

CS 571 - Data Visualization & Exploration

Visual Encodings: Marks, Channels

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UMassAmherst

Upcoming Dates

Mar 14: Homework 2 Due at 11:59pm Eastern

Apr 4: Project Milestone

Group Activity Next Class (Mar 11)

No Quiz this Week (Quiz 3 will be released on Tuesday Mar 11 and due Friday Mar 14)

Analyzing Data Visualizations

What is shown?

Why is the user looking at it?

How is it shown?

Abstract vocabulary allows us to avoid domain-specific terms

What-Why-How framework is a scaffold we can use to systematically think about the huge visualization design space

what?

Why?

How?

Analyzing Data Visualizations

The **visual encodings** we use to represent the data

what?

Why?

How?

Visual Encodings

Marks

Channels

Marks

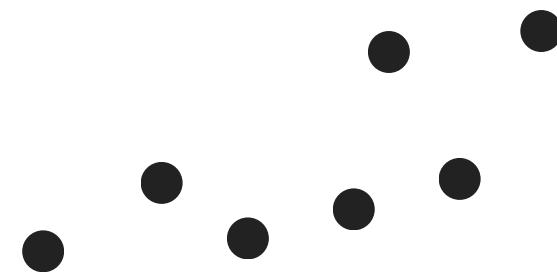
A **mark** is a “geometric primitive object”

Marks

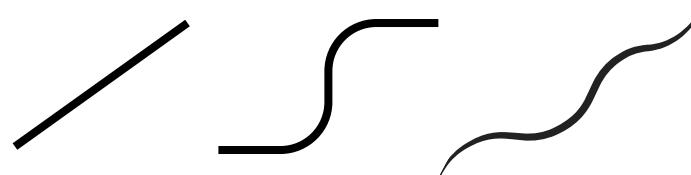
A **mark** is a **simple graphical element** in an image

Three types of marks:

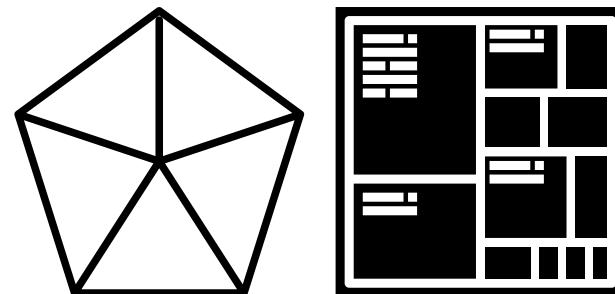
- 0-dimensional (0D): **Points**
- 1-dimensional (1D): **Lines**
- 2-dimensional (2D): **Areas**



(0D) Points



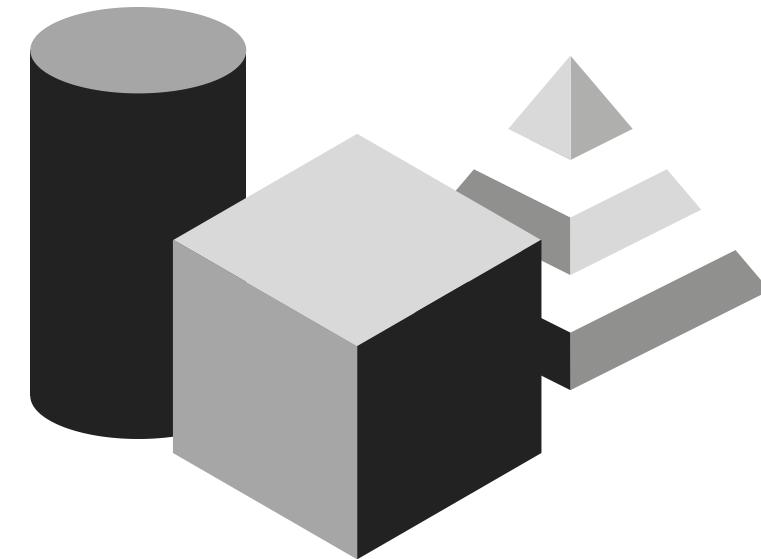
(1D) Lines



(2D) Areas

Marks

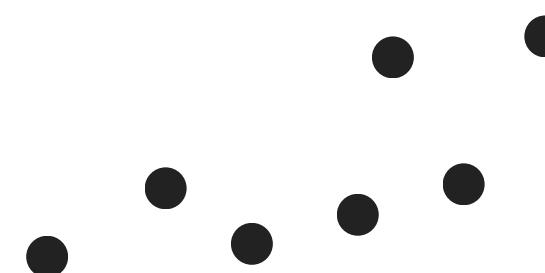
Technically, there's a fourth type of mark, but you **shouldn't use it**



(3D) Volumes

Marks

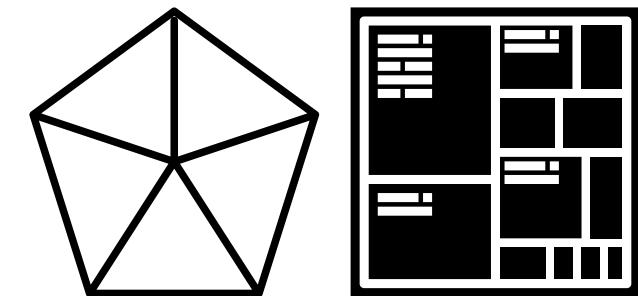
We typically use marks to represent **individual items**, especially when our dataset is a **table**



(0D) Points

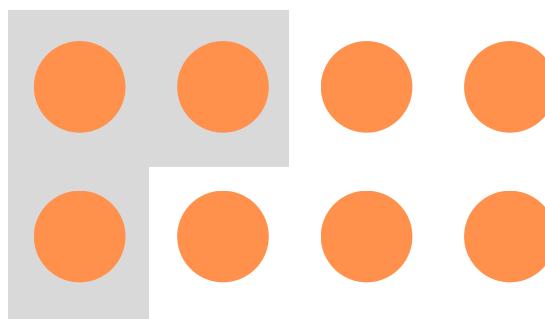


(1D) Lines

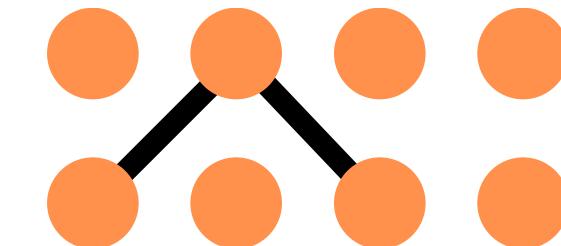


(2D) Areas

But marks can also be used to **represent links** in a network



Containment



Connection

Channels

A visual **channel** is a **parameter** that controls the appearance of marks

Five types of channels:

