Data and Image Models

The big picture

task

data
- physical type
  - int, float, etc.
- abstract type
  - nominal, ordinal, etc.

domain
- metadata
- semantics
- conceptual model

processing
algorithms

mapping
- visual encoding
- visual metaphor

image
- visual channel
- retinal variables

[based on slide from Munzner]

Data

Data models vs. Conceptual models

Data models are low level descriptions of the data

- Math: Sets with operations on them
- Example: integers with + and operators

Conceptual models are mental constructions

- Include semantics and support reasoning

Examples (data vs. conceptual)

- (1D floats) vs. Temperature
- (3D vector of floats) vs. Space

Taxonomy

- 1D (sets and sequences)
- Temporal
- 2D (maps)
- 3D (shapes)
- nD (relational)
- Trees (hierarchies)
- Networks (graphs)

Are there others?

The eyes have it: A task by data type taxonomy for information visualization [Schneiderman 96]

Types of variables

Physical types

- Characterized by storage format
- Characterized by machine operations

Example:

bool, short, int32, float, double, string, …

Abstract types

- Provide descriptions of the data
- May be characterized by methods/attributes
- May be organized into a hierarchy

Example:

plants, animals, metazoans, …

Nominal, ordinal and quantitative

N - Nominal (labels)

- Fruits: Apples, oranges, …

O - Ordered

- Quality of meat: Grade A, AA, AAA

Q - Interval (Location of zero arbitrary)

- Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)
- Like a geometric point. Cannot compare directly
- Only differences (i.e. intervals) may be compared

Q - Ratio (zero fixed)

- Physical measurement: Length, Mass, Temp, …
- Counts and amounts
- Like a geometric vector, origin is meaningful

S. S. Stevens, On the theory of scales of measurements, 1946

From data model to data type

Data model

- 32.5, 54.0, -17.3, …
- floats

Conceptual model

- Temperature

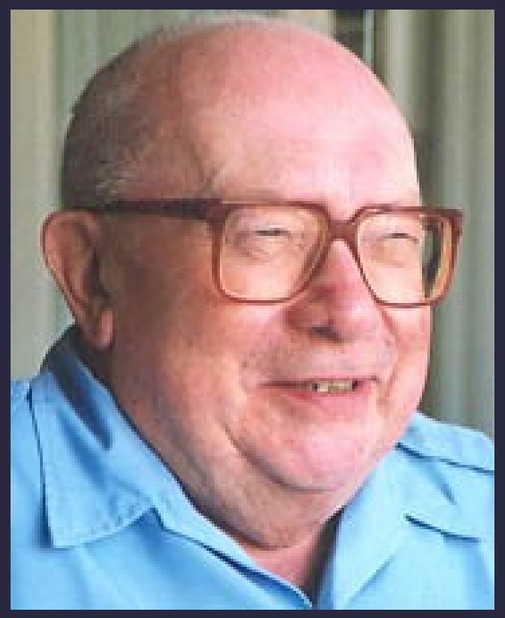
Data type

- Burned vs. Not burned (N)
- Hot, warm, cold (O)
- Continuous range of values (Q)

[based on slide from Munzner]

