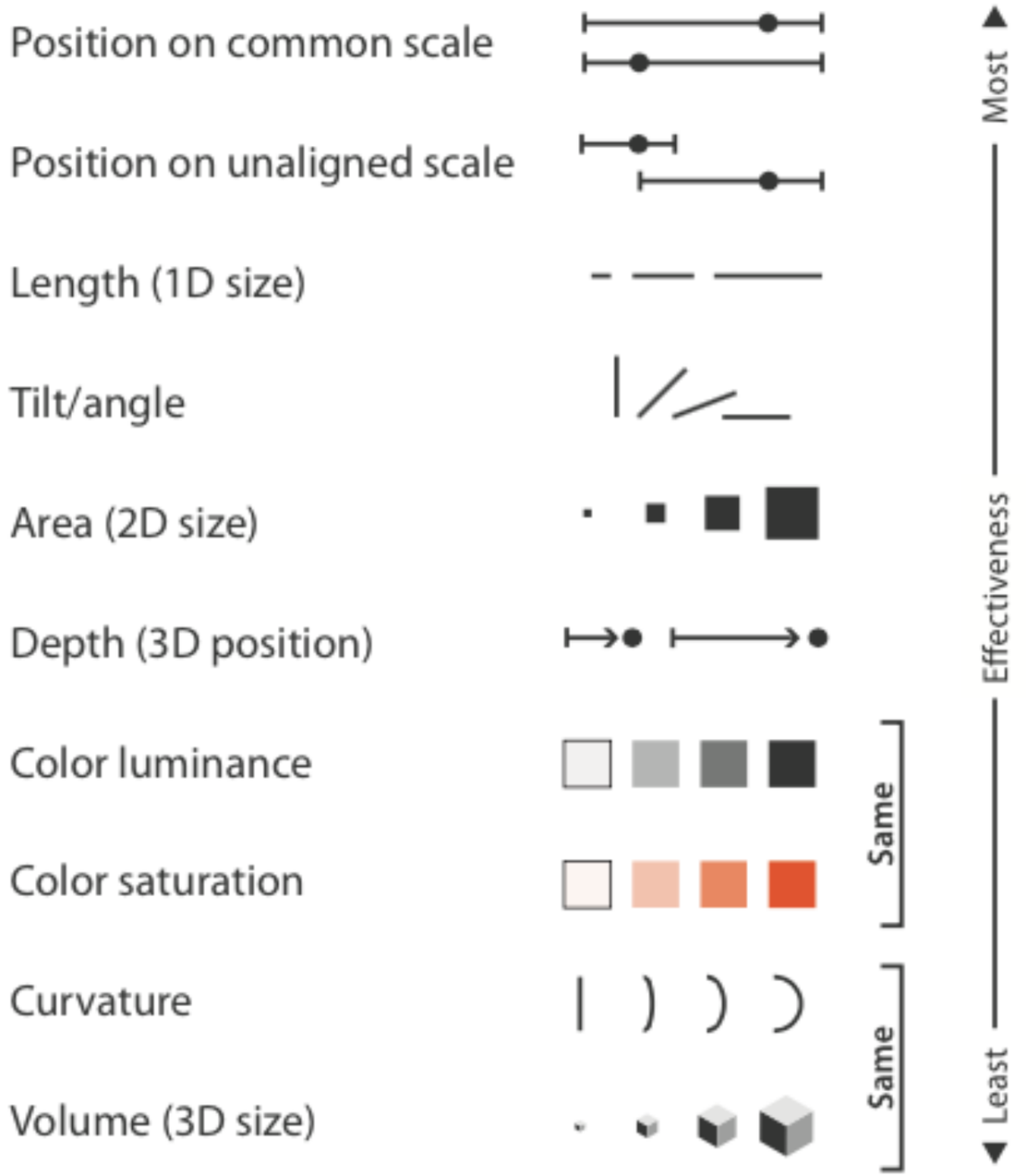
Angle

Volume

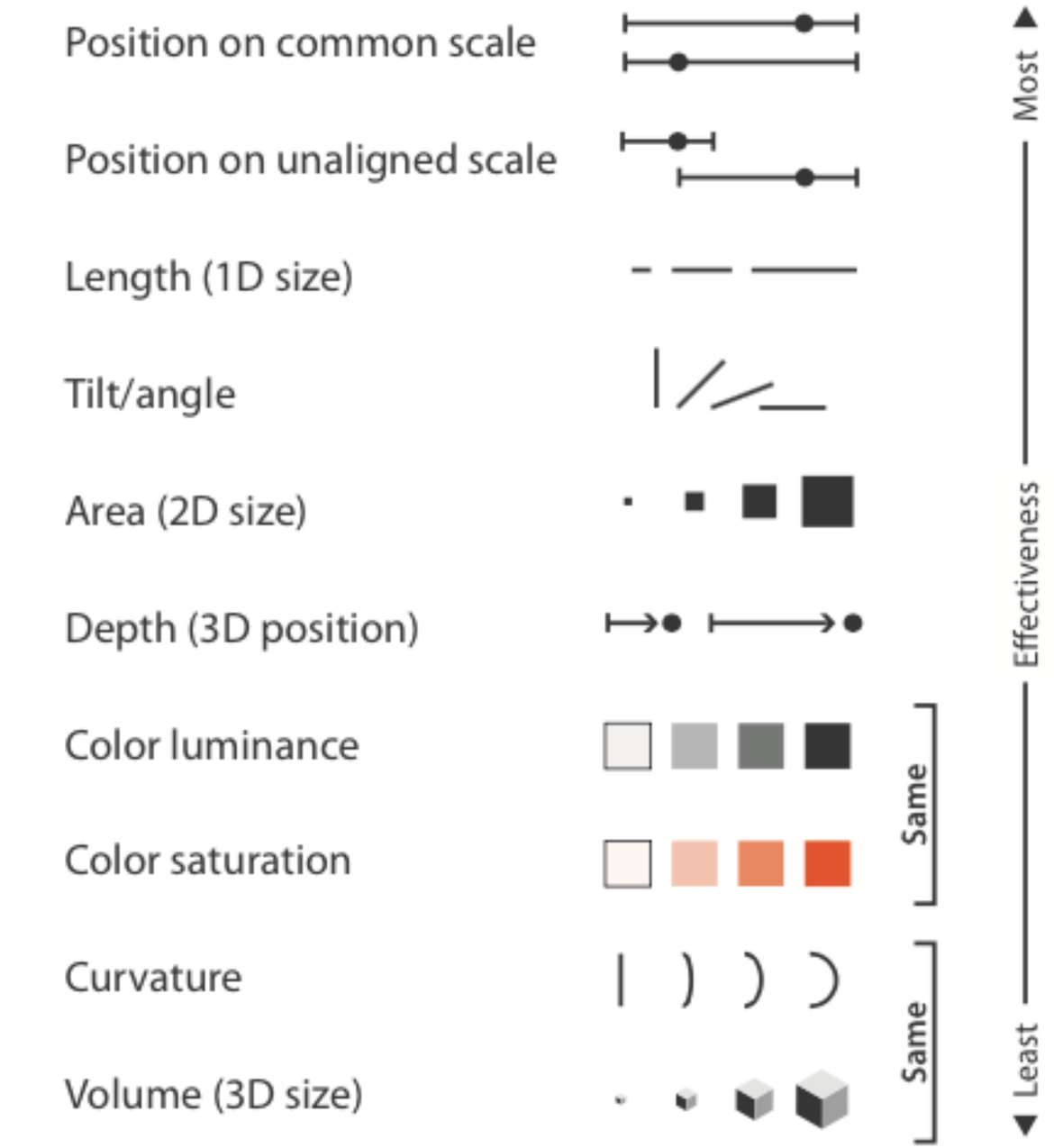
Accurate encoding does not ensure accurate perception!