- position

Channels: Position

Channels: Position



Channels: Position



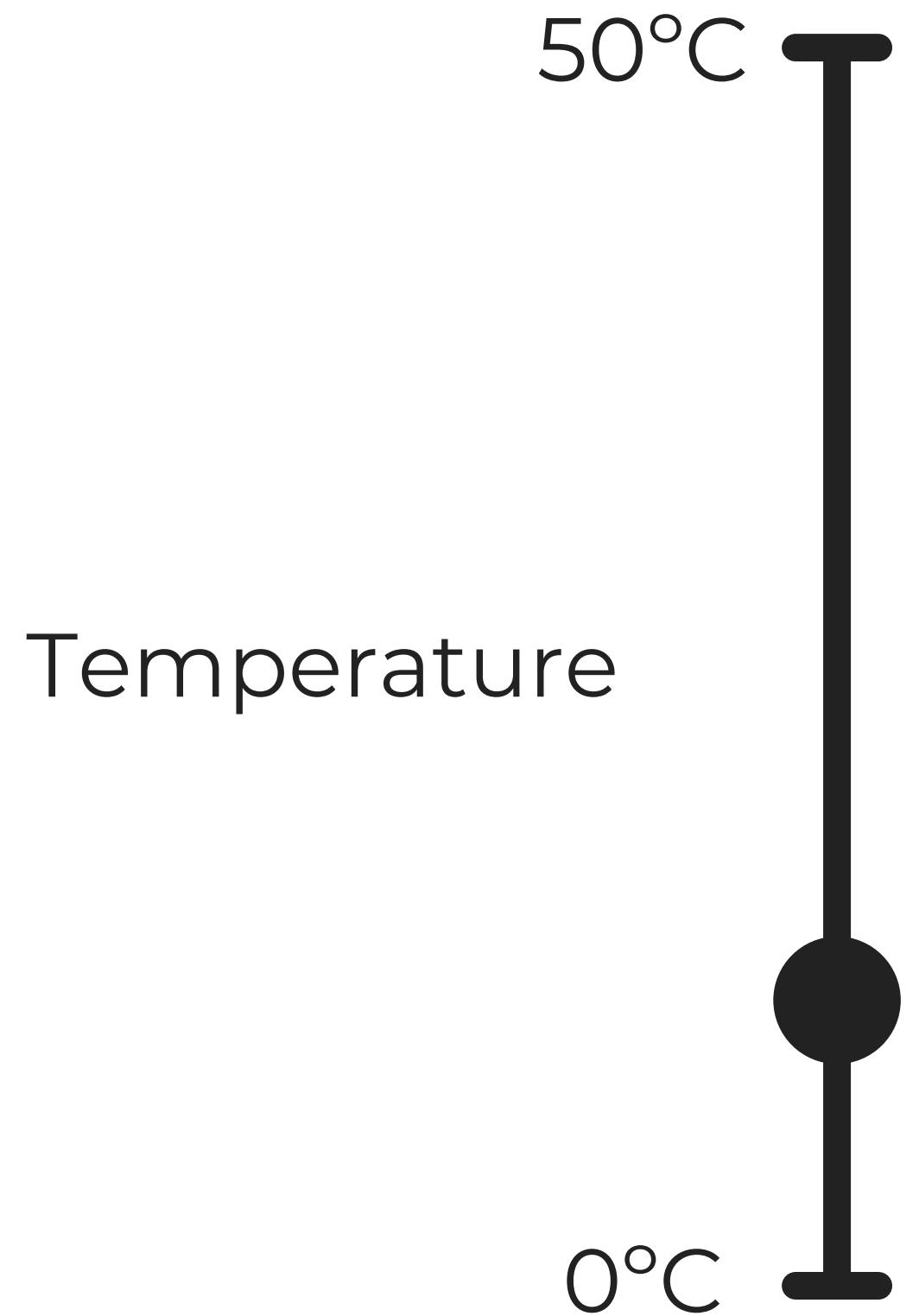
Channels: Position



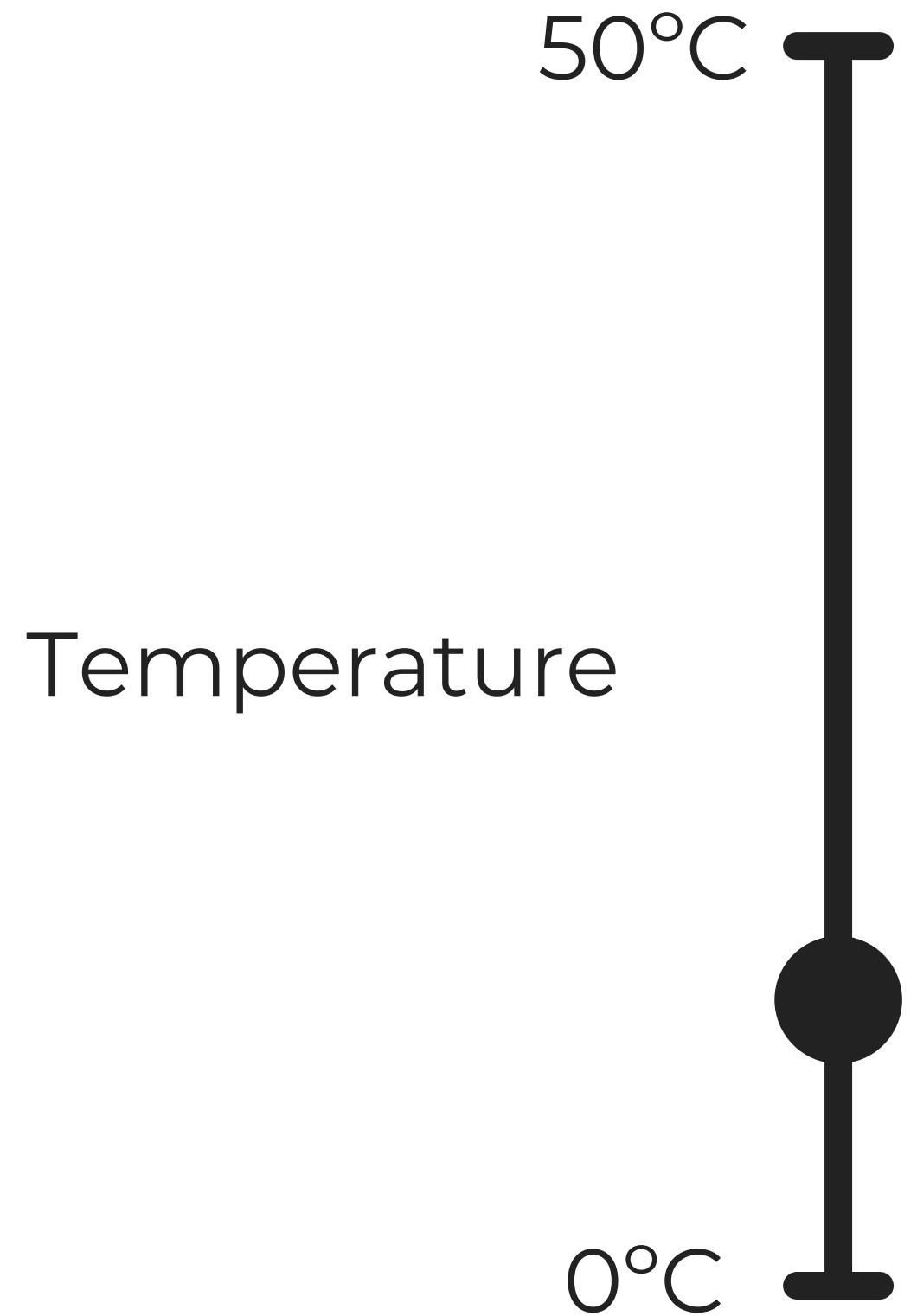
Channels: Position



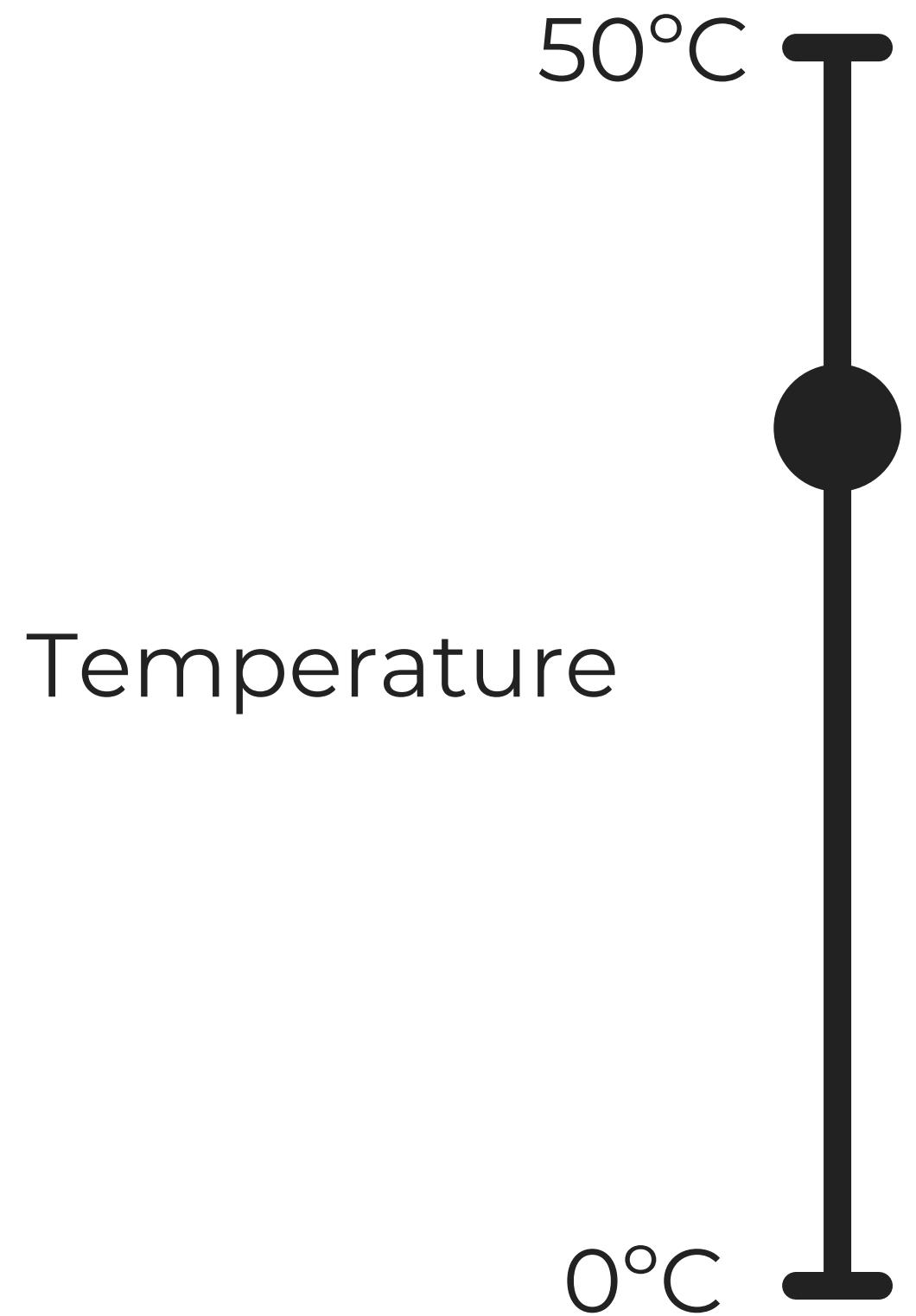
Channels: Position



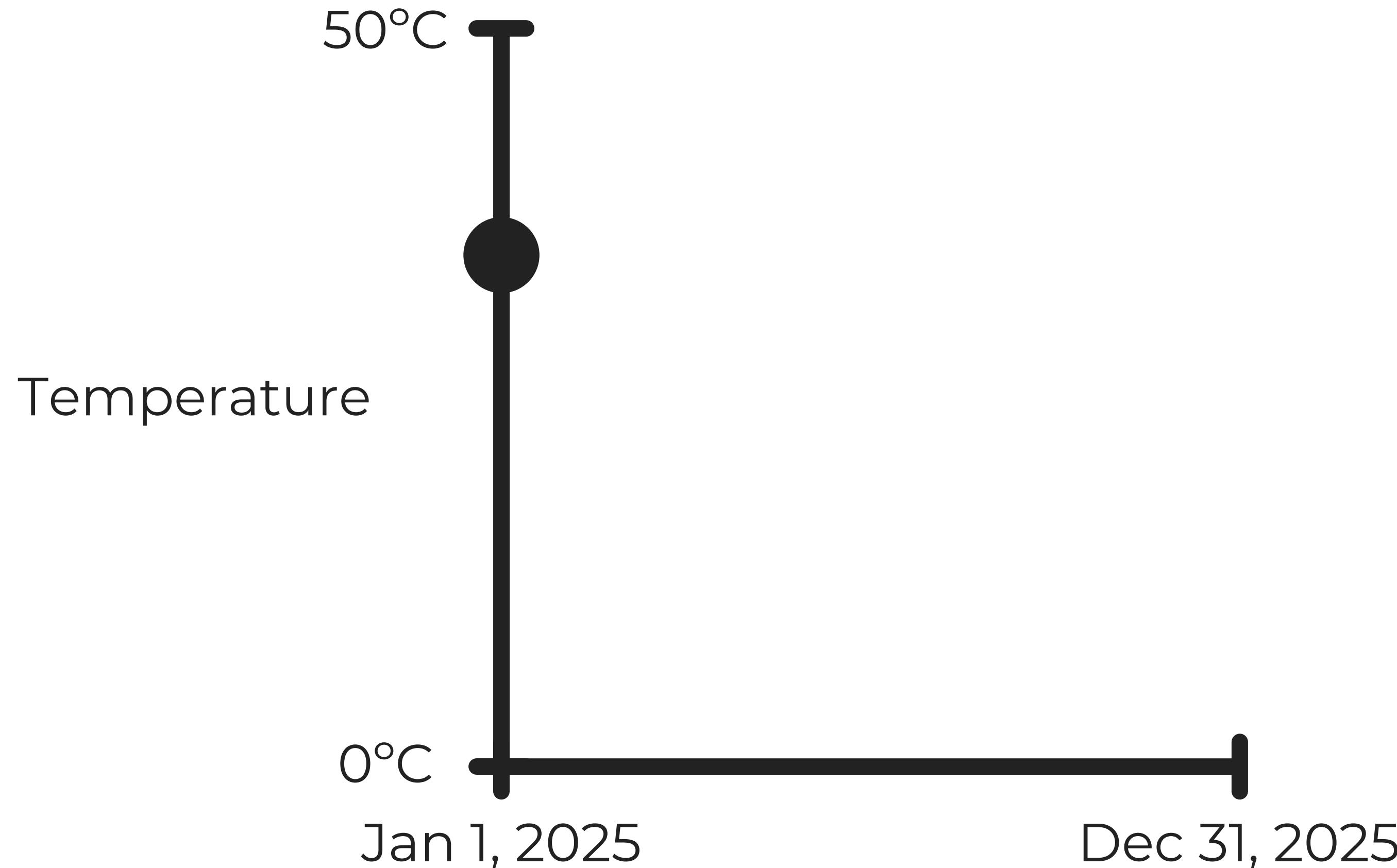
Channels: Position



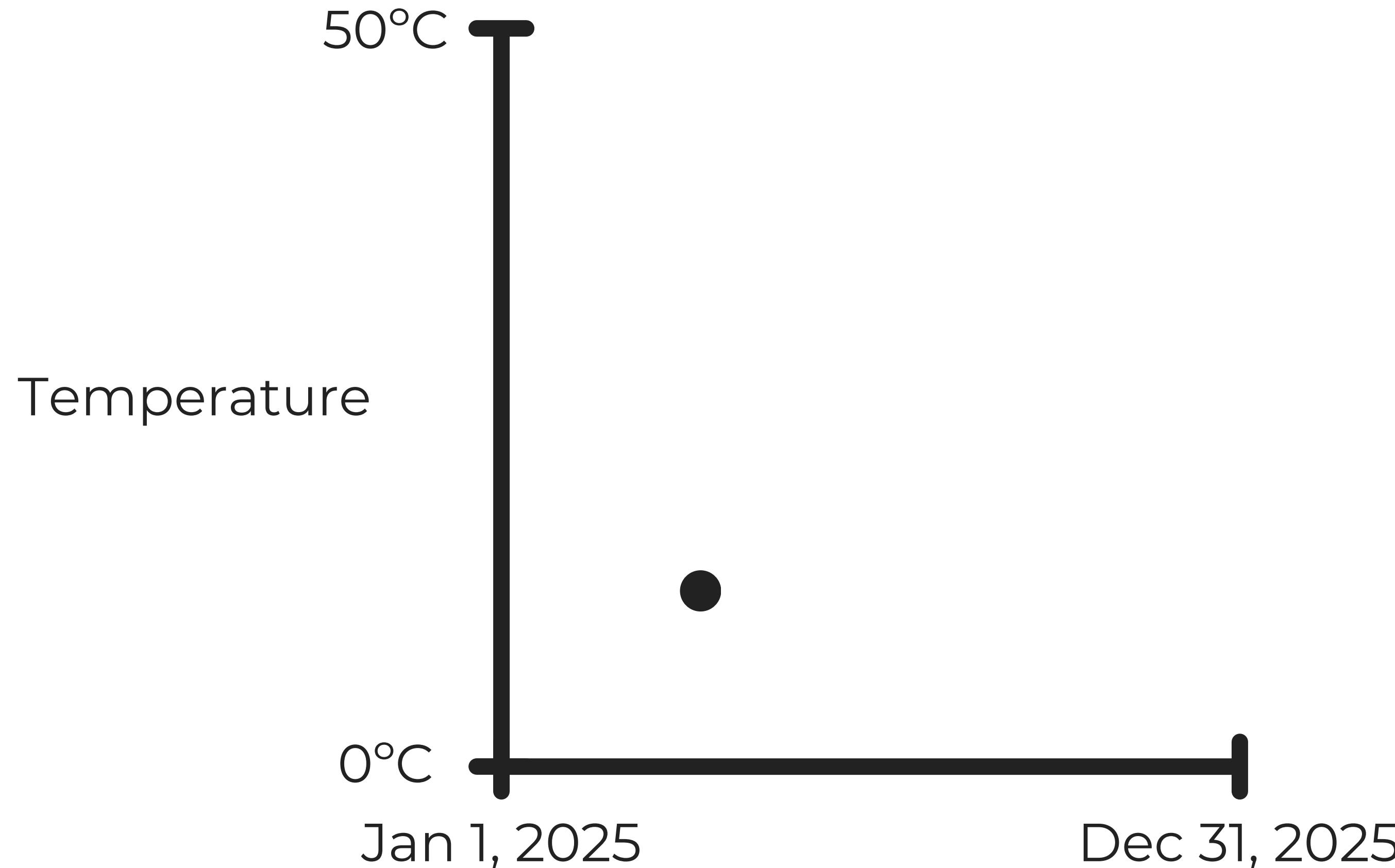
Channels: Position



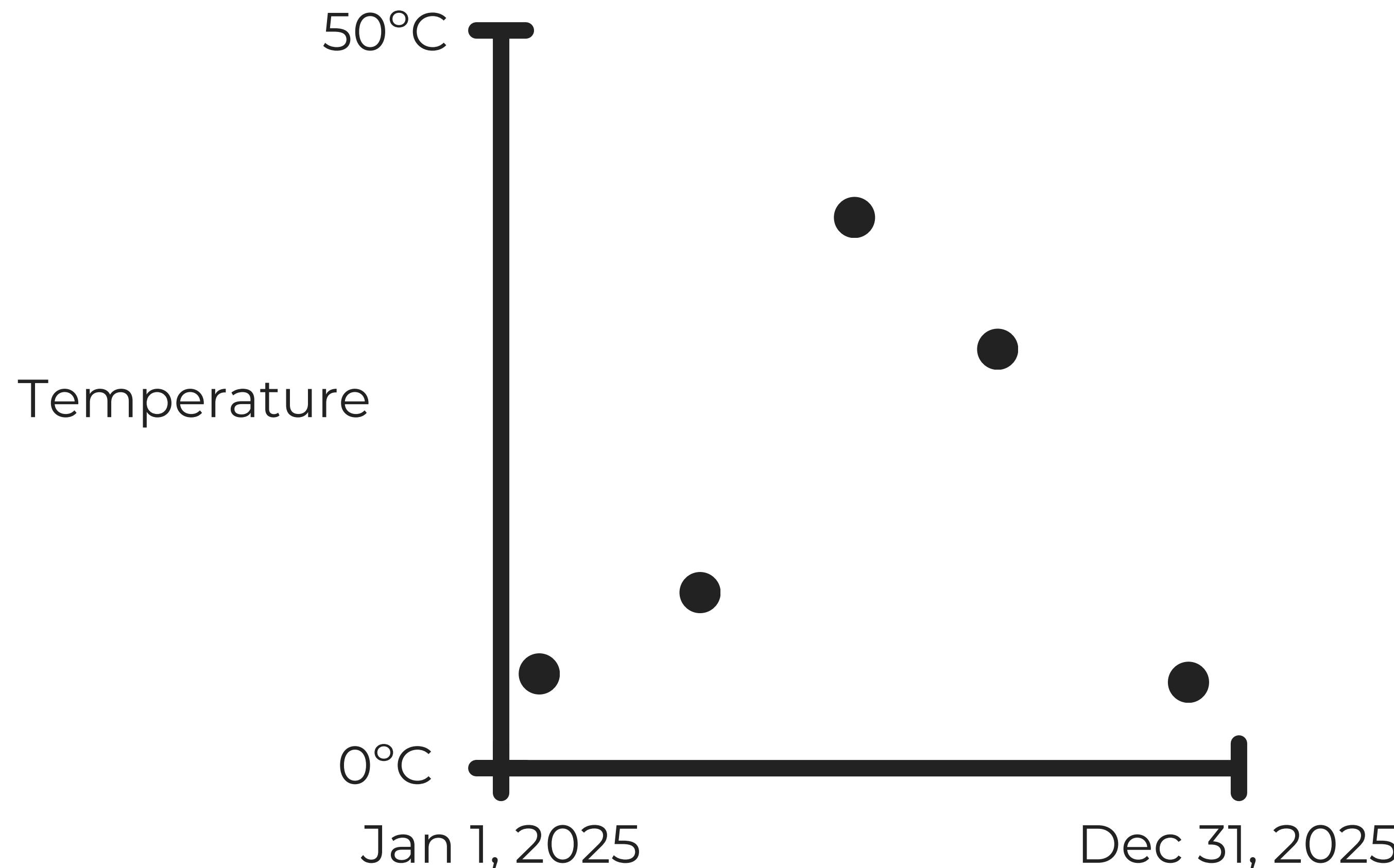
Channels: Position



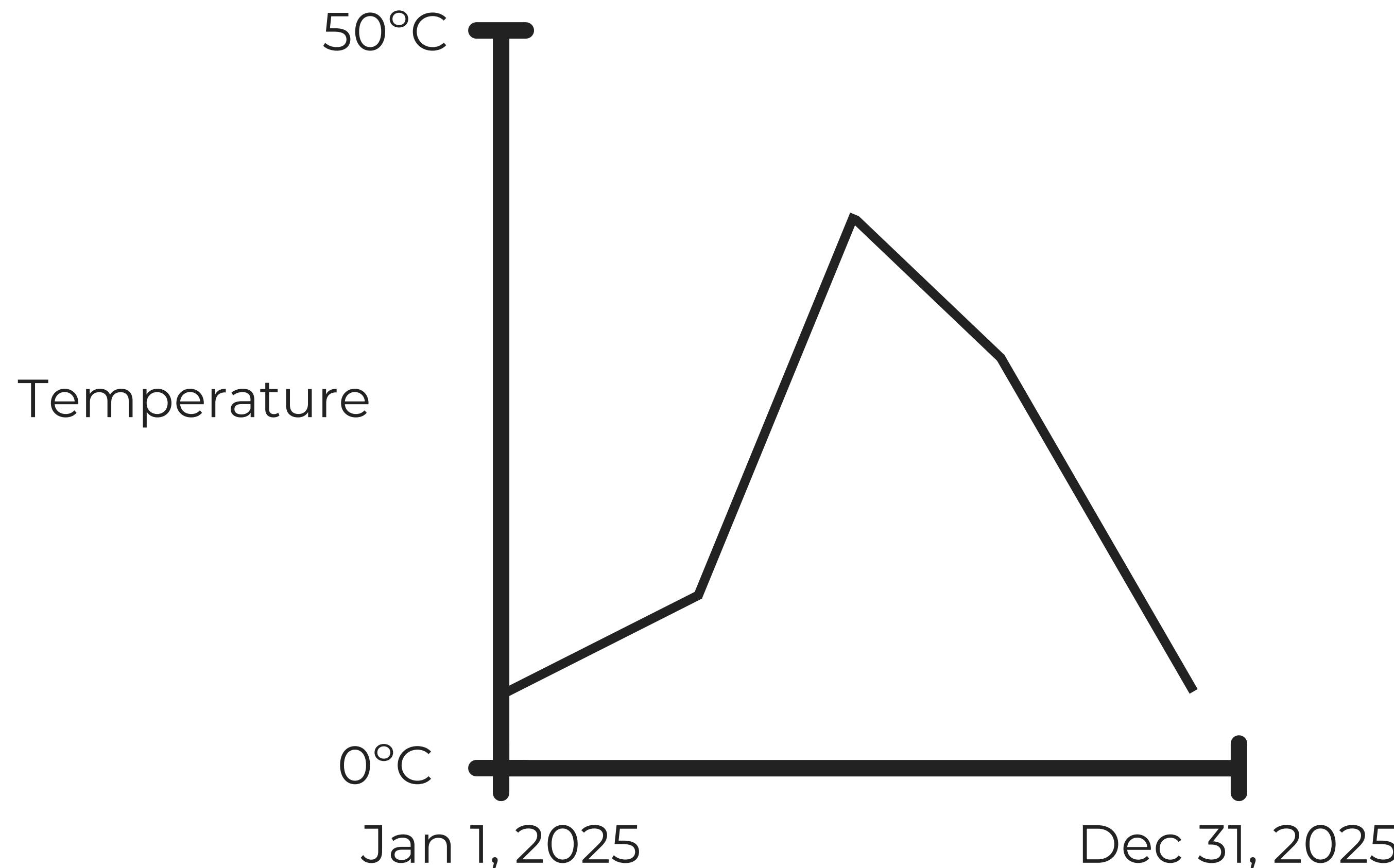
Channels: Position



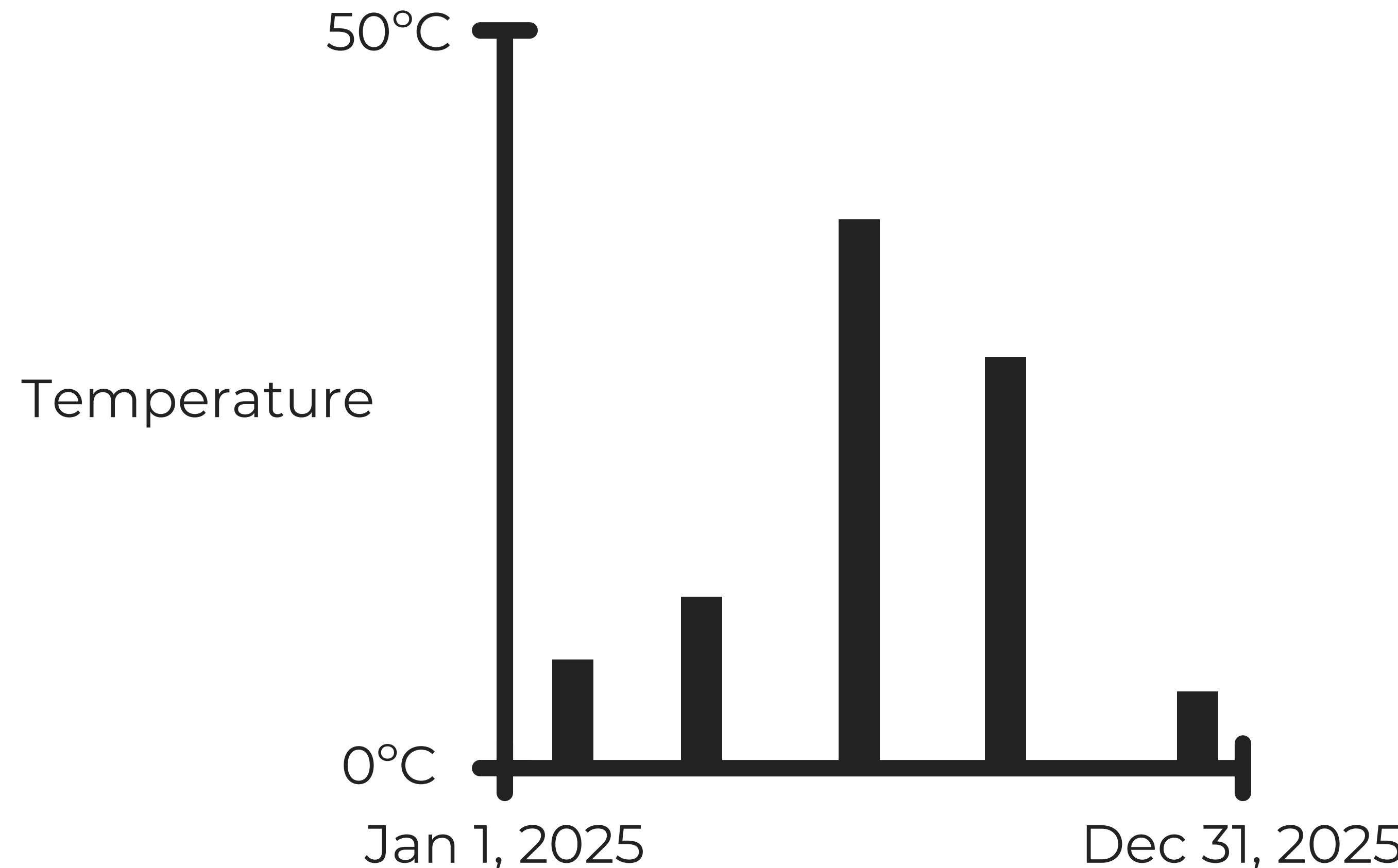
Channels: Position



Channels: Position



Channels: Position



Channels: Position



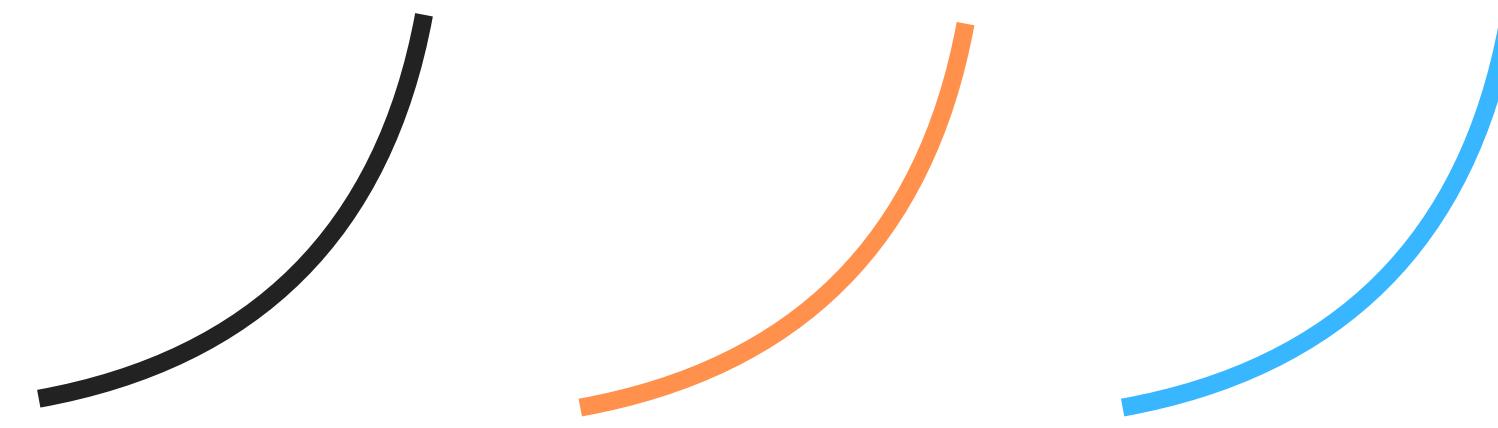
Channels

A visual **channel** is a **parameter** that controls the appearance of marks

Five types of channels:

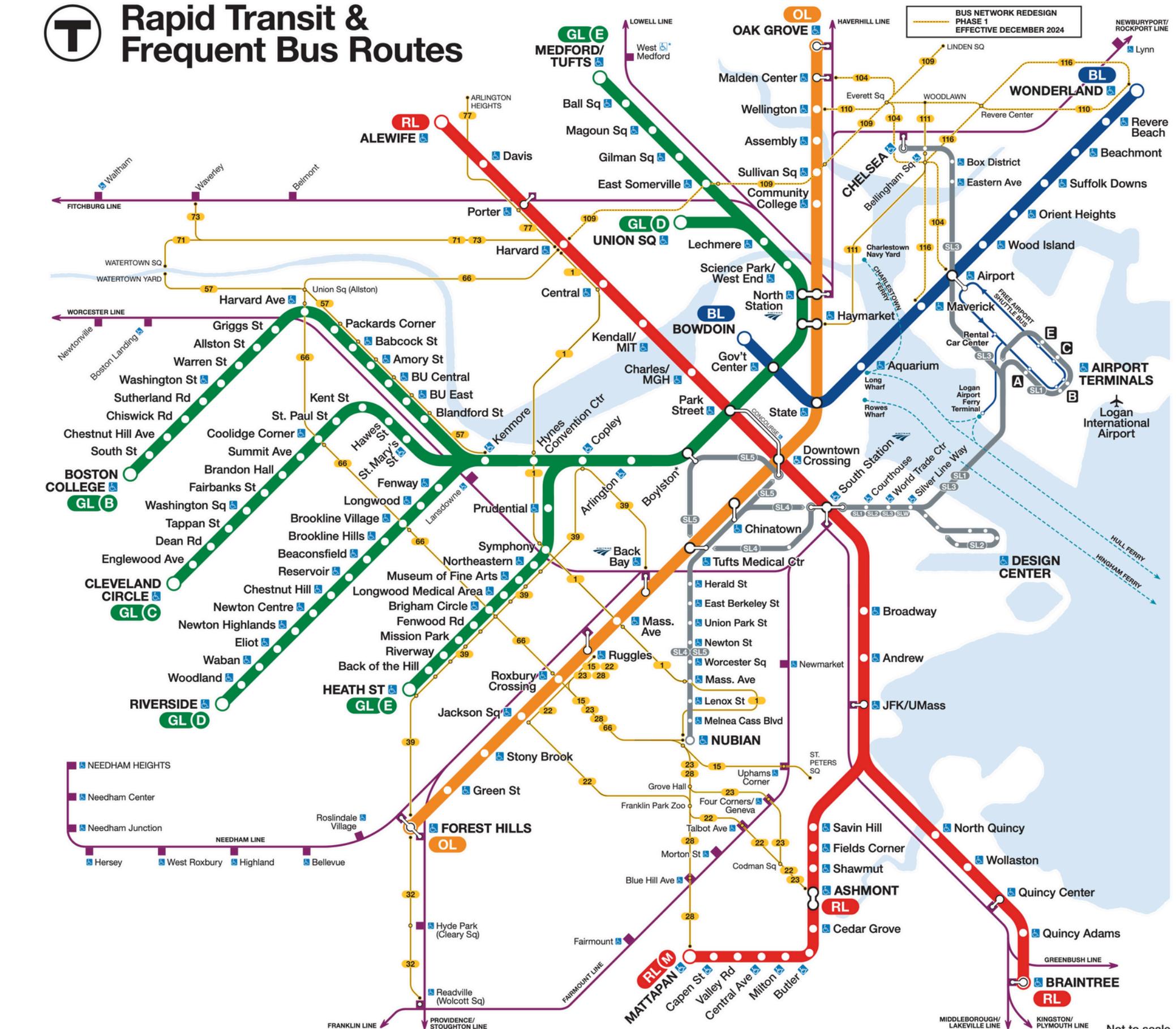
- position
- color

Channels: Color



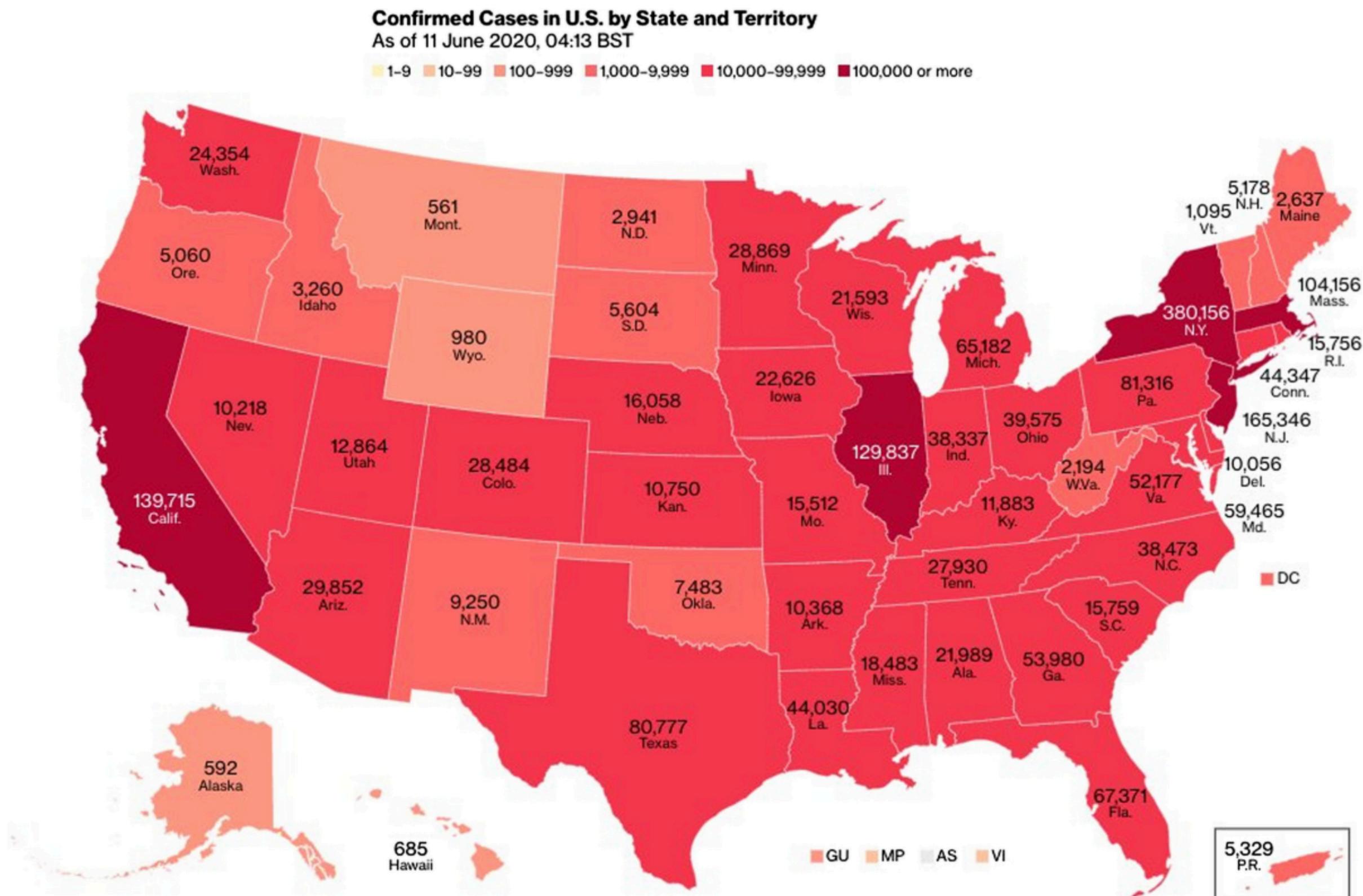
Rapid Transit & Frequent Bus Routes

Channels: Color



- | | | | | | | | | |
|------------------------|-----------------------------------------|-------------------------------------------|--------------------------------|---------------------------------------|-----------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BL Blue Line | GL Green Line | OL Orange Line | RL Red Line | RL/M Mattapan Line | 000 Frequent Bus Route | SL Silver Line | + Commuter Rail | X @MBTA |
| OL Orange Line | B Boston College to Gov't Center | C Cleveland Circle to Gov't Center | D Riverside to Union Sq | E Heath St to Medford/Tufts | Scheduled every 15 minutes or better, 5AM-1AM | SL1 SL2 SL3 SL4 SL5 SLW | + Ferry | ? Customer Communications & Travel Info: www.mbta.com
617-222-3200 / 800-392-6100 / TTY 617-222-5146
Media Inquiries: MBTAMediarelations@mbta.com |
| RL Red Line | Community Rail | RL/M Mattapan Line | RL Red Line | RL/M Mattapan Line | 000 Bus terminus | SL Silver Line | + Amtrak | @TheMBTA |
| M Mattapan Line | + Bus terminus | RL Red Line | RL Red Line | RL/M Mattapan Line | 000 Bus transfer/key point | + Free airport shuttle bus provided by Massport | + MBTA Transit Police: 911 / TTY 617-222-1000 | @TheMBTA |
| | + Service Transfer | + Rapid Transit Transfer | + Bus Transfer | + Future accessibility planned | | | + Elevator/escalator/lift updates: 617-222-2828 | @TheMBTA |
| | + Rapid Transit Transfer | + Bus Transfer | | | | | + All bus service is accessible. Ferry accessibility may vary with tides. *Boylston: only Silver Line is accessible. | |

Channels: Color



Note: State figures may not reflect repatriated patients from the Diamond Princess cruise ship or those evacuated from Wuhan, China.

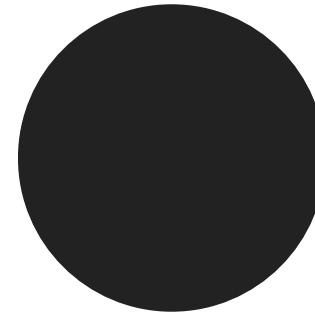
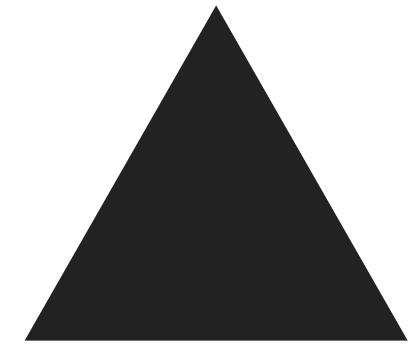
Channels

A visual **channel** is a **parameter** that controls the appearance of marks

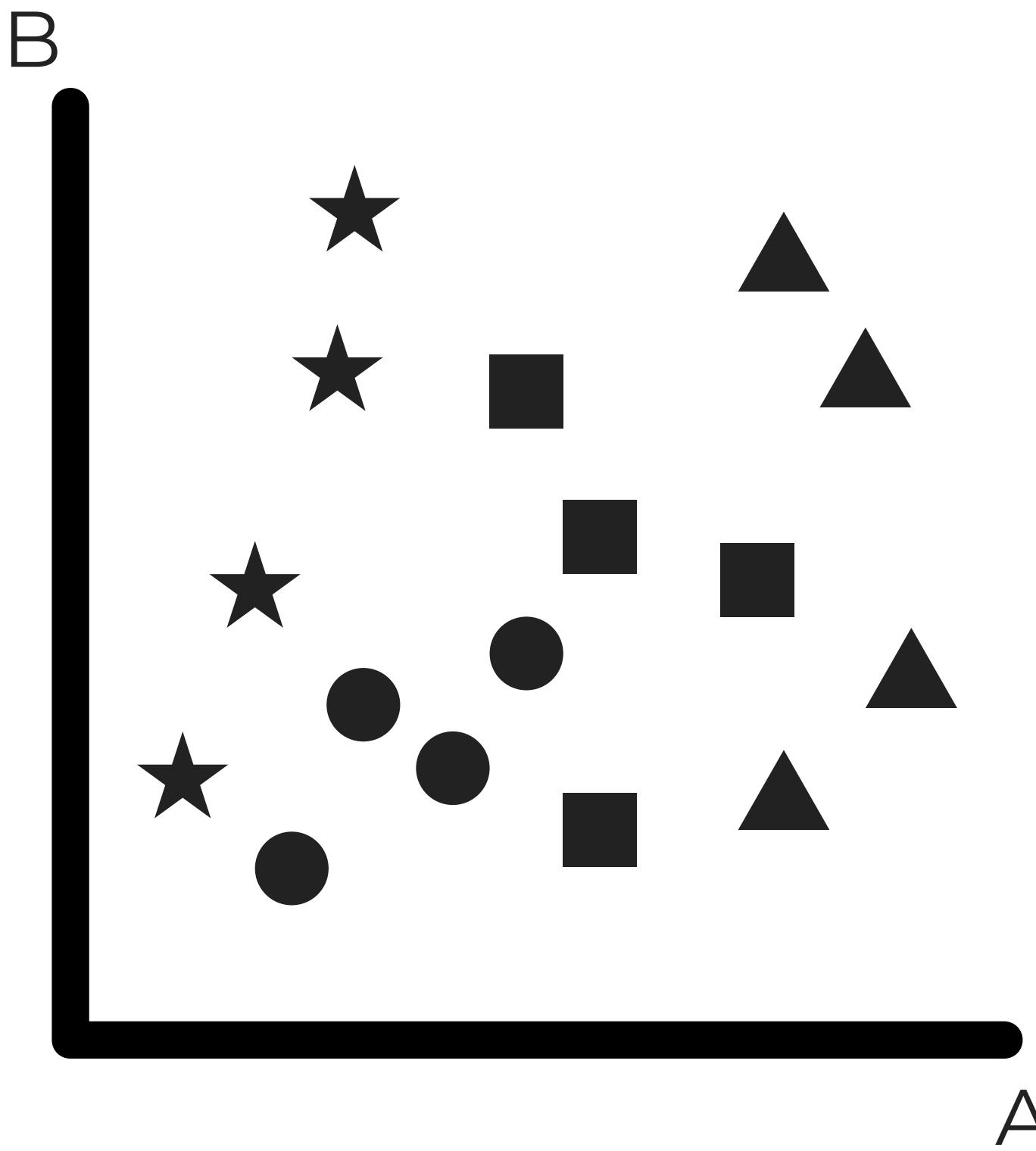
Five types of channels:

- position
- color
- shape

Channels: Shape



Channels: Shape



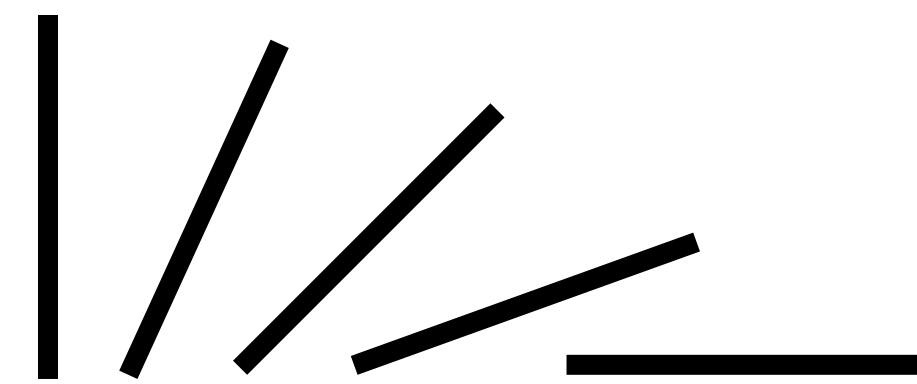
Channels

A visual **channel** is a **parameter** that controls the appearance of marks

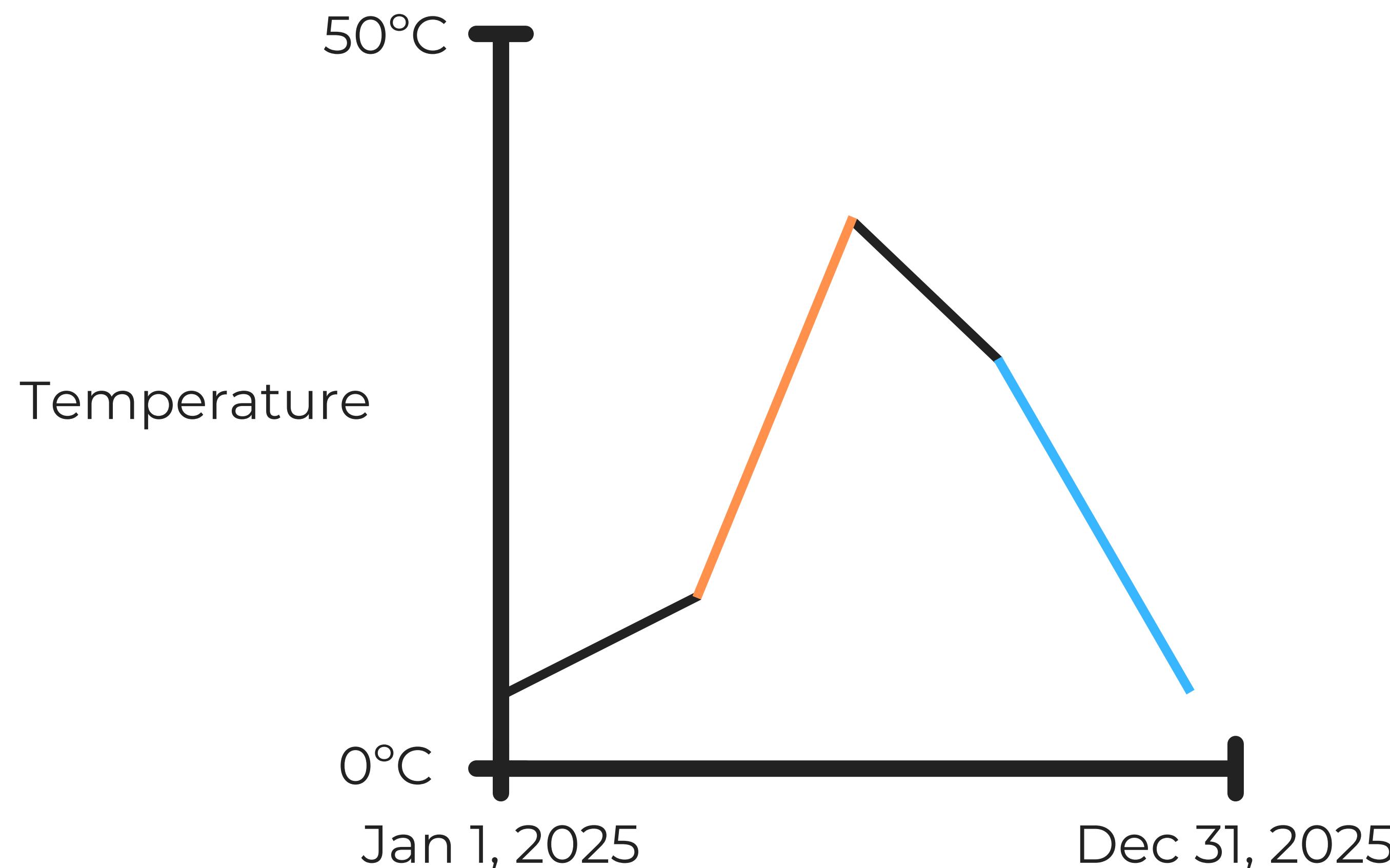
Five types of channels:

- position
- color
- shape
- tilt/orientation

Channels: Tilt/Orientation



Channels: Tilt/Orientation



Channels: Tilt/Orientation



Channels

A visual **channel** is a **parameter** that controls the appearance of marks

Five types of channels:

- position
- color
- shape
- tilt/orientation
- size

Channels: Size

For 1D marks, the size channel is **length**



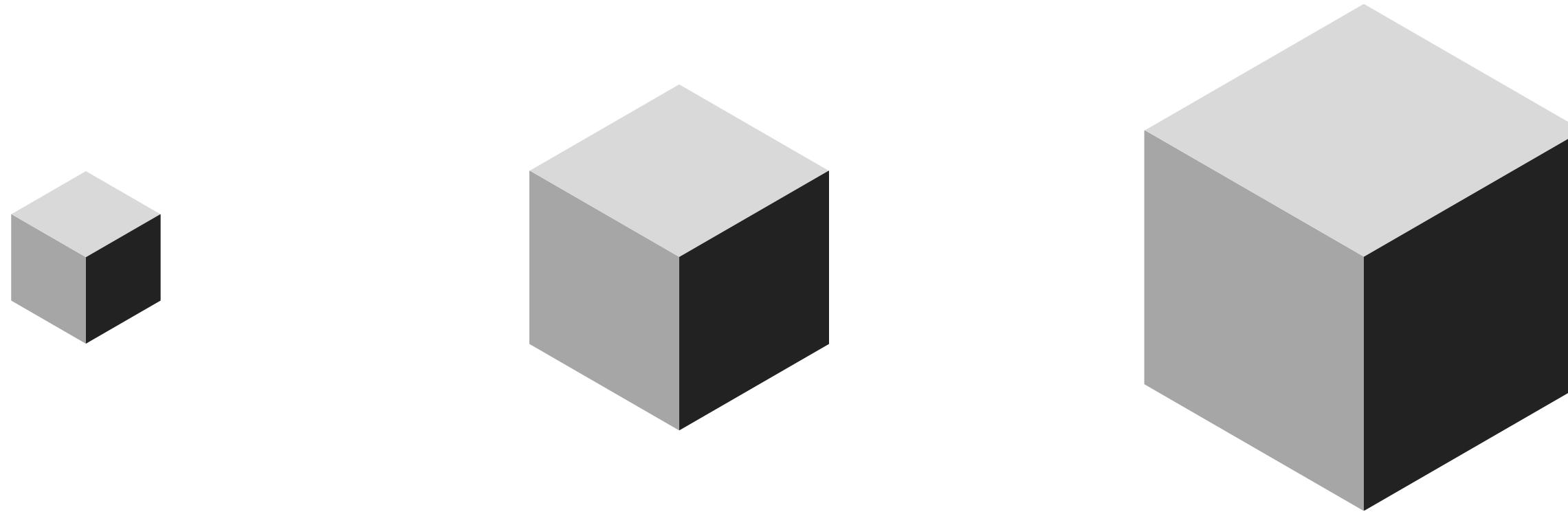
For 2D marks, the size channel is **area**



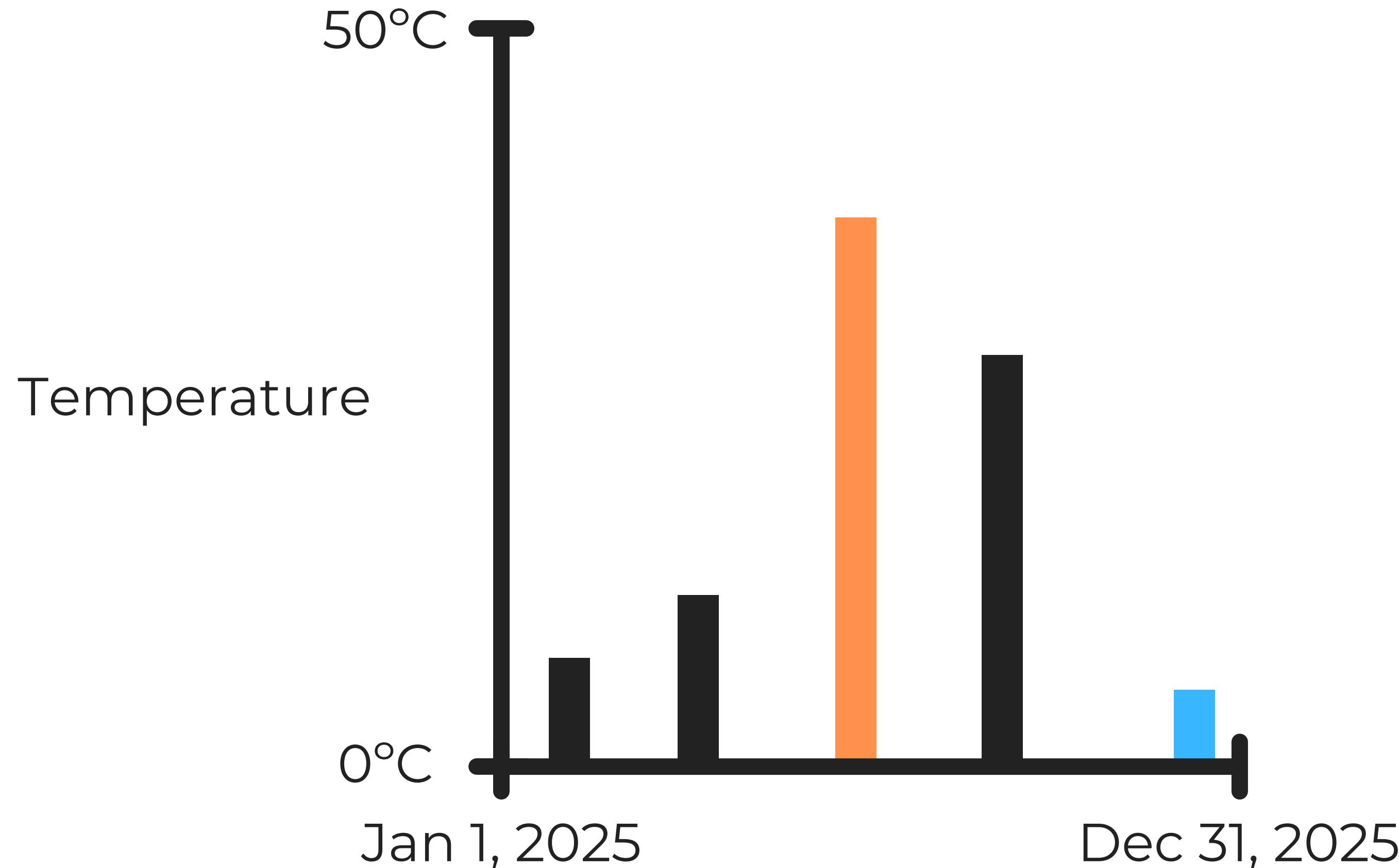
Size doesn't apply to 0D marks

Channels: Size

For 3D marks, the size channel is **volume**
(but again, probably don't use it)

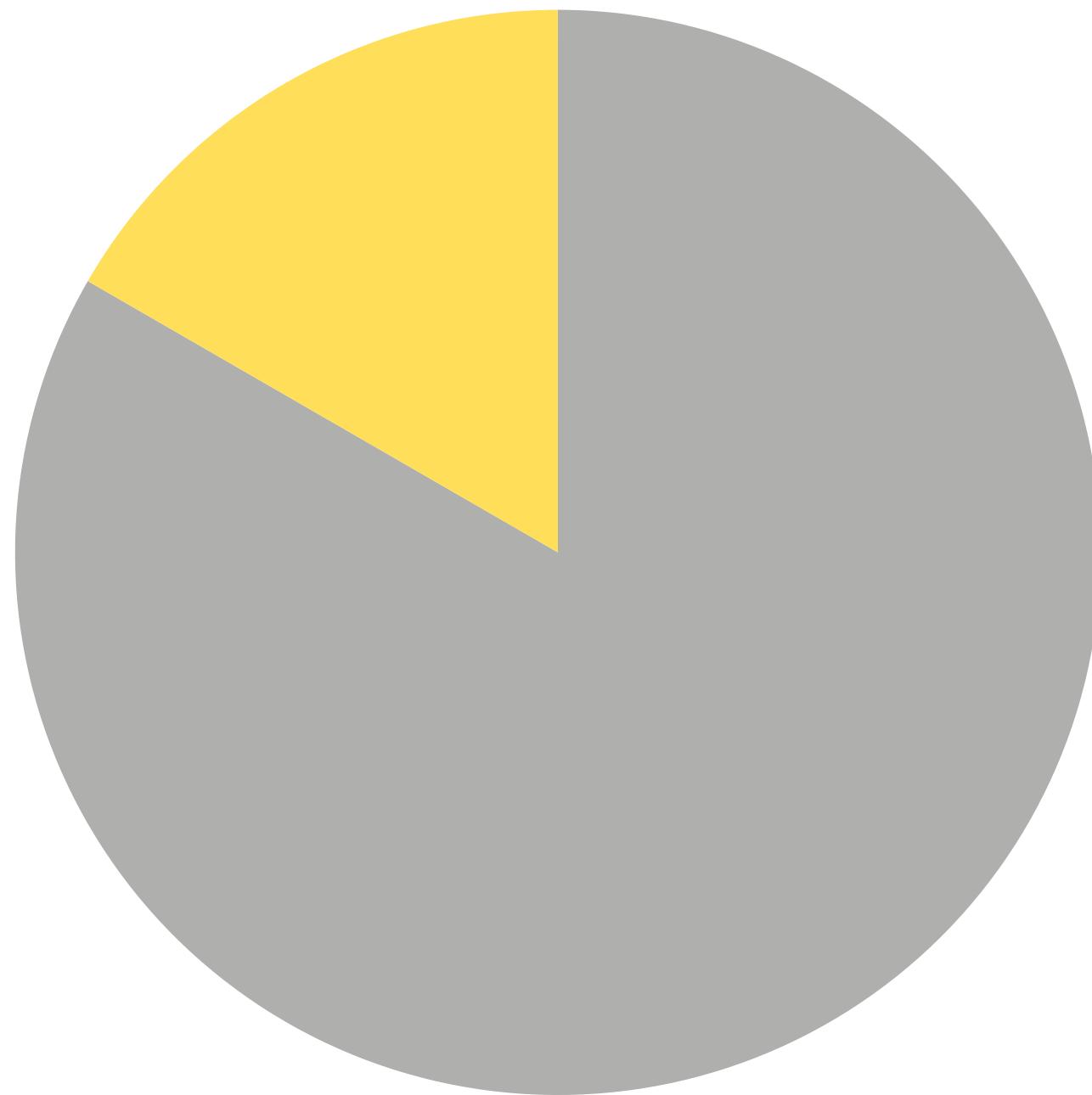


Channels: Size



Channels: Size

■ Yes ■ Yes in yellow



Channels

A visual **channel** is a **parameter** that controls the appearance of marks

Five types of channels:

- position
- color
- shape
- tilt/orientation
- size

④ Position



④ Color



④ Shape



④ Tilt



④ Size

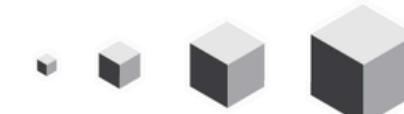
→ Length



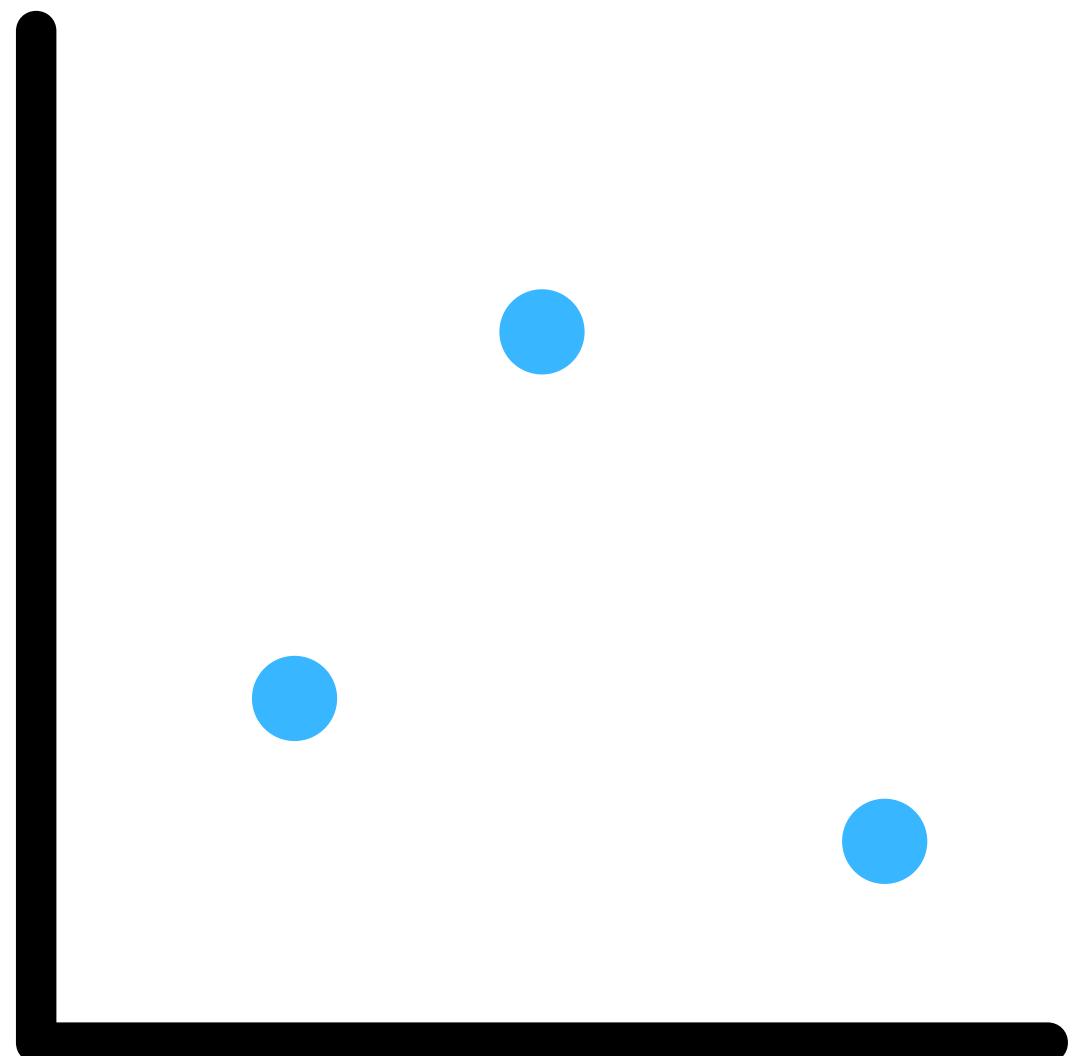
→ Area



→ Volume



Name the marks + channels



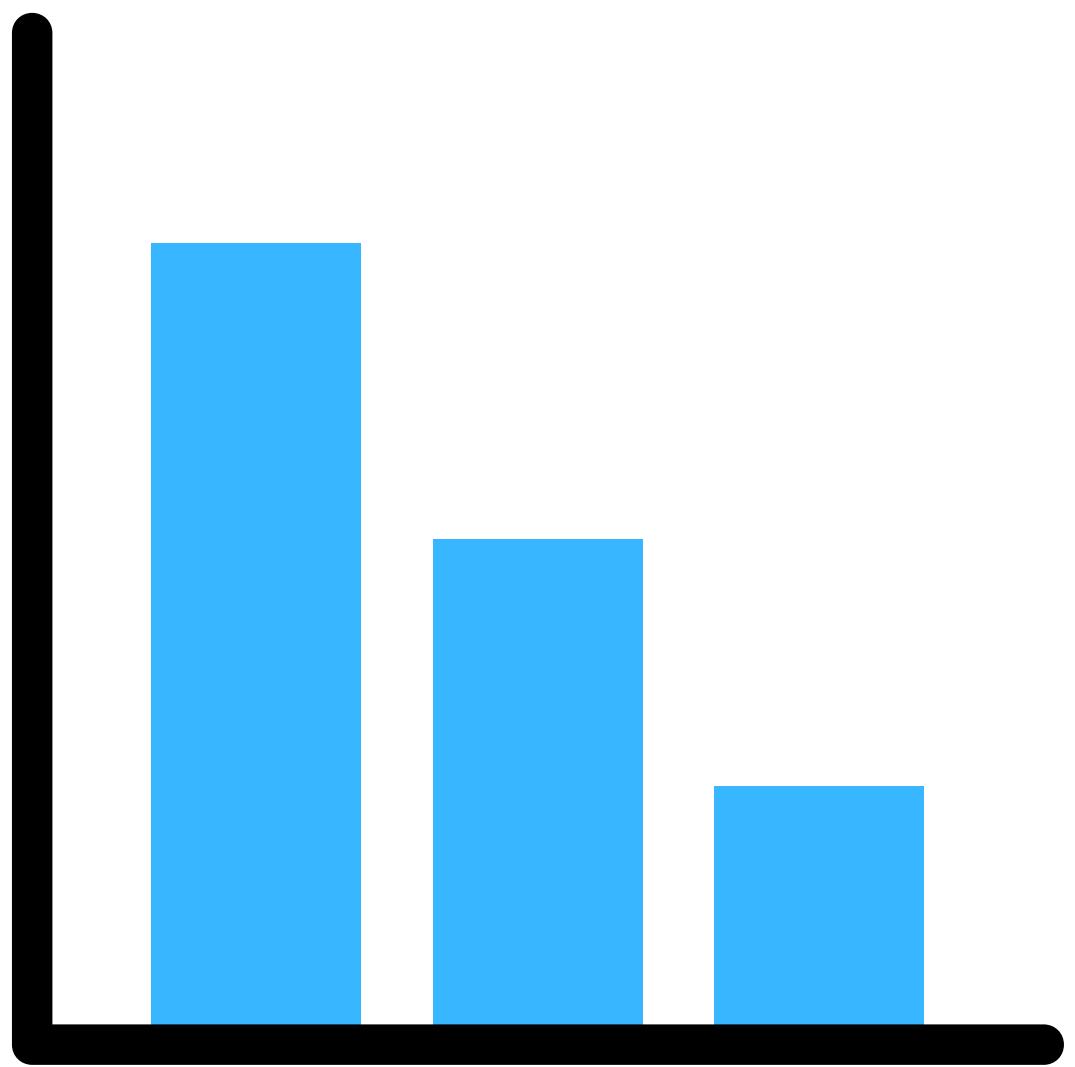
Mark Types

- 0D (Points)
- 1D (Lines)
- 2D (Lines)

Channel Types

- Position
- Color
- Shape
- Tilt/Orientation
- Size

Name the marks + channels



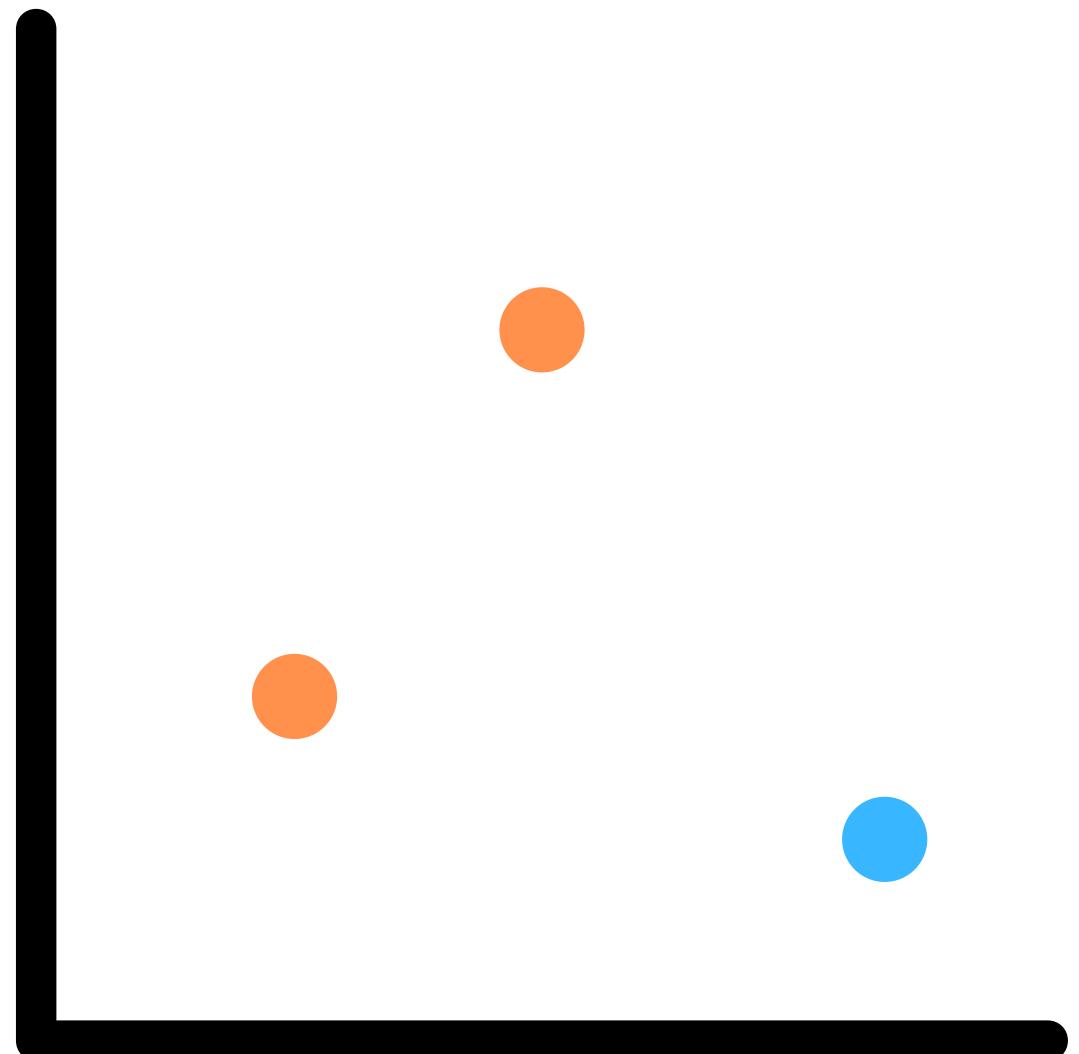
Mark Types

- 0D (Points)
- 1D (Lines)
- 2D (Lines)

Channel Types

- Position
- Color
- Shape
- Tilt/Orientation
- Size

Name the marks + channels



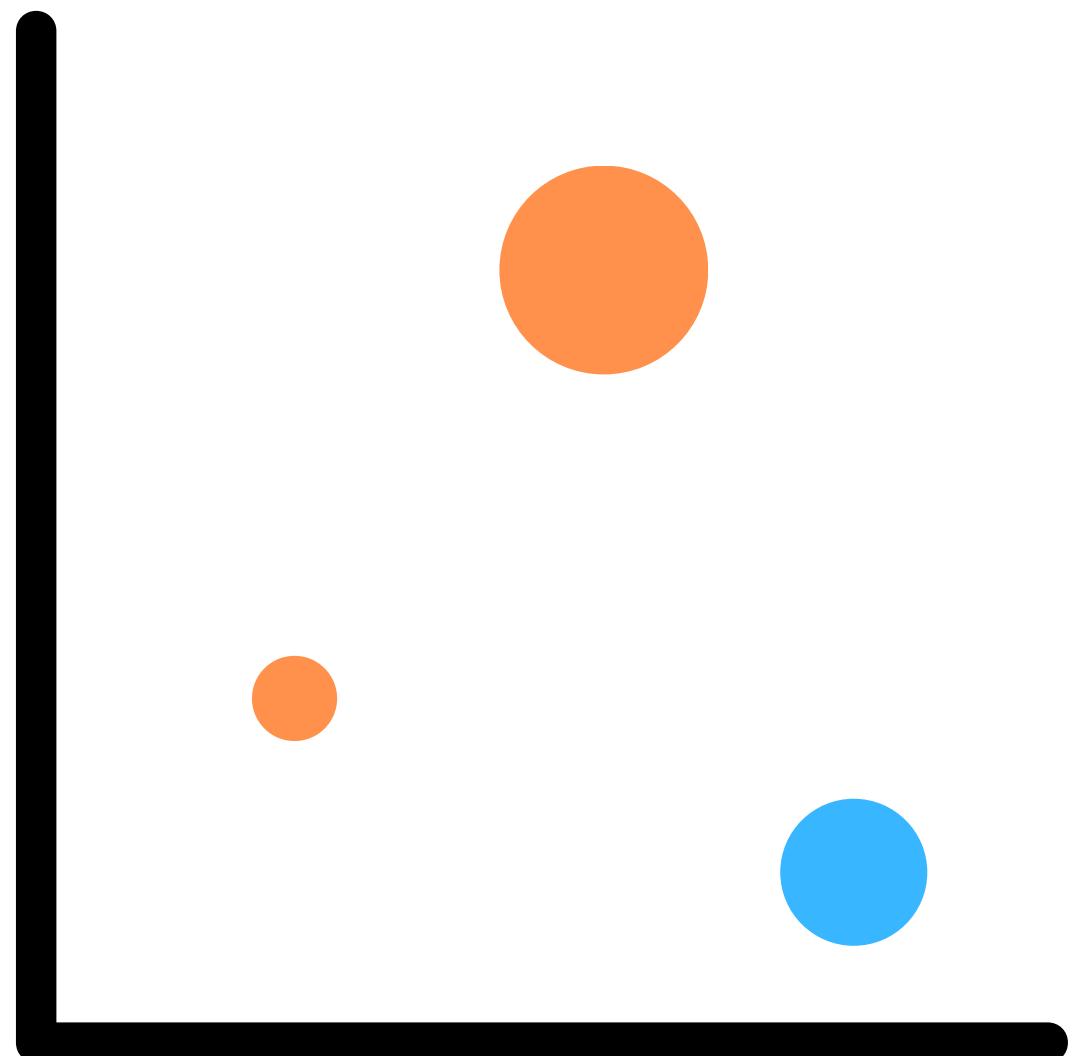
Mark Types

- 0D (Points)
- 1D (Lines)
- 2D (Lines)

Channel Types

- Position
- Color
- Shape
- Tilt/Orientation
- Size

Name the marks + channels



Mark Types

- 0D (Points)
- 1D (Lines)
- 2D (Lines)

Channel Types

- Position
- Color
- Shape
- Tilt/Orientation
- Size

Expressiveness and Effectiveness

The **expressiveness principle** states that a visual encoding should express all of, and only, the information in the attributes being visualized

Ordered attributes (ordinal and quantitative) should be shown in a way that we visually perceive as ordered

Unordered attributes (categorical) should **not** be shown in a way that implies an ordering

Expressiveness and Effectiveness

→ Magnitude Channels: Ordered Attributes

Position on common scale



Position on unaligned scale



Length (1D size)



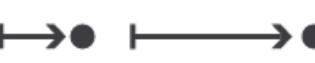
Tilt/angle



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 or Where?

How much?

Expressiveness and Effectiveness

The **effectiveness principle** states that we should use the most salient (noticeable) channels to encode the most important attributes

Factors that influence **effectiveness**:

- accuracy

Expressiveness and Effectiveness

→ 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

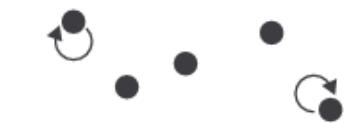
Spatial region



Color hue



Motion



Shape



↑ Most Effective ↓ Least Effective Same

Expressiveness and Effectiveness

→ Magnitude Channels: Ordered Attributes

Position on common scale



Position on unaligned scale



Length (1D size)



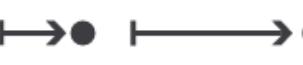
Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



→ Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



Shape

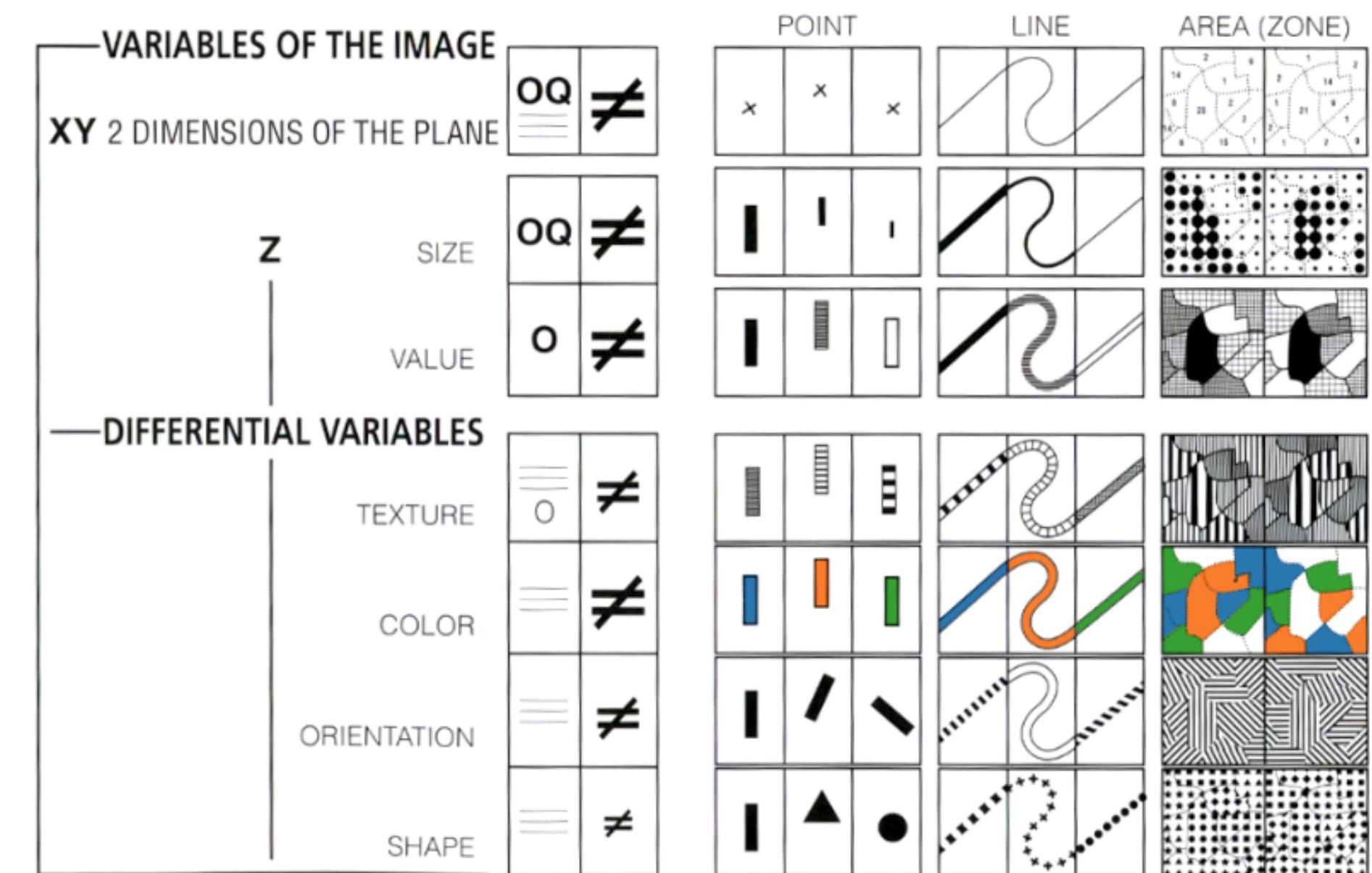


↑ Most
Effectiveness
Same
Least ↓

Expressiveness and Effectiveness

These rankings are synthesized from various prior works:

Jacques Bertin (1967)
“Semiology of Graphics”