Image

Visual language is a sign system



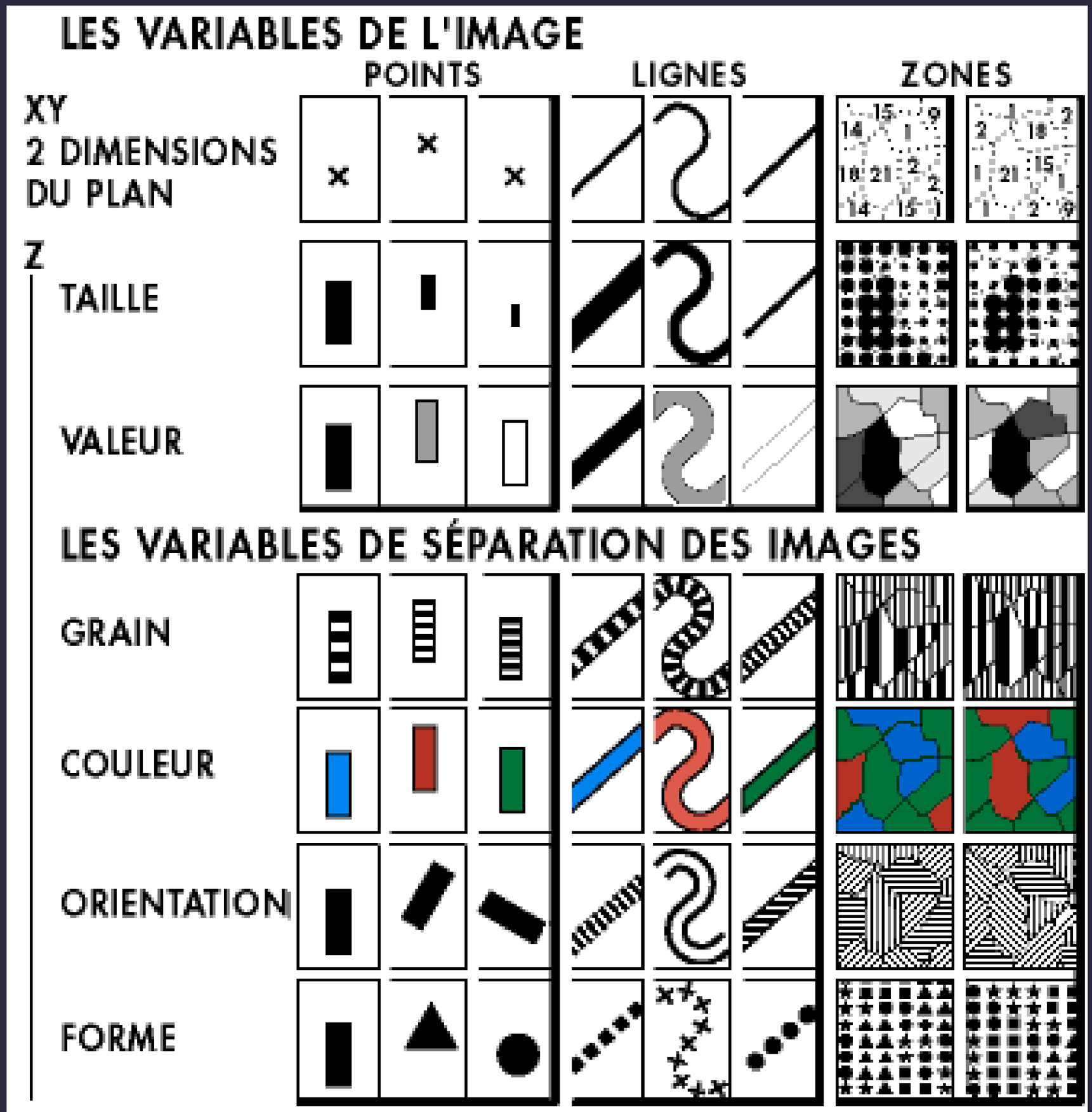
Jacques Bertin

Images perceived as a set of signs

Sender encodes information in signs

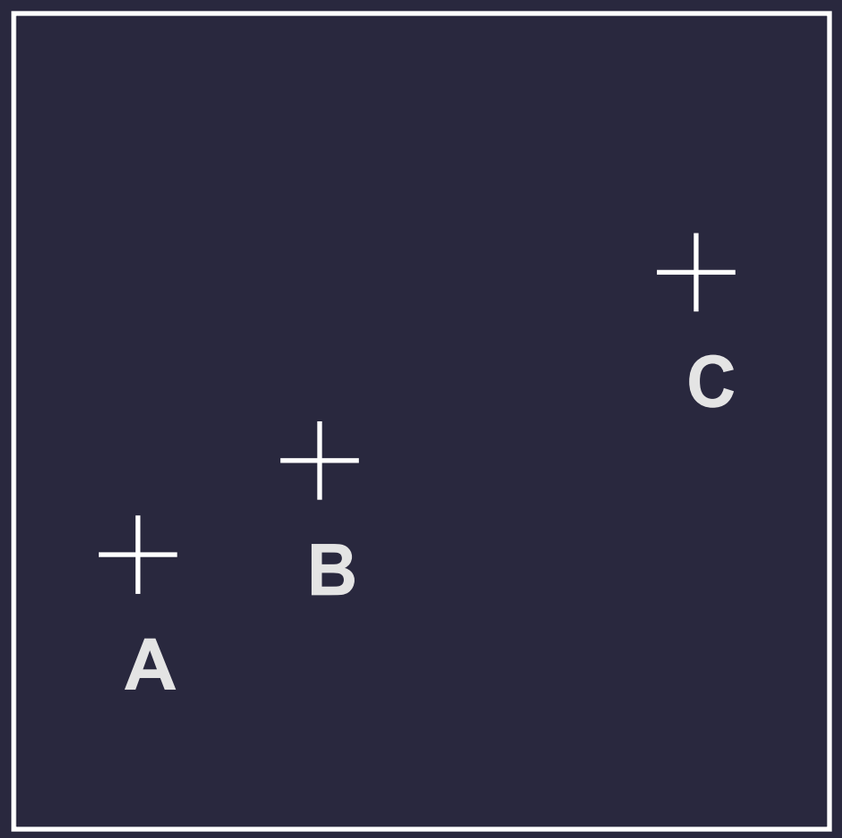
Receiver decodes information from signs

Semiology of Graphics, 1983



[Bertin, Semiology of Graphics, 1983]

Information in position



1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.