Magnitude Channels: Ordered Attributes

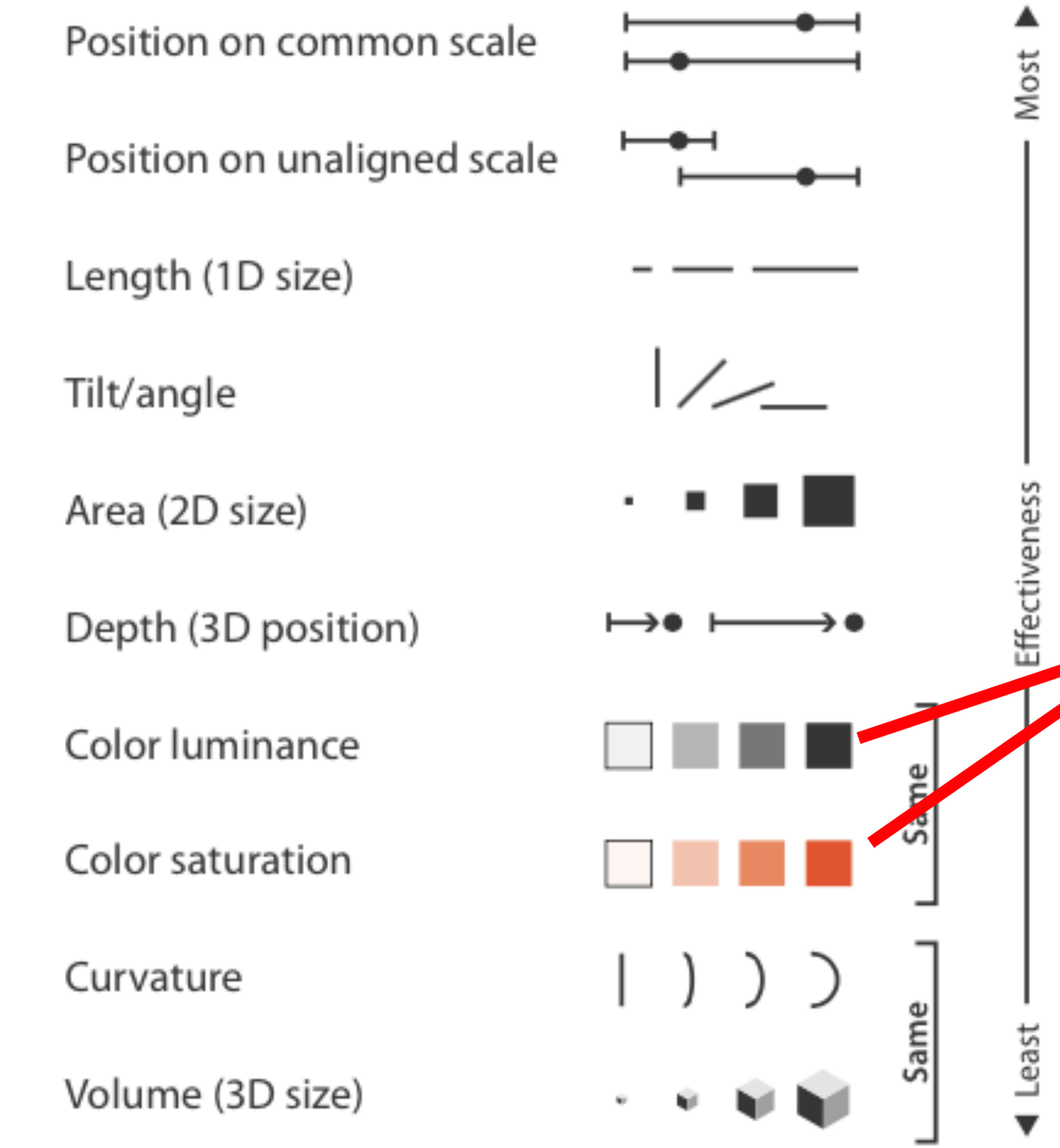


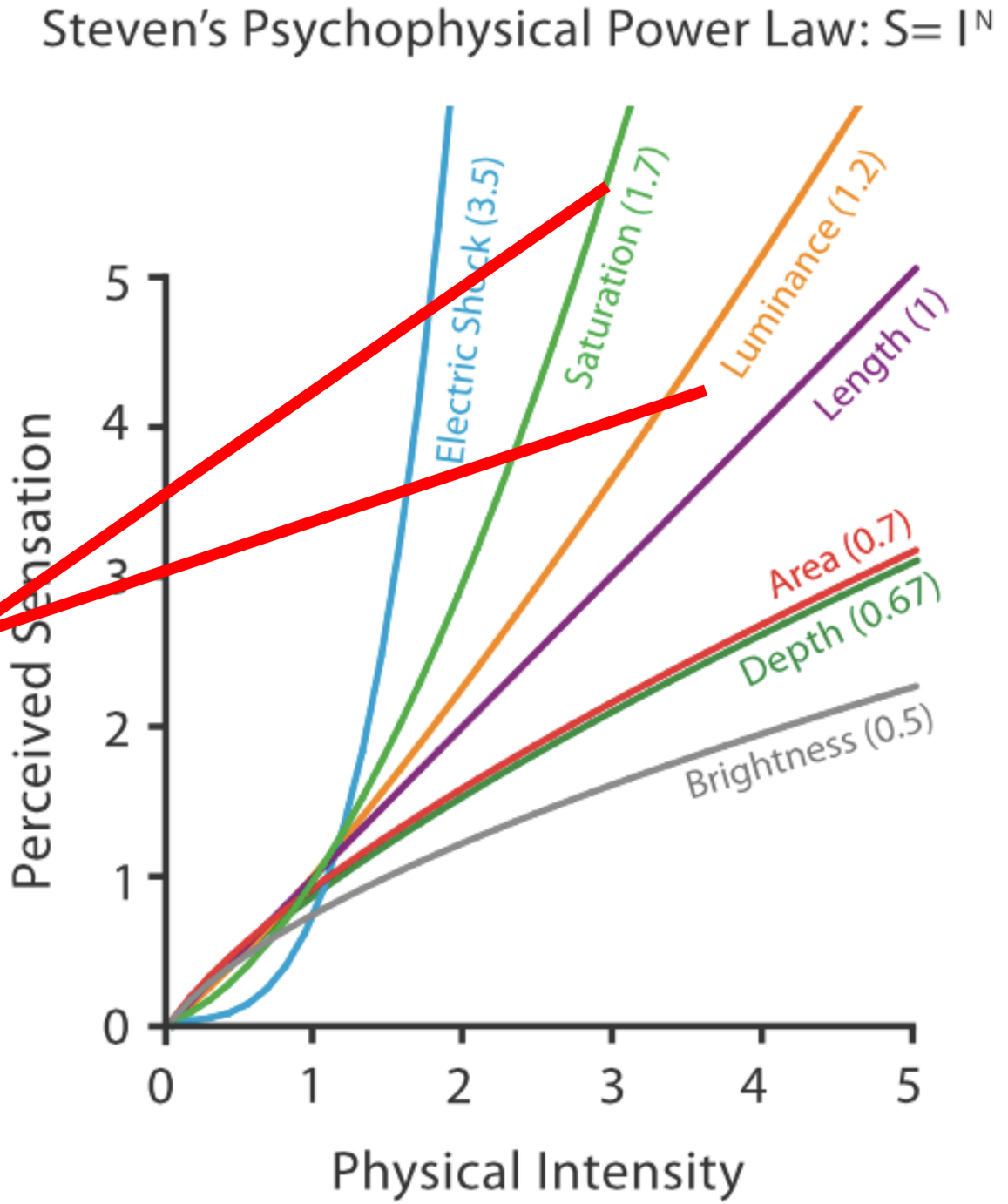
Magnitude Channels: Ordered Attributes



Luminance and Saturation—really the same?