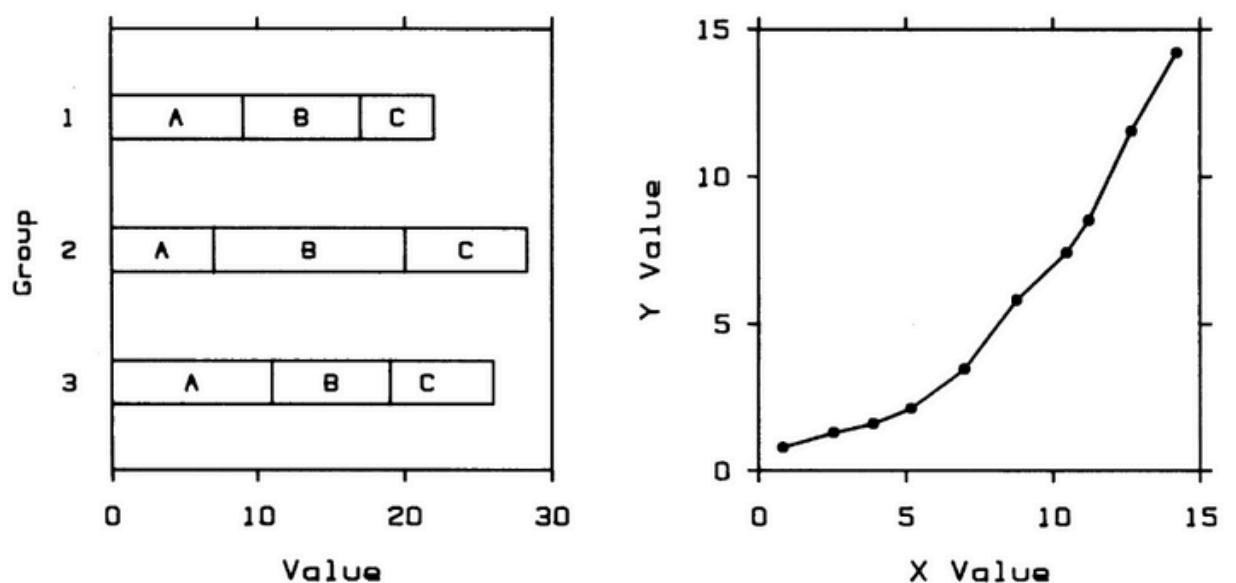
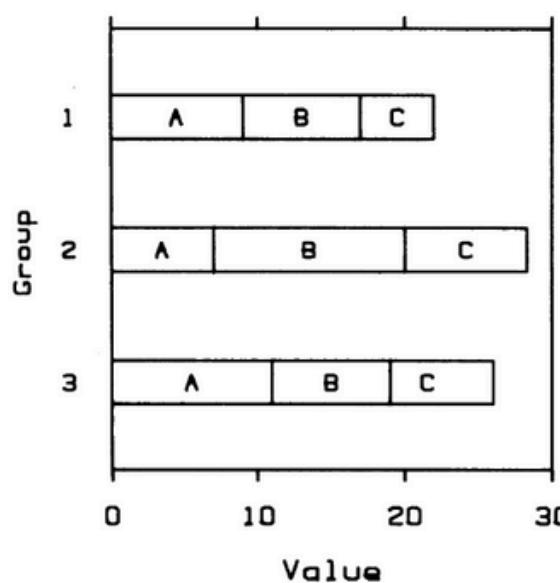
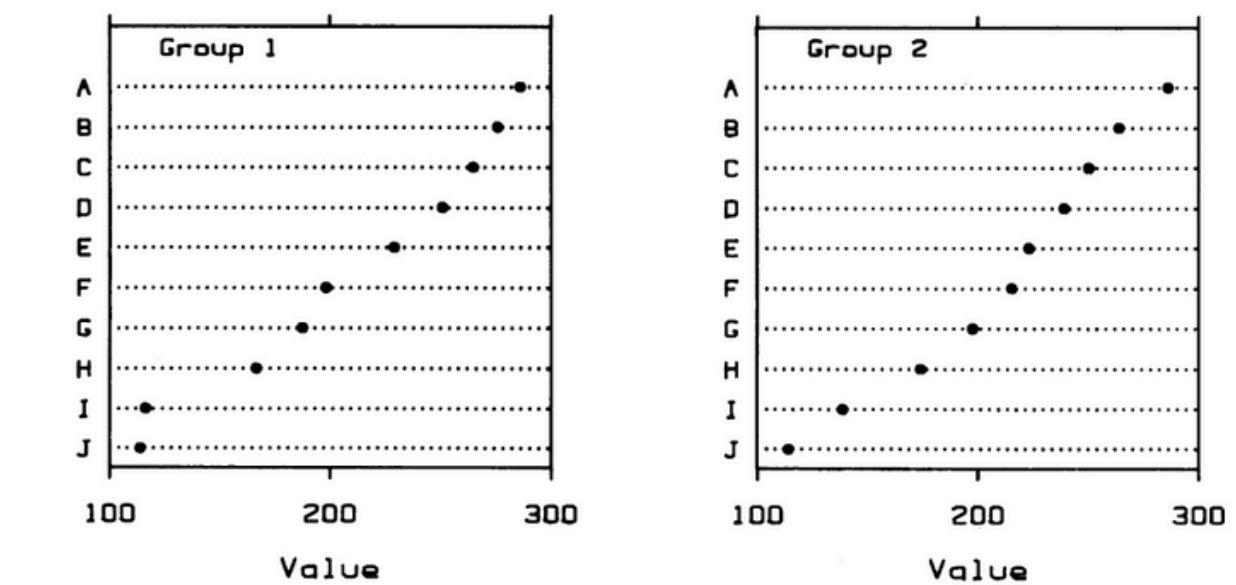
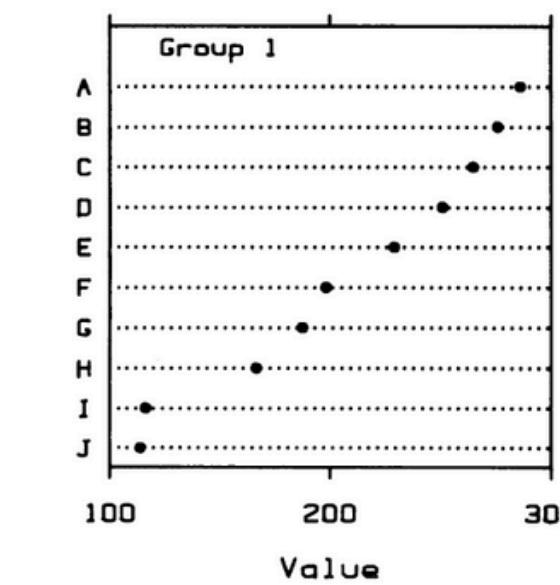


Expressiveness and Effectiveness

These rankings are synthesized from various prior works:

Cleveland & McGill (1985)

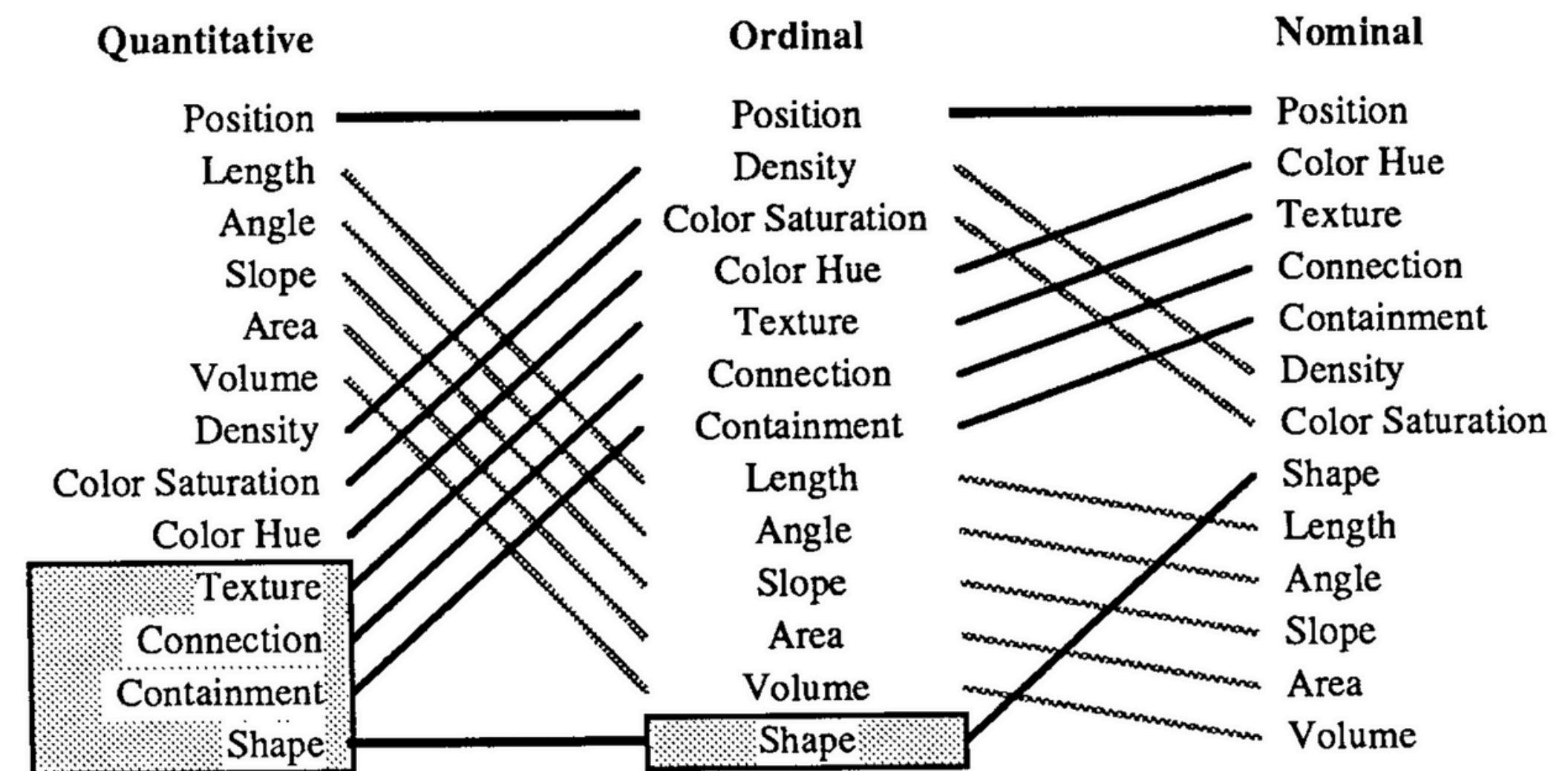
“Graphical Perception and Graphical Methods for Analyzing Scientific Data”



Expressiveness and Effectiveness

These rankings are synthesized from various prior works:

MacKinlay (1986)
“Automating the
Design of Graphical
Presentations of
Relational Information”



Expressiveness and Effectiveness

These rankings are synthesized from various prior works:

Heer & Bostock (2010)

“Crowdsourcing Graphical Perception:
Using Mechanical Turk to Assess
Visualization Design”

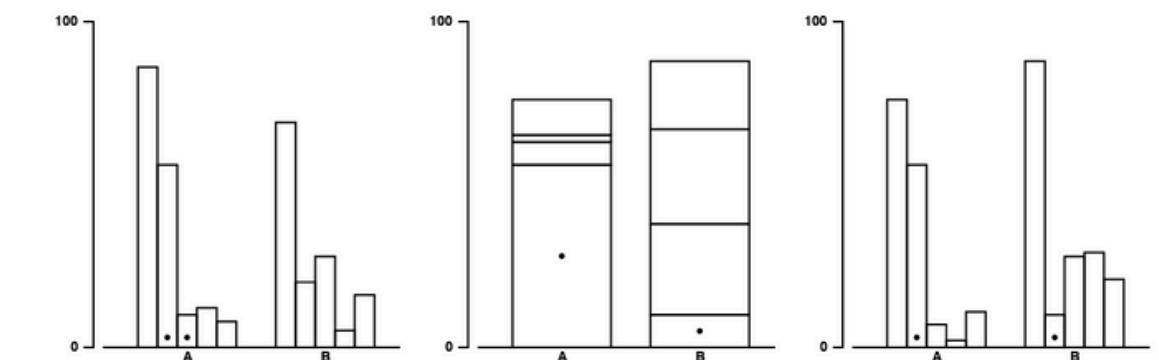


Figure 1: Stimuli for judgment tasks T1, T2 & T3. Subjects estimated percent differences between elements.

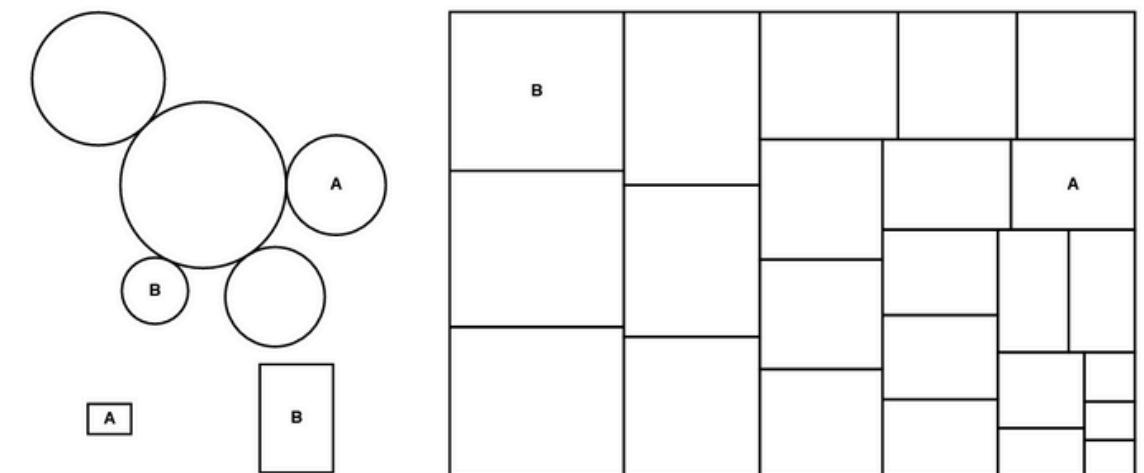


Figure 2: Area judgment stimuli. Top left: Bubble chart (T7), Bottom left: Center-aligned rectangles (T8), Right: Treemap (T9).

Expressiveness and Effectiveness

→ Magnitude Channels: Ordered Attributes

Position on common scale



Position on unaligned scale



Length (1D size)



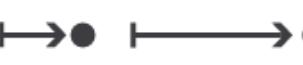
Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



→ Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



Shape



Most
Effectiveness

Effectiveness

Same

Least

Expressiveness and Effectiveness

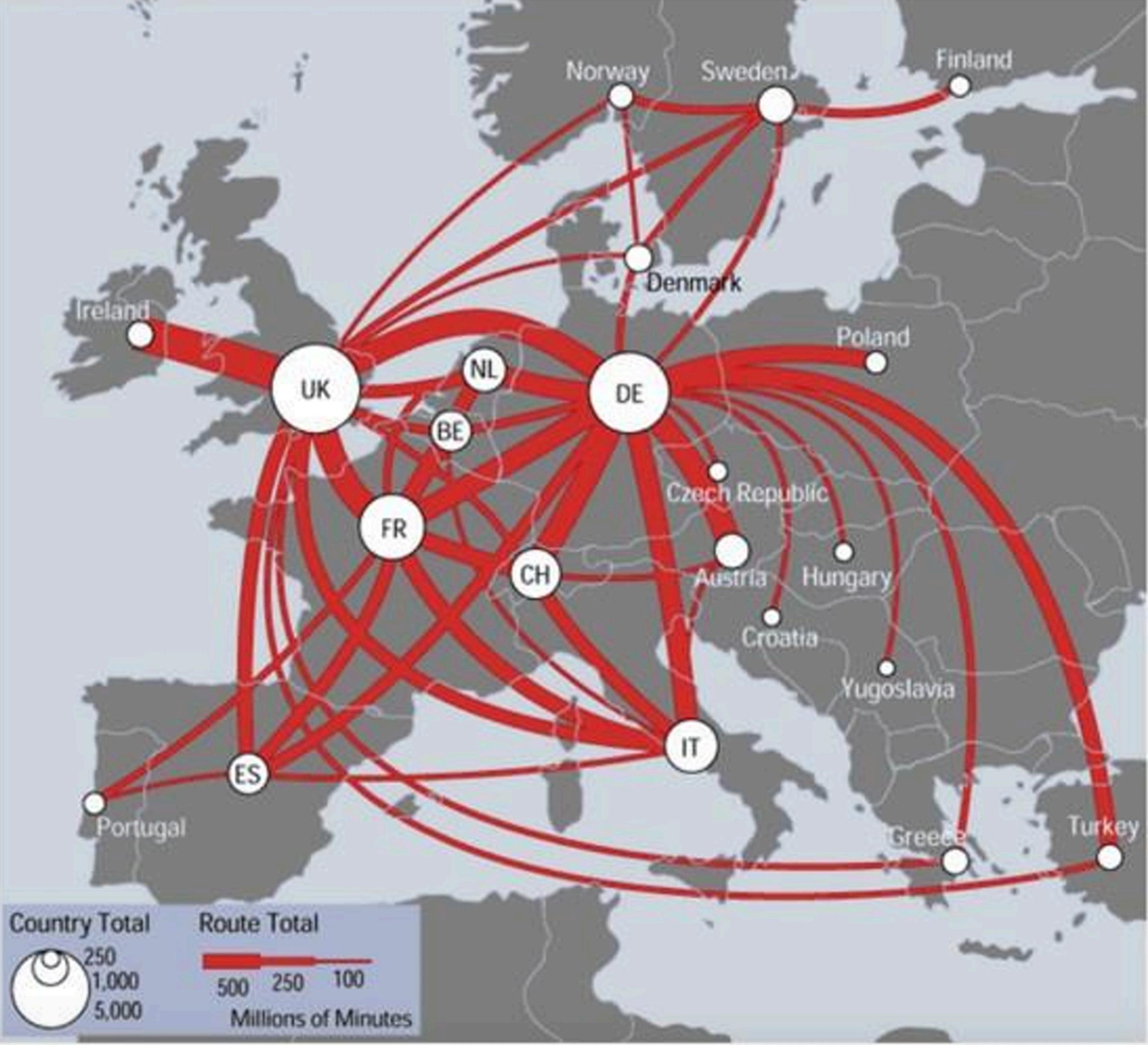
The **effectiveness principle** states that we should use the most salient (noticeable) channels to encode the most important attributes

Factors that influence **effectiveness**:

- accuracy
- discriminability

Discriminability

Can the differences within a channel be perceived easily?