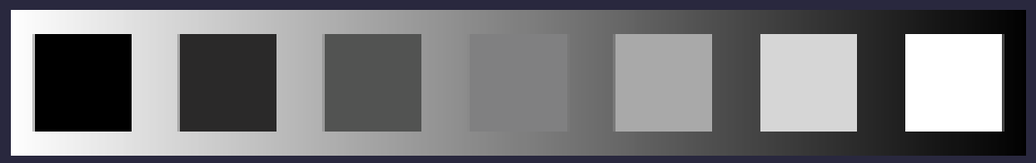
∴ Encode quantitative variables (Q)

"Resemblance, order and proportional are the three signfields in graphics.” - Bertin

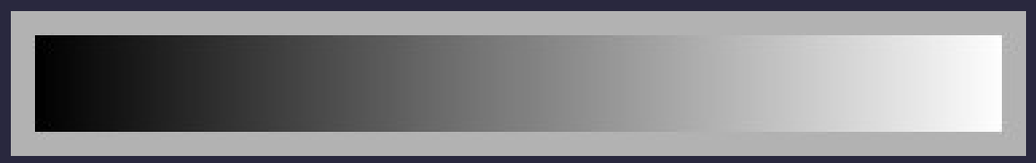
Information in color and value

Value is perceived as ordered

∴ Encode ordinal variables (O)



∴ Encode continuous variables (Q) [not as well]