Magnitude Channels: Ordered Attributes

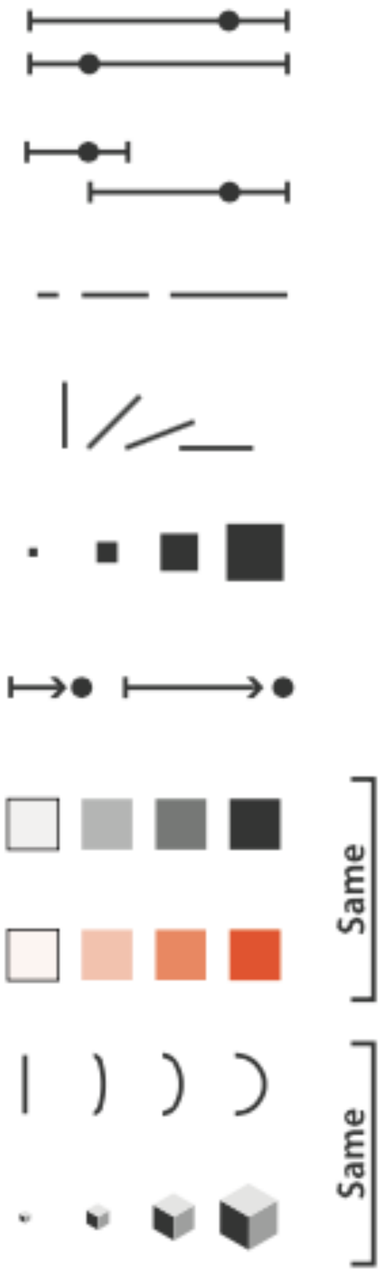




Identity

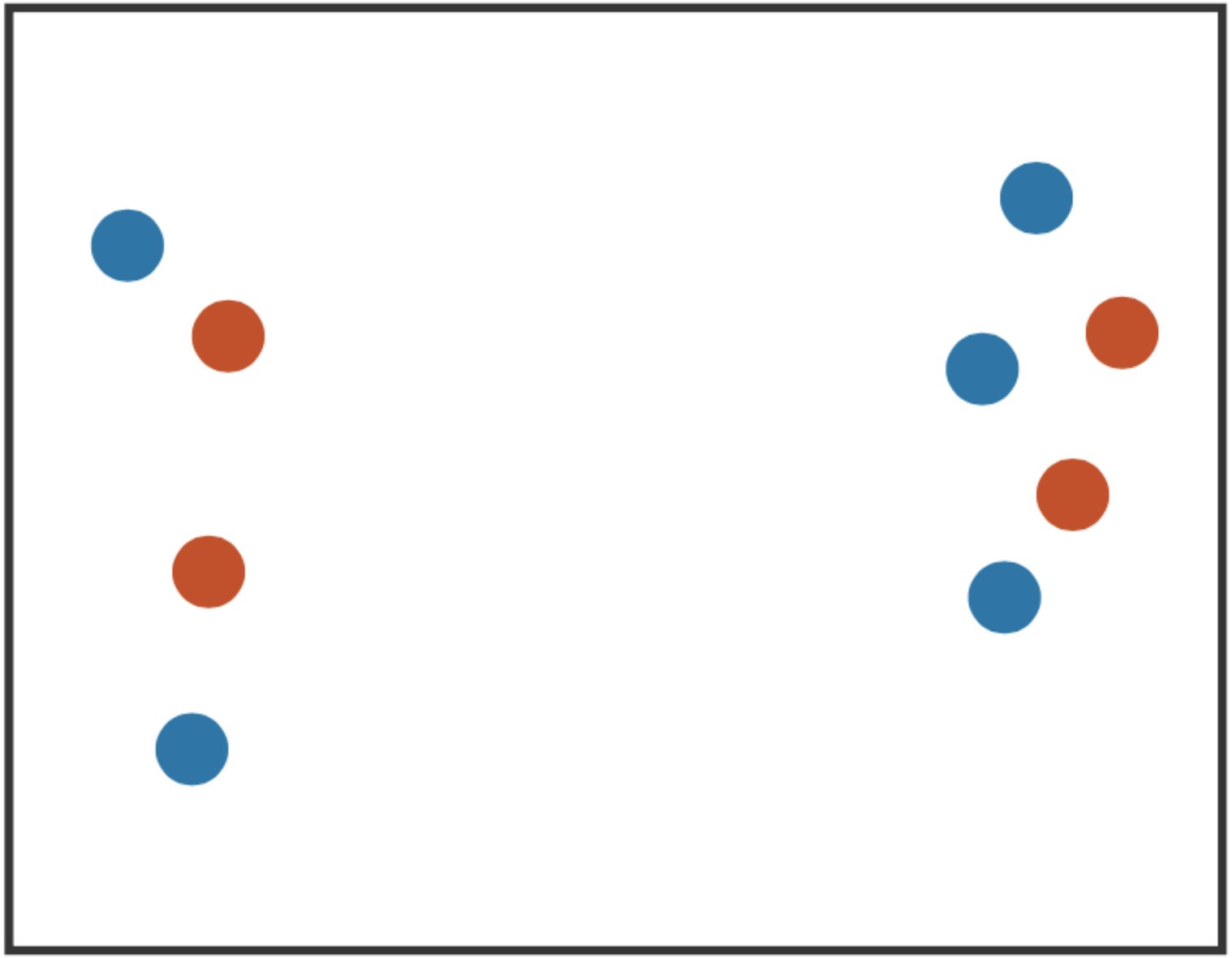
Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)



Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape



Spatial Region

Hue bad for magnitude:

Hue bad for magnitude:

Hue is great for identity:

Shape

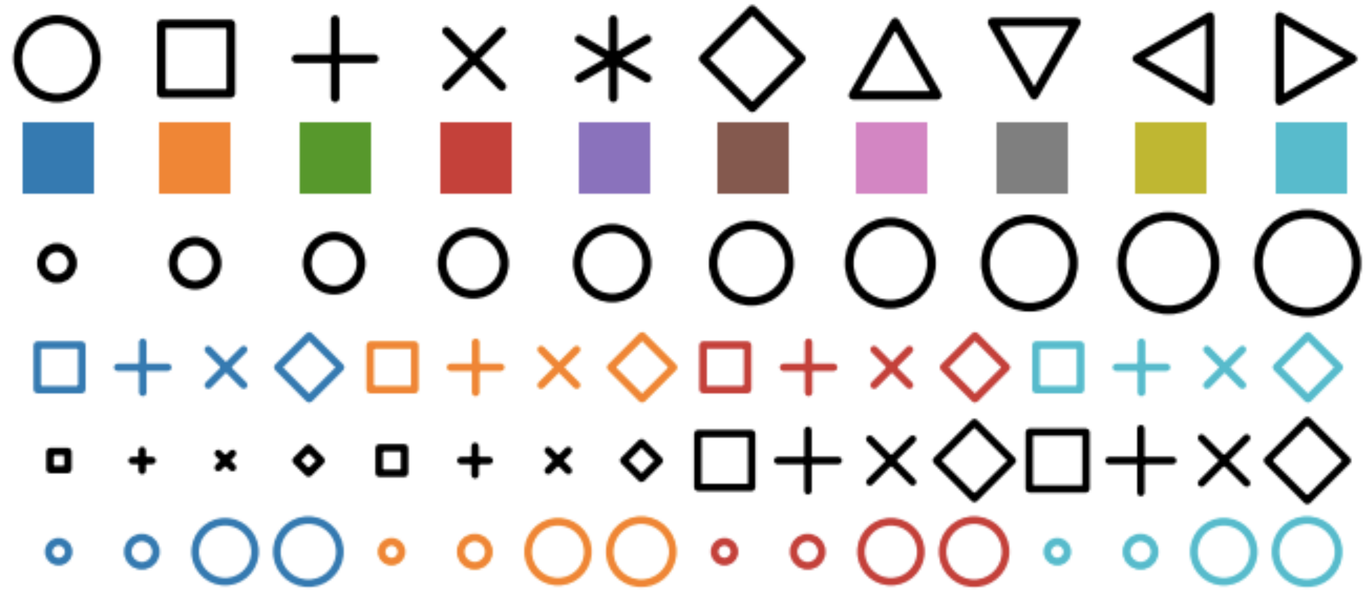


Fig. 2: Palettes of visual stimuli used in our experiments: shape, color, size, shape-color, shape-size, size-color.