Expressiveness and Effectiveness

The **effectiveness principle** states that we should use the most salient (noticeable) channels to encode the most important attributes

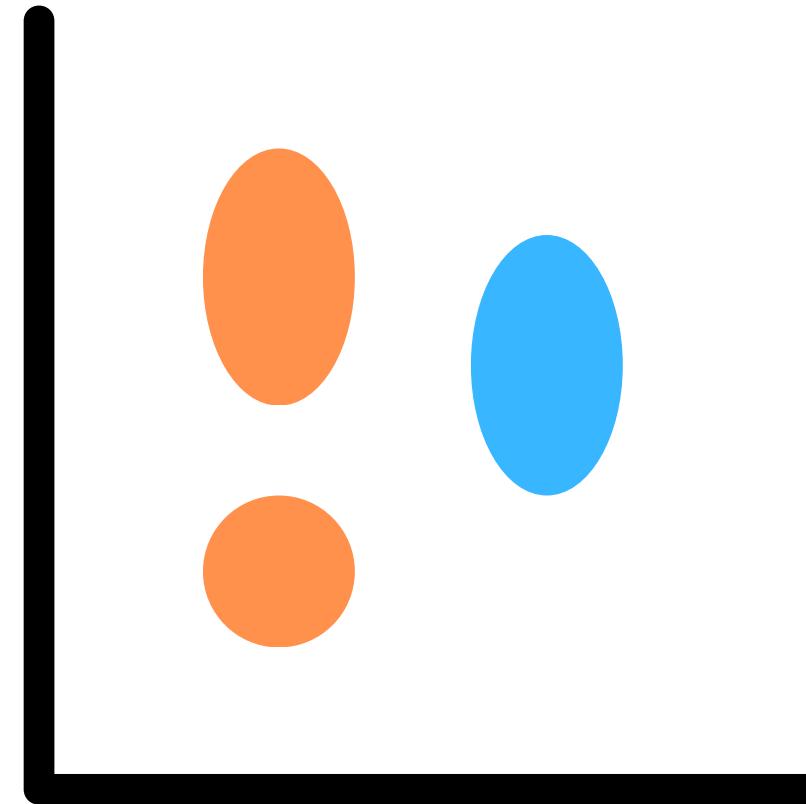
Factors that influence **effectiveness**:

- accuracy
- discriminability
- separability vs integrality

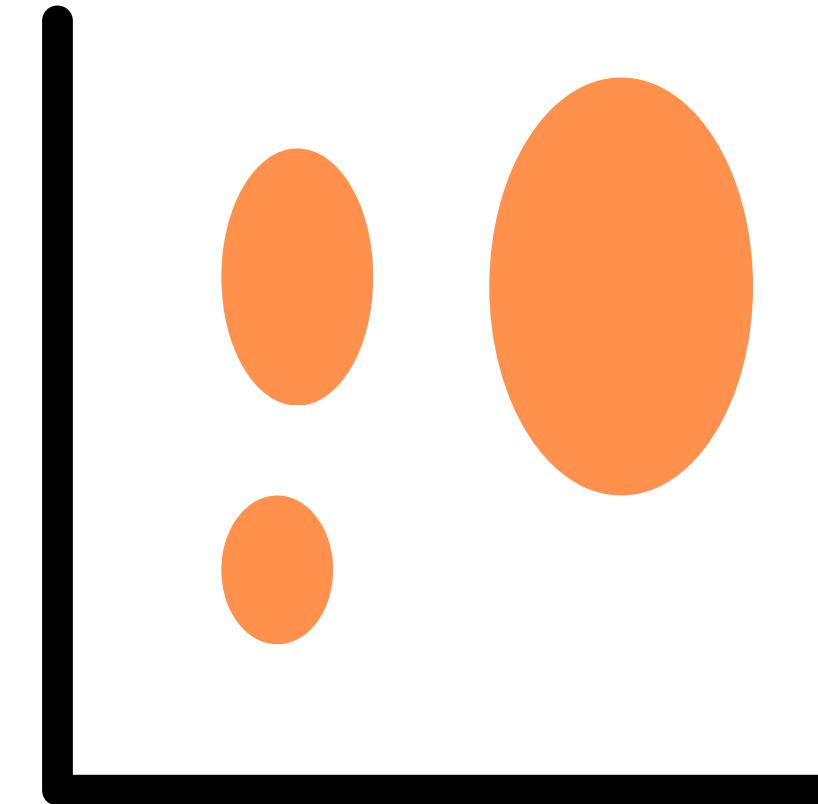
Separable vs Integral Channels

Two channels are **separable** when they can be judged individual

Two channels are **integral** when they are perceived holistically



Height and Color
are **separable**



Width and Height
are **integral**

Separable vs Integral Channels

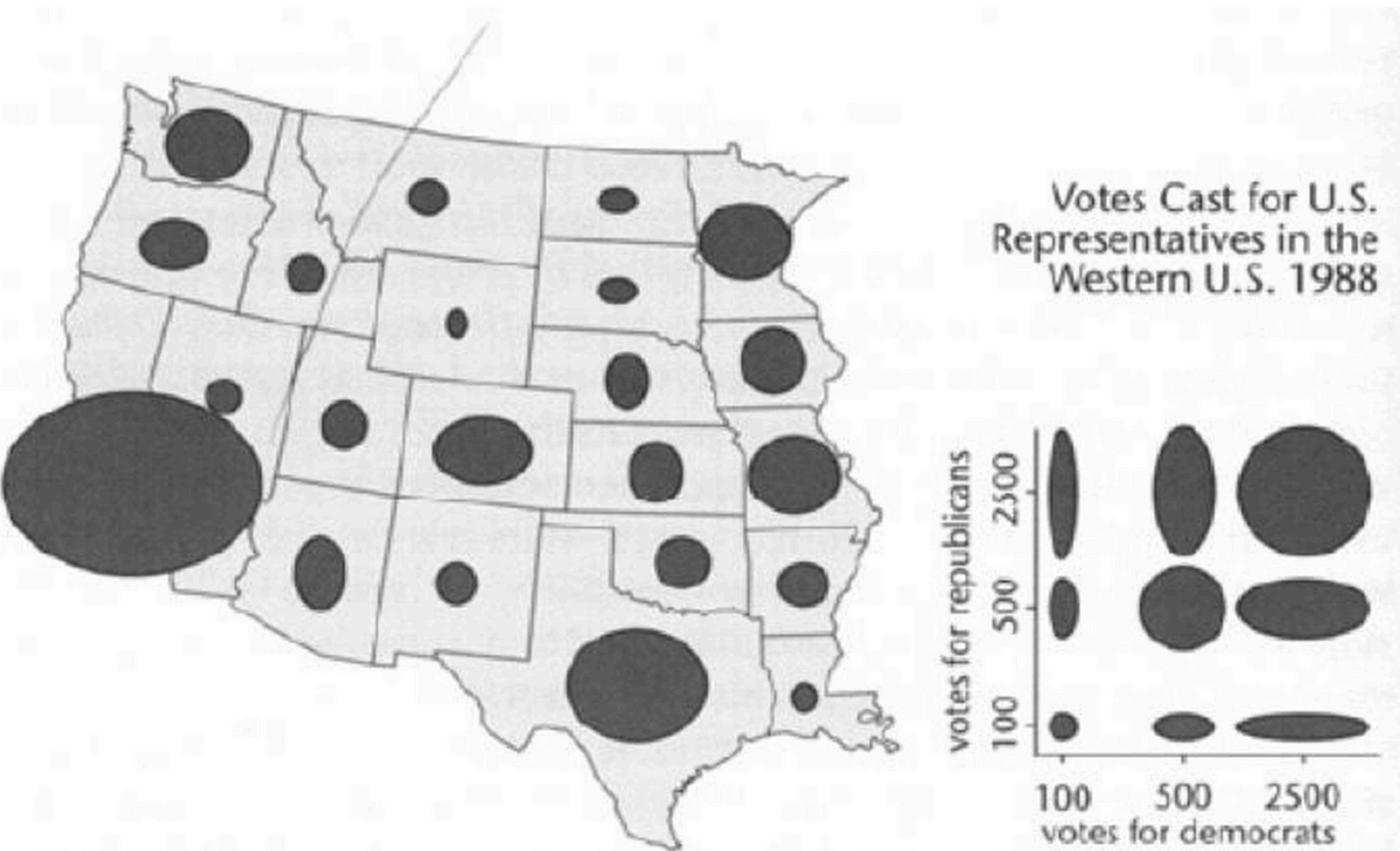
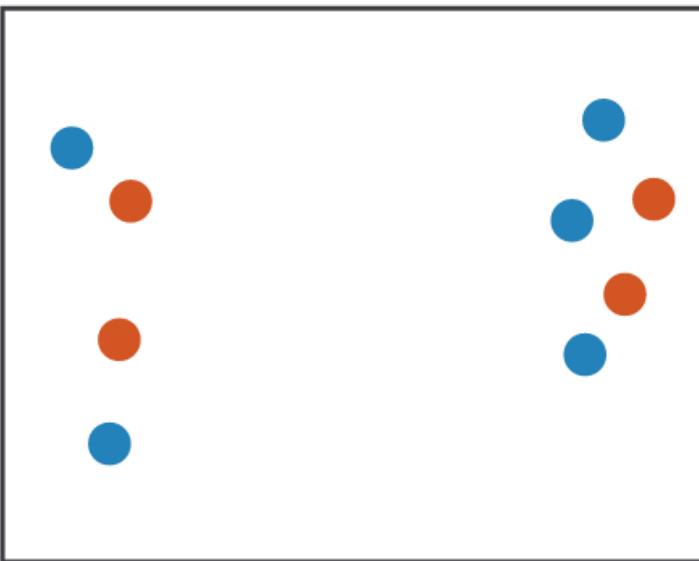


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

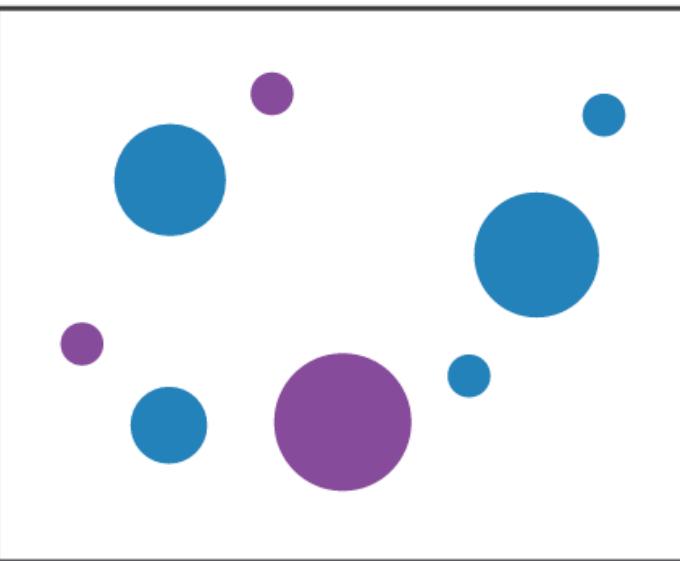
Separable vs Integral Channels

Position
+ Hue (Color)



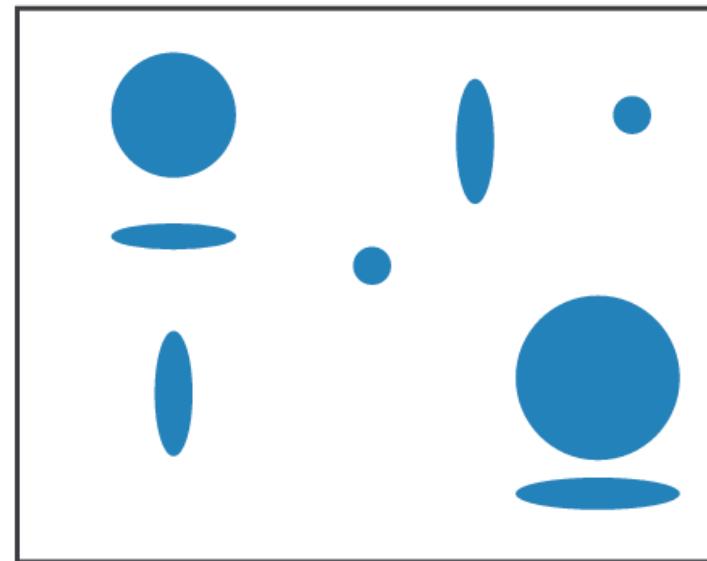
Fully separable

Size
+ Hue (Color)



Some interference

Width
+ Height



Some/significant
interference

Red
+ Green



Major interference

Expressiveness and Effectiveness

The **effectiveness principle** states that we should use the most salient (noticeable) channels to encode the most important attributes

Factors that influence **effectiveness**:

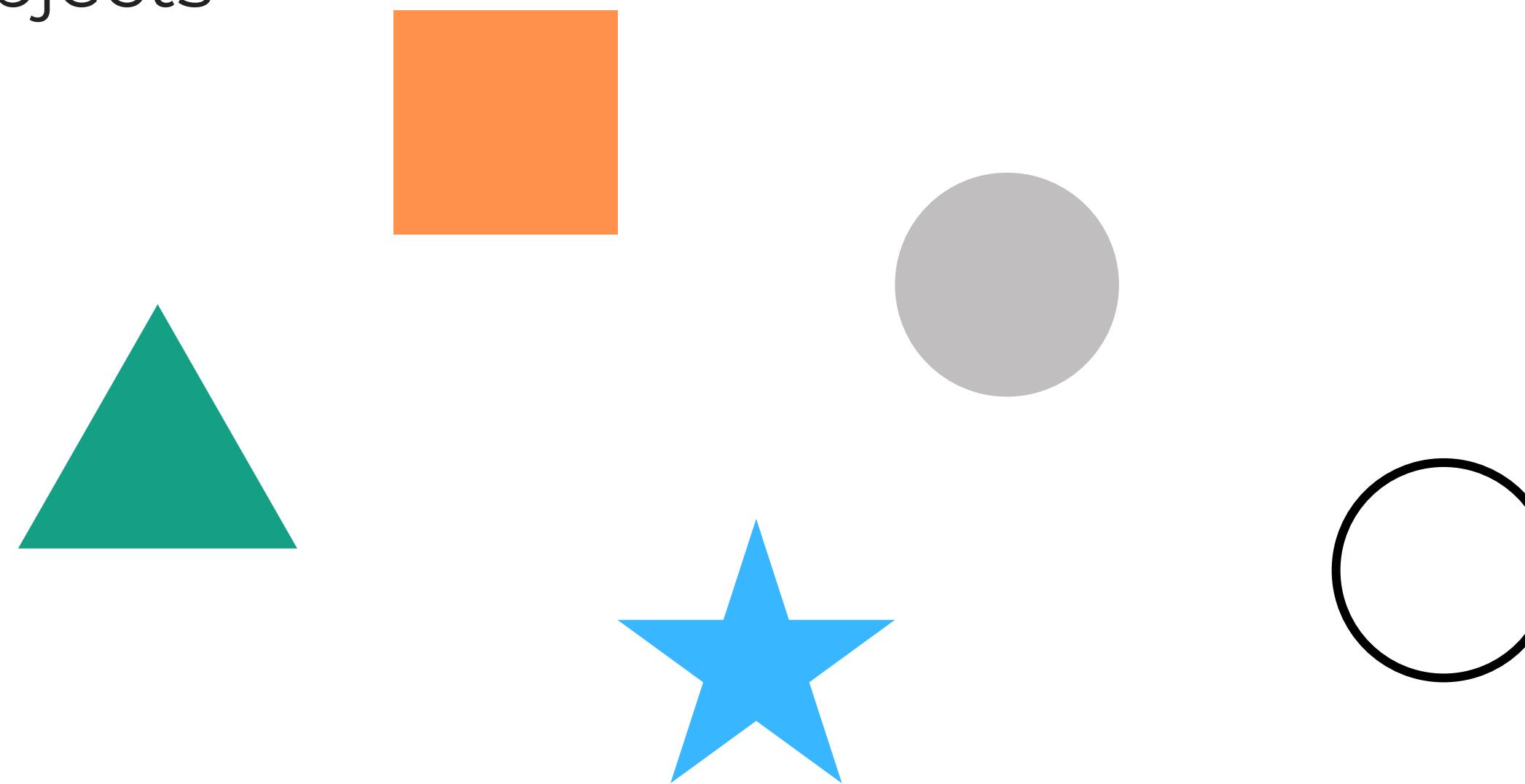
- accuracy
- discriminability
- separability vs integrality
- encoding semantics

Encoding Semantics

Certain encodings imply specific semantic interpretations

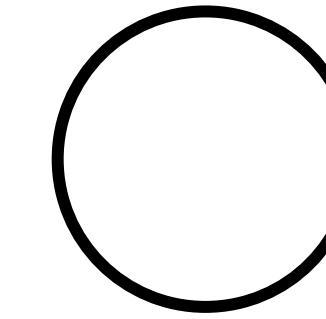
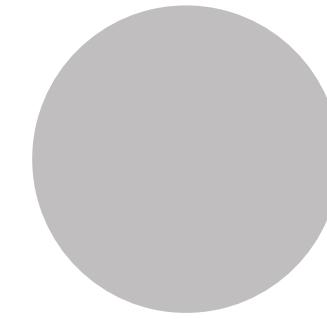
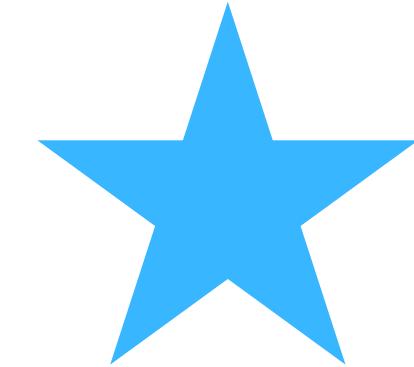
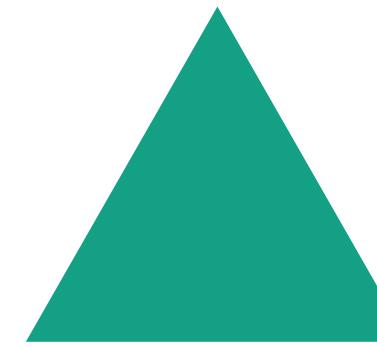
Encoding Semantics

Small closed-shape marks are perceived as items, nodes, and/or individual objects



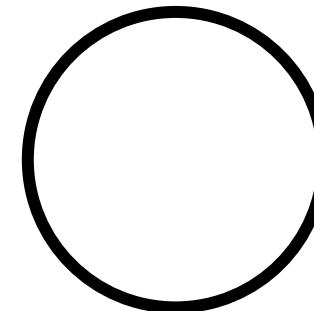
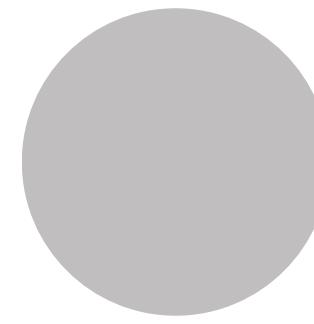
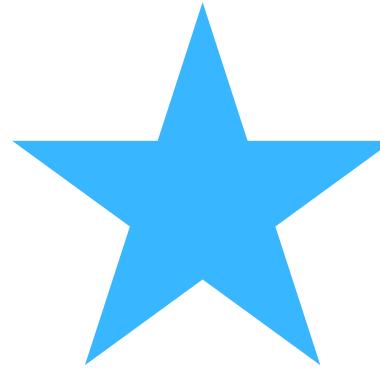
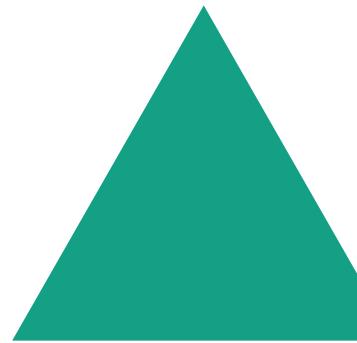
Encoding Semantics