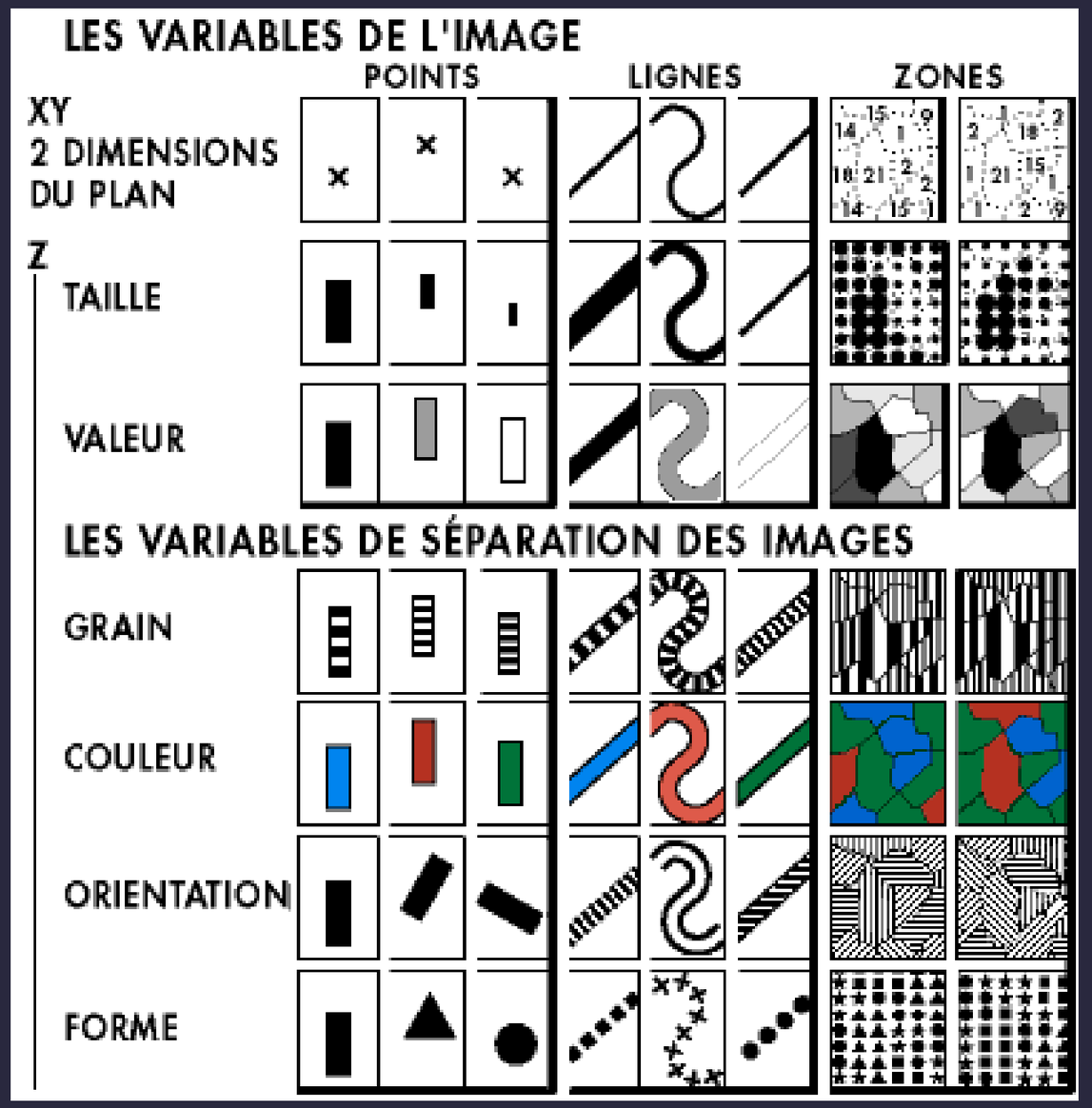


Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

Visual variables

- Position
- Size
- Value
- Texture
- Color
- Orientation
- Shape



Note: Bertin does not consider 3D or time
Note: Card and Mackinlay extend the number of vars.

Bertins' "Levels of Organization"

Position	N	O	Q
Size	N	O	Q
Value	N	O	Q
Texture	N	O	
Color	N		
Orientation	N		
Shape	N		

N Nominal
O Ordered
Q Quantitative

Note: Q < O < N

Note: Bertin actually breaks visual variables down into differentiating (≠) and associating (≡)