Demiralp et al., 2014

Shape

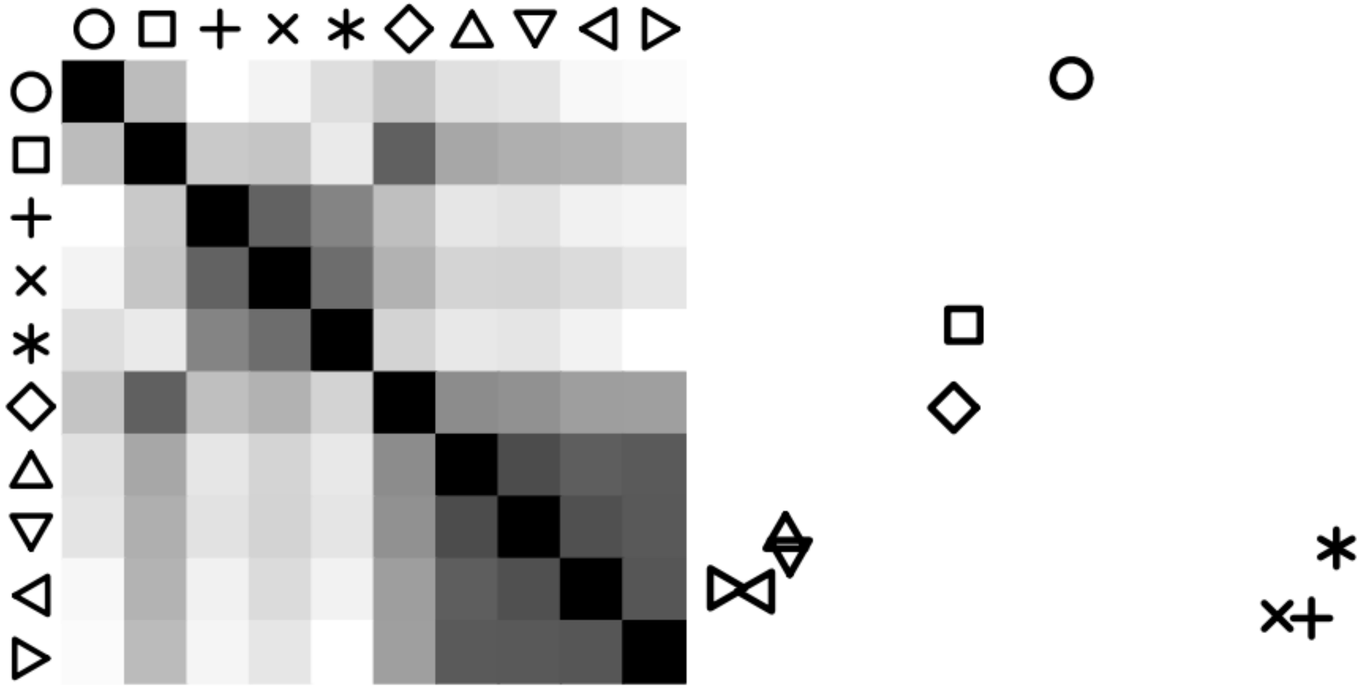
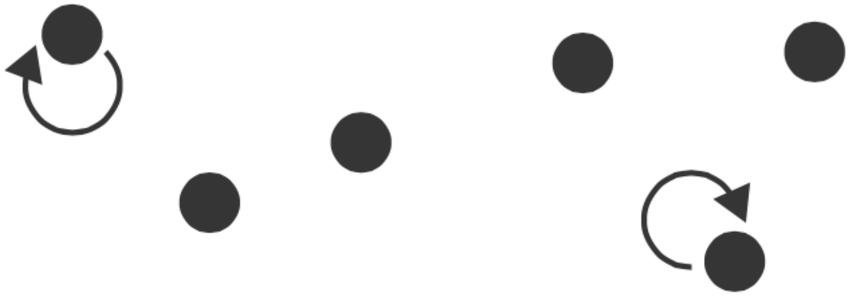


Fig. 1: (Left) A crowd-estimated perceptual kernel for a shape palette. The kernel was obtained using ordinal triplet matching. (Right) A two-dimensional projection of the palette shapes obtained via multidimensional scaling of the perceptual kernel.

Demiralp et al., 2014

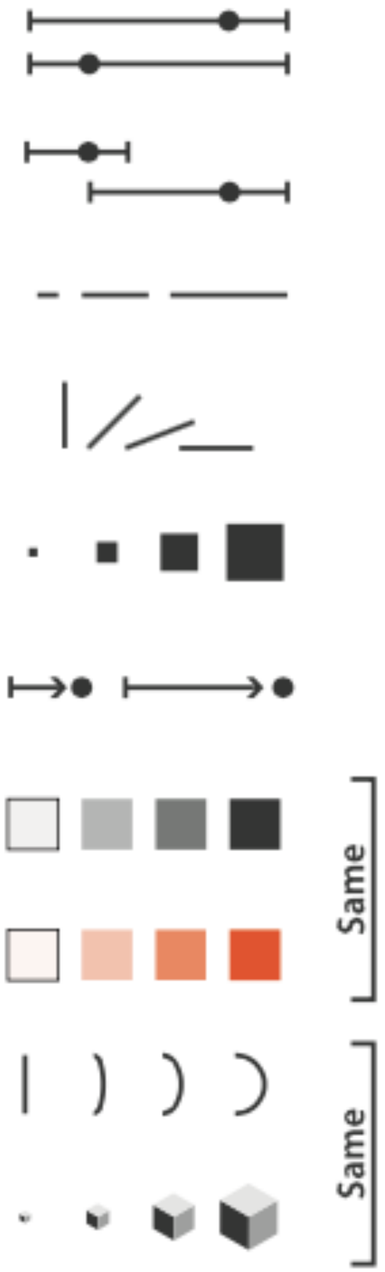
Motion



(huge attention grabber, use with caution)

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)



Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

What happens when

Data Vars > Visual Vars ?

What happens when

Visual Vars > Data Vars ?