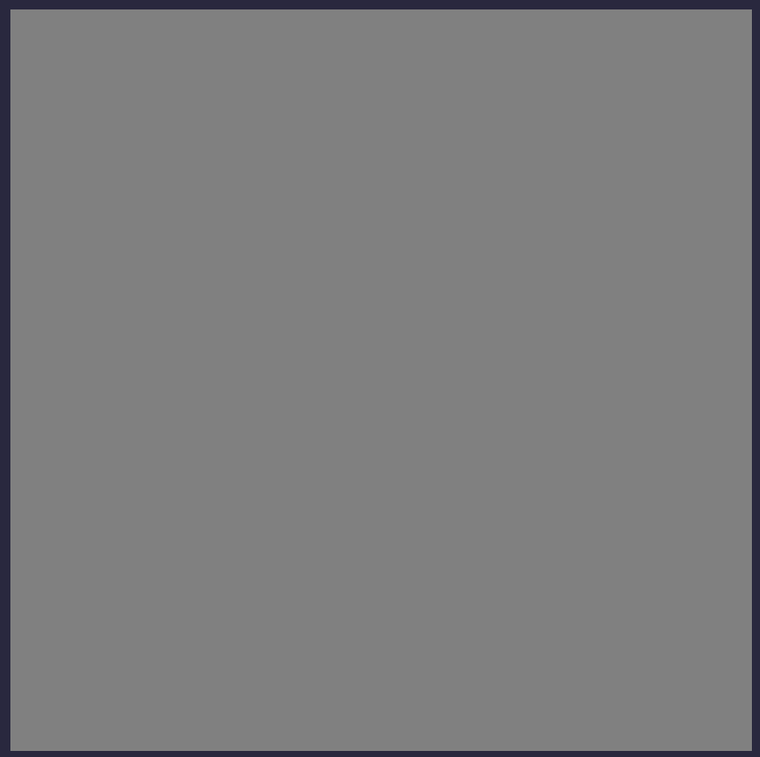
Detection

Detecting brightness

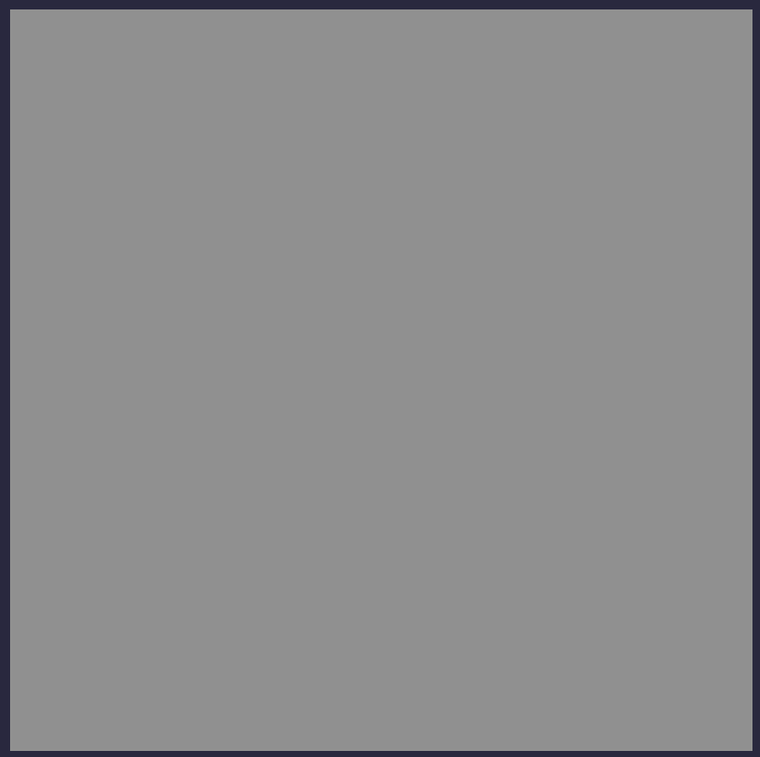
Which is brighter?

Detecting brightness

(128, 128, 128)



(144, 144, 144)



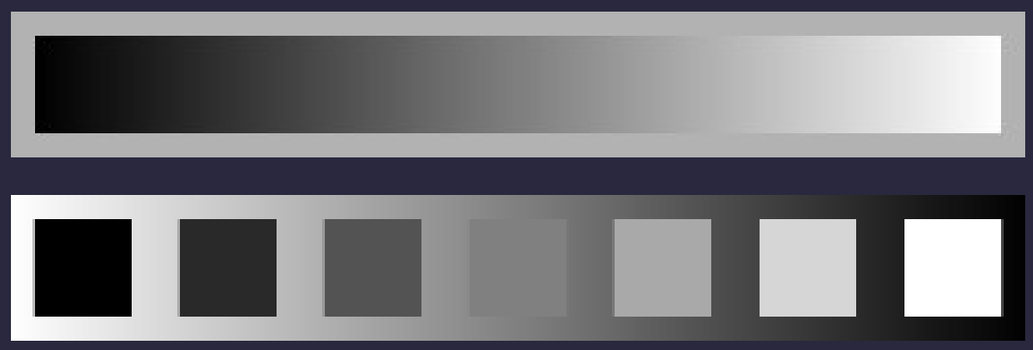
Which is brighter?

Just noticeable difference

JND (Weber's Law)

$$\Delta S = k \frac{\Delta I}{I}$$

- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps

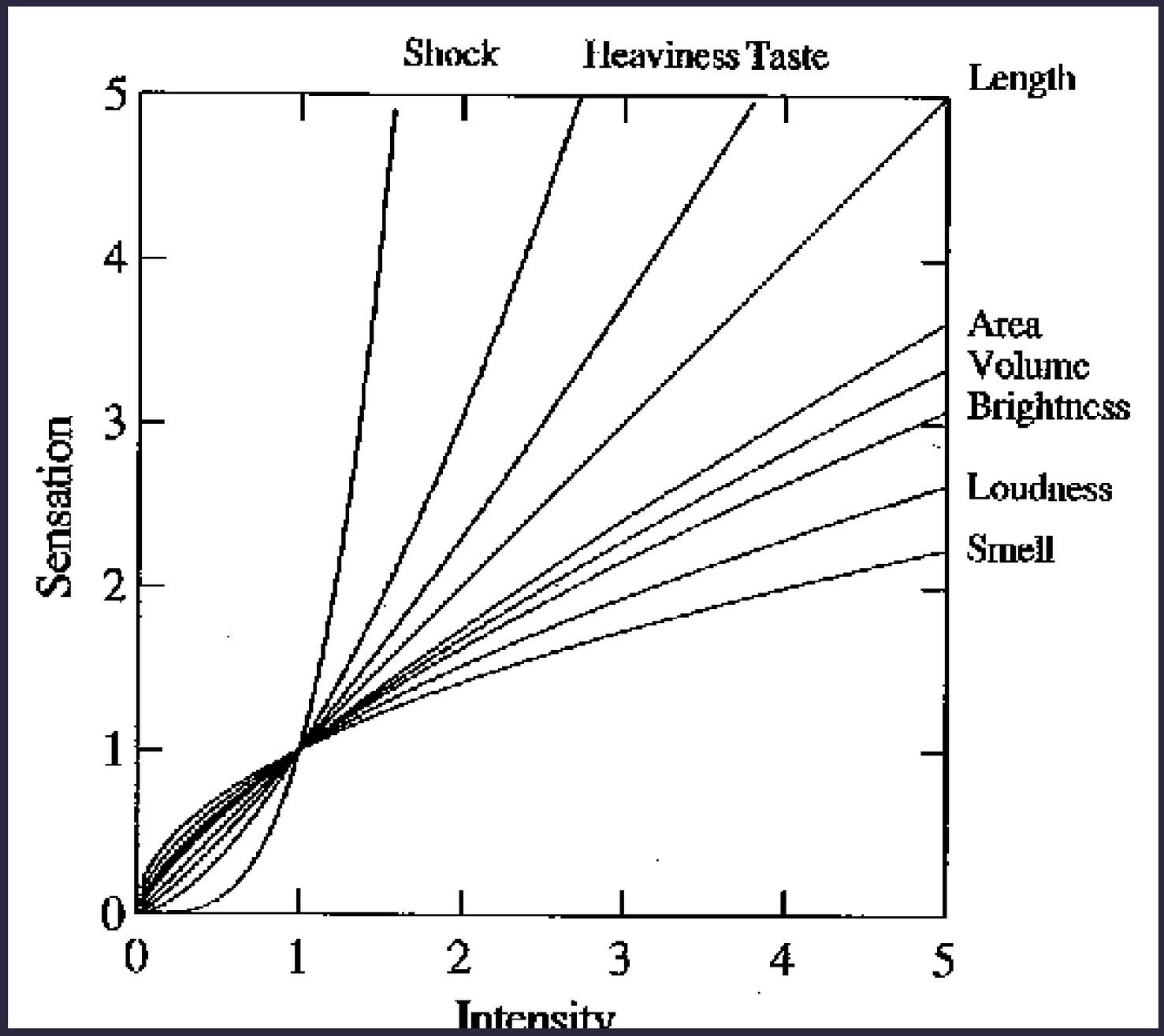


Estimating Magnitude

Steven's power law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



[graph from Wilkinson 99, based on Stevens 61]

Exponents of power law

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) - 0.6 (Heptane)
Taste	0.6 (Saccharine) -1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electic Shock	3.5

[Psychophysics of Sensory Function, Stevens 61]

Cleveland and McGill

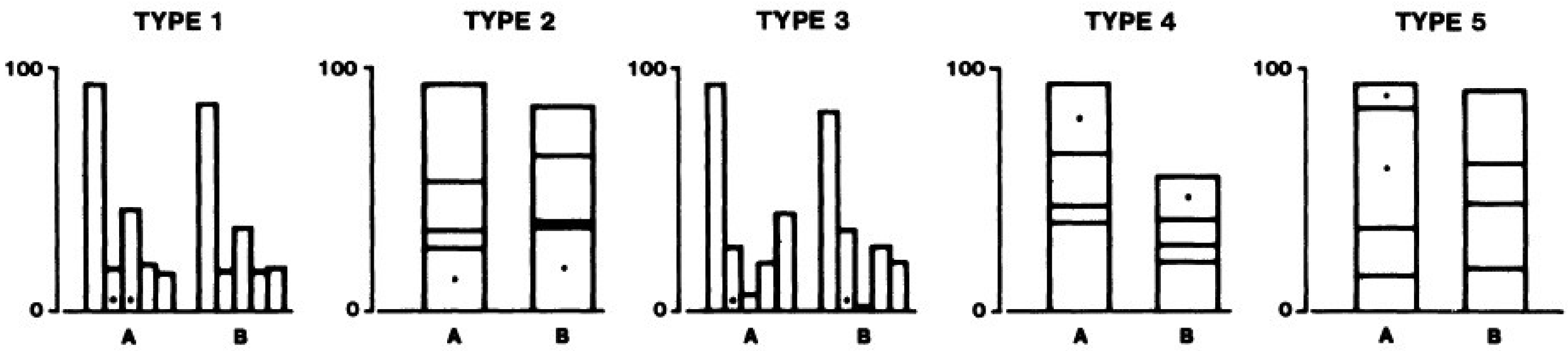


Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

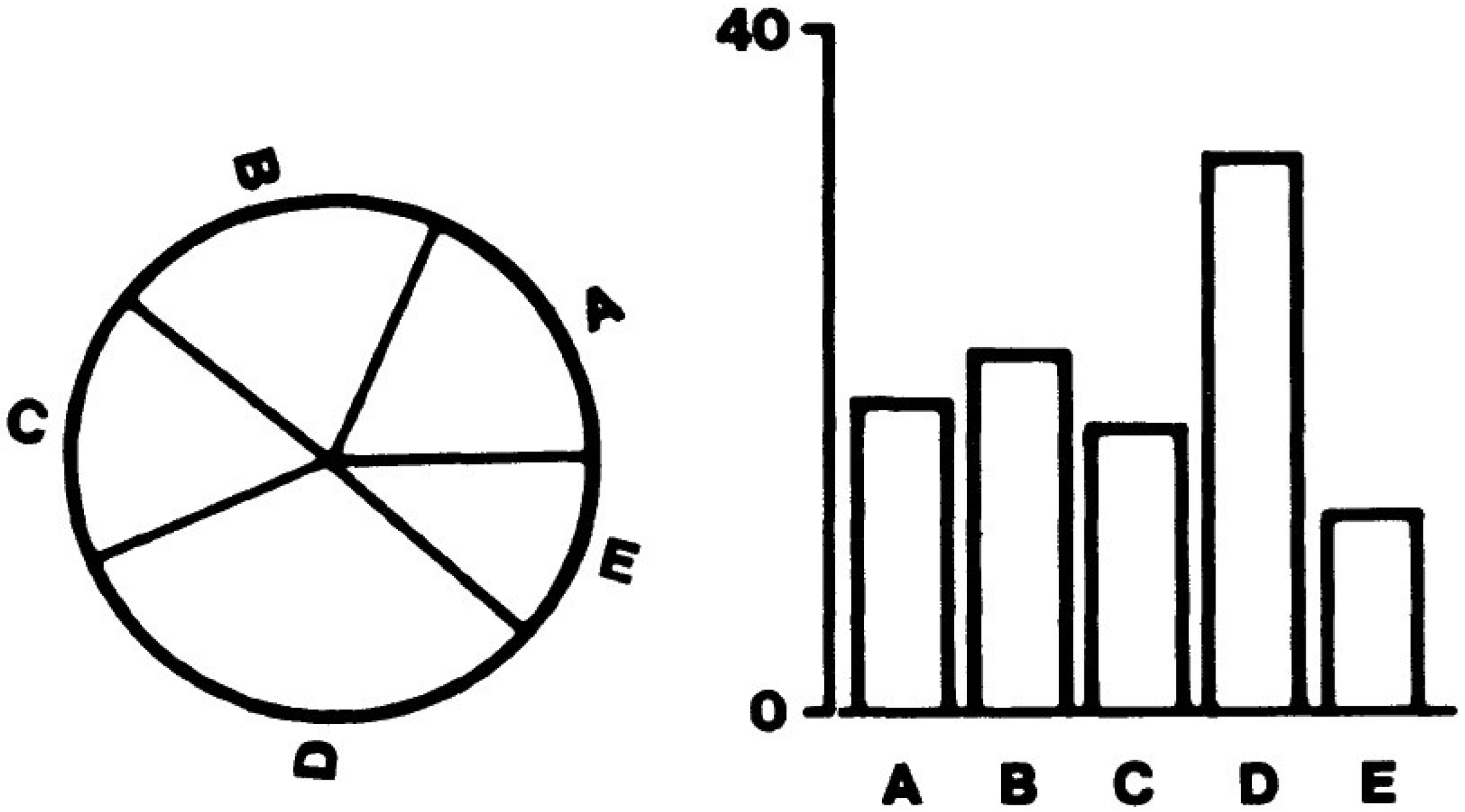


Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

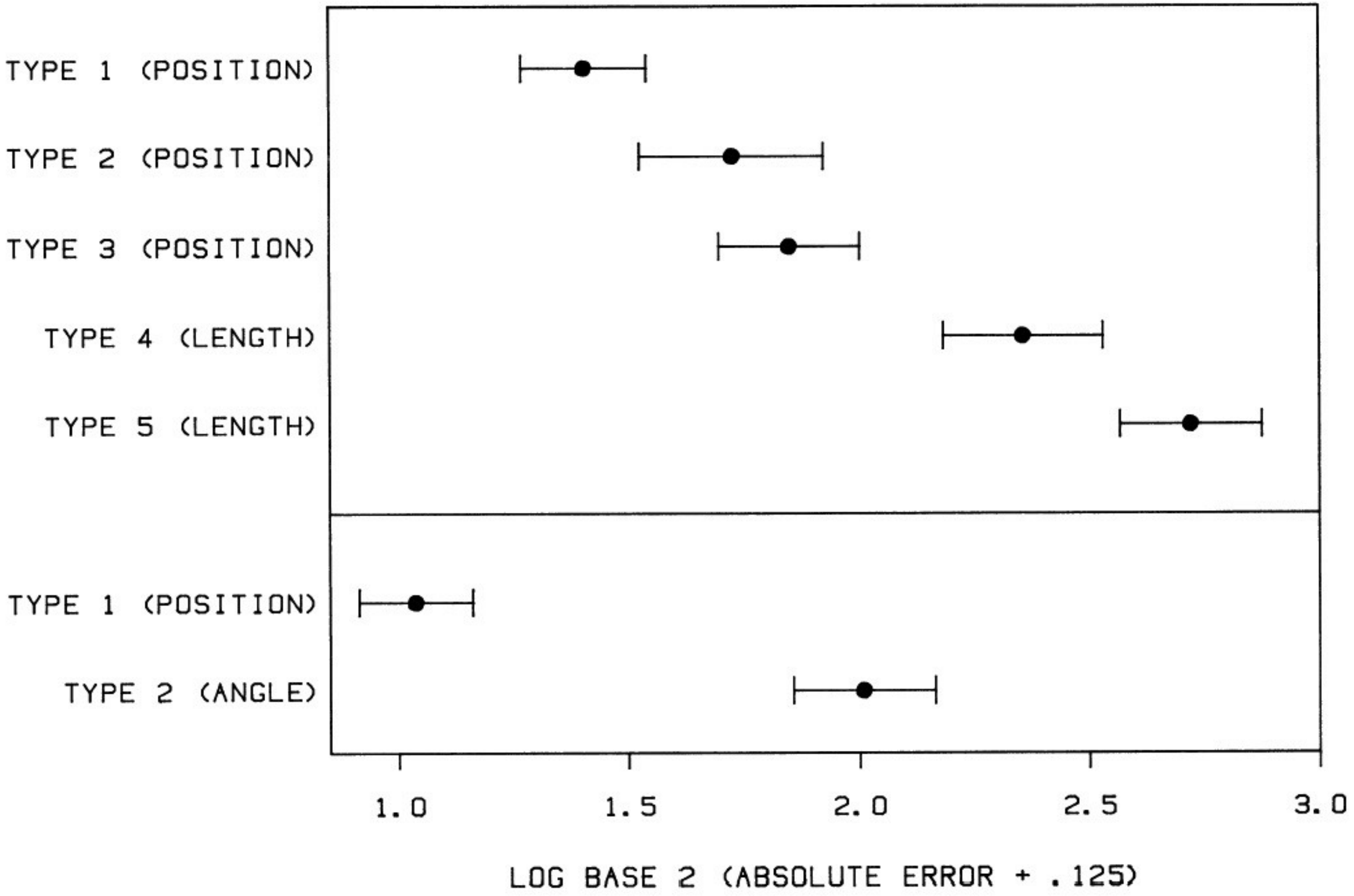
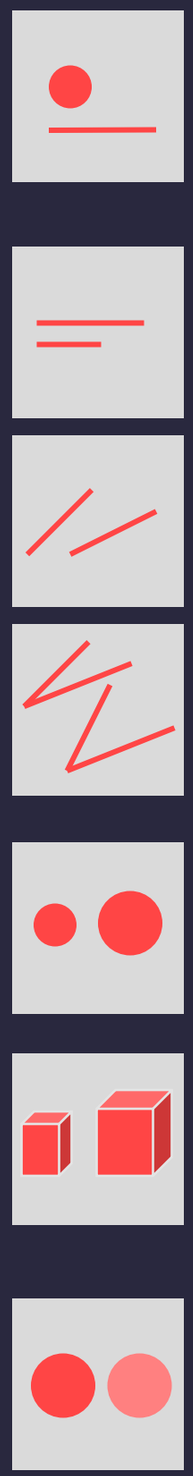


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]

Relative magnitude estimation

Most accurate



Least accurate

Position (common) scale

Position (non-aligned) scale

Length

Slope

Angle

Area

Volume

Color hue-saturation-density