Spatially-ordered closed-shape marks are perceived as a sequence (from left to right for a Western audience)



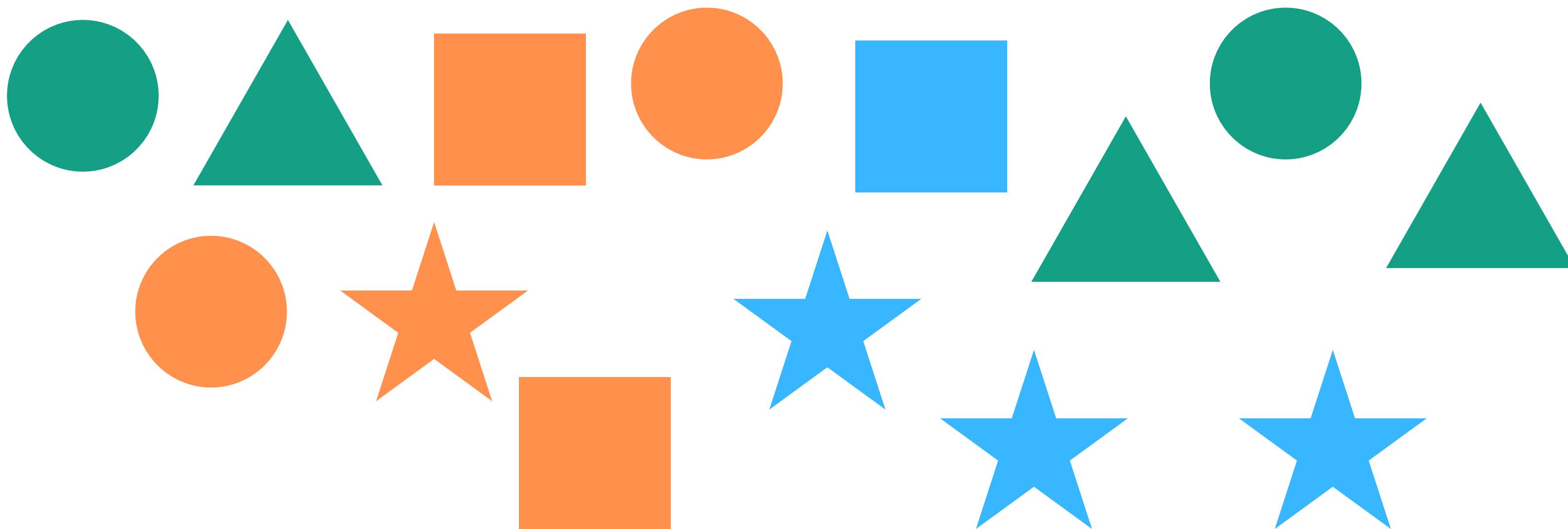
Encoding Semantics

Marks in proximity are perceived to encode related information



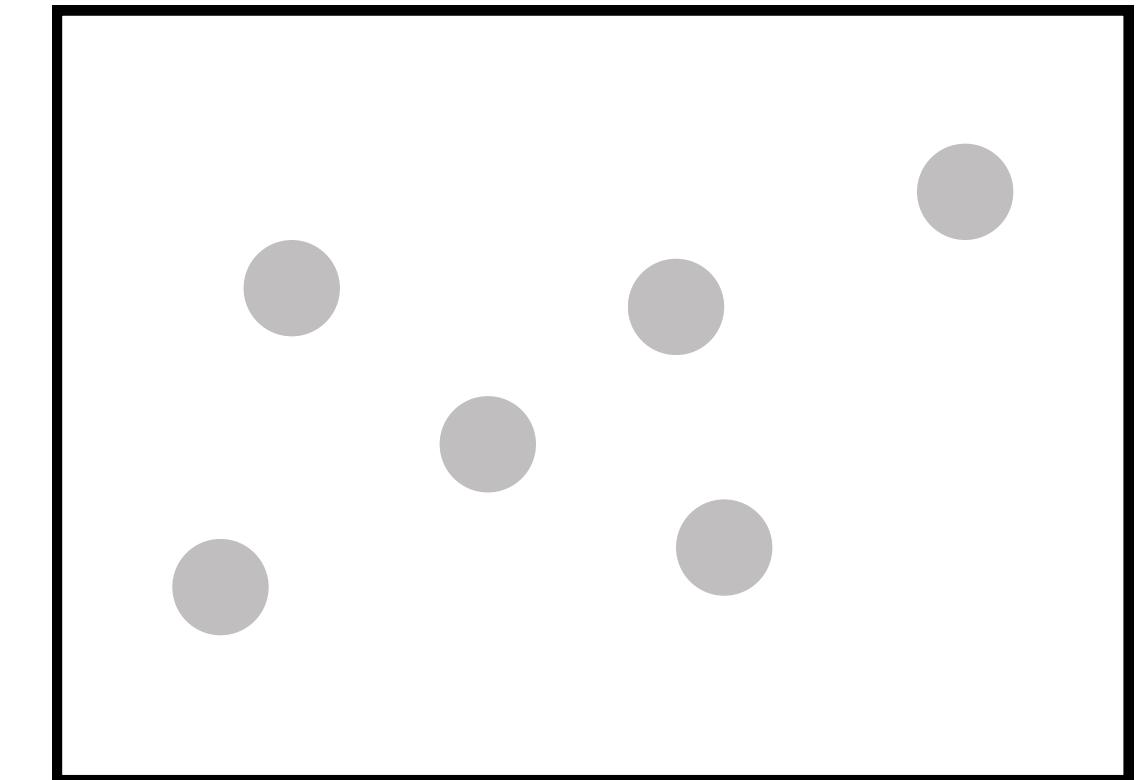
Encoding Semantics

Marks with the same color or shape are perceived to encode related information



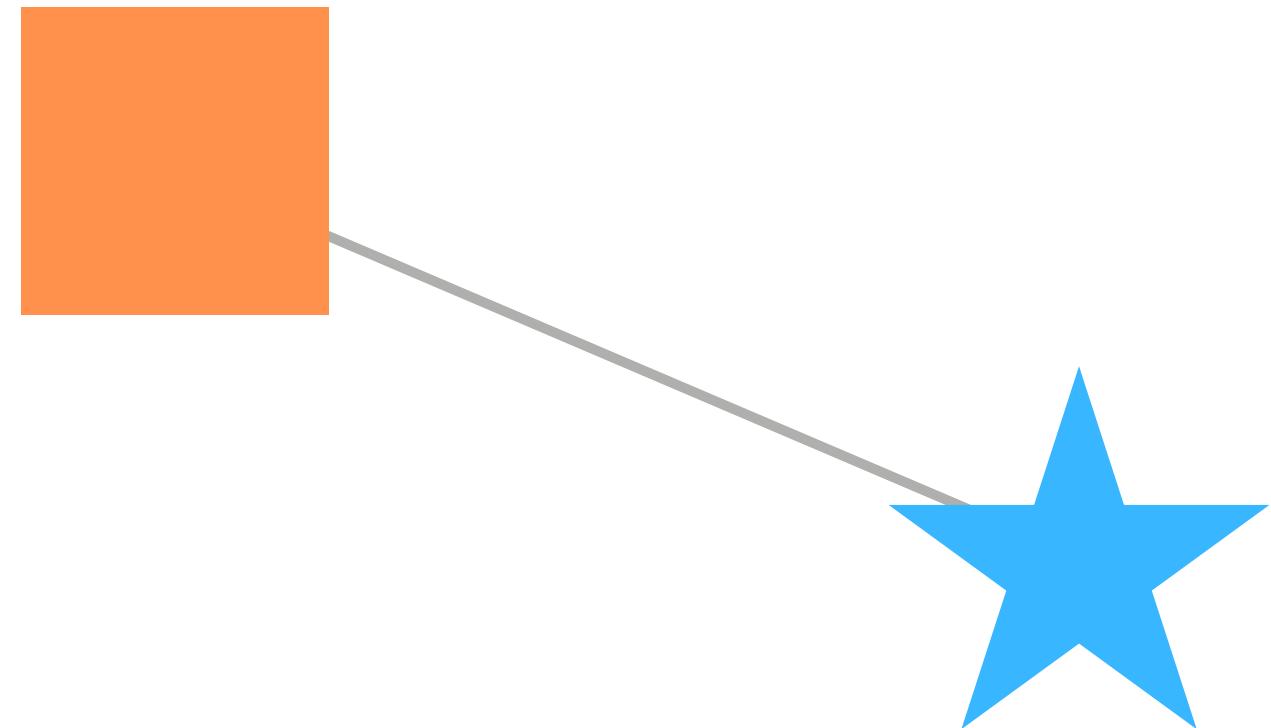
Encoding Semantics

The size or height of a mark indicates magnitude, amount, or importance



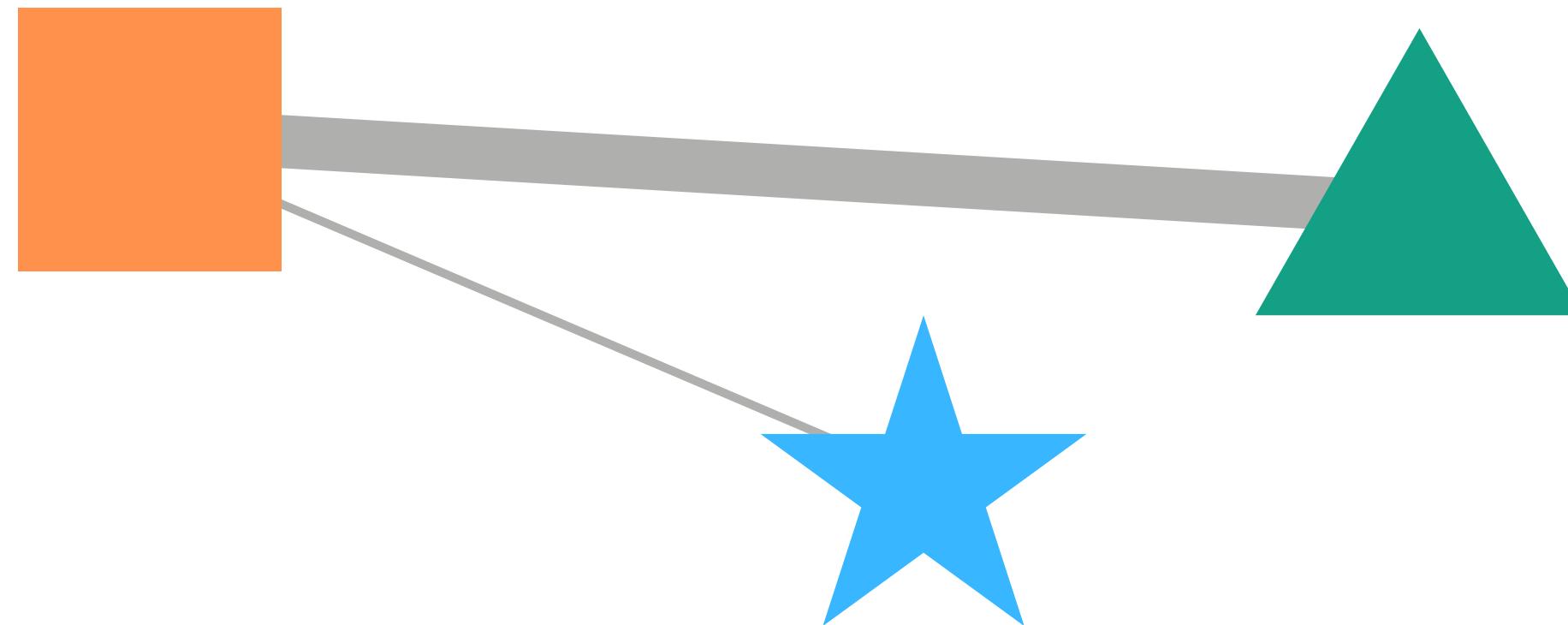
Encoding Semantics

Closed-shape marks connected by a line/contour are perceived to encode related information



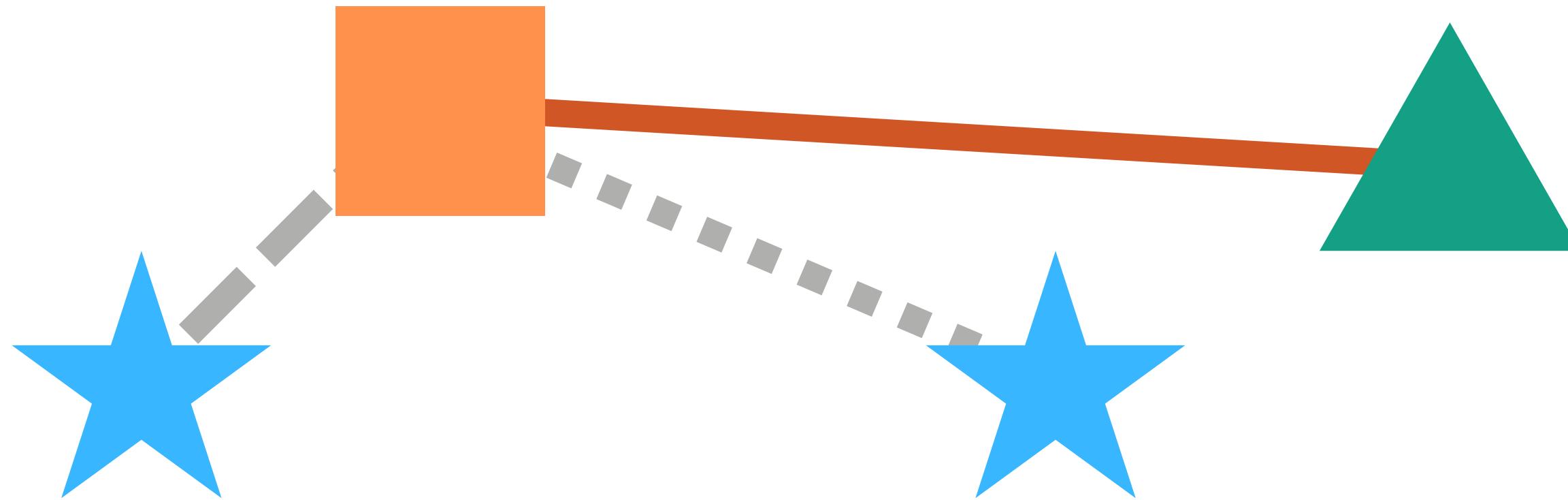
Encoding Semantics

The thickness of connecting contours implies the strength of the relationship (thicker line = more related)



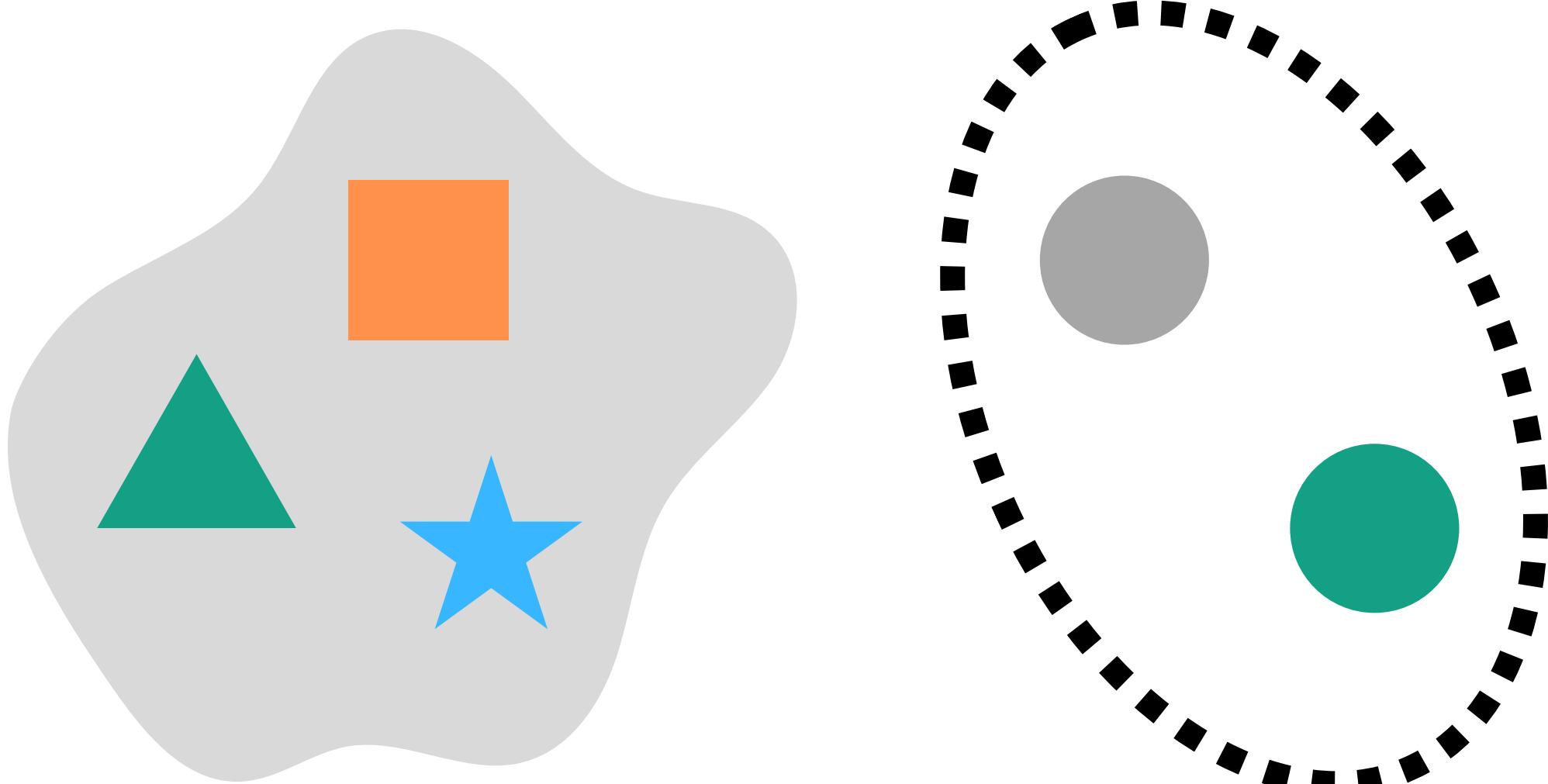
Encoding Semantics

Different colors and textures of lines/contours imply different relationship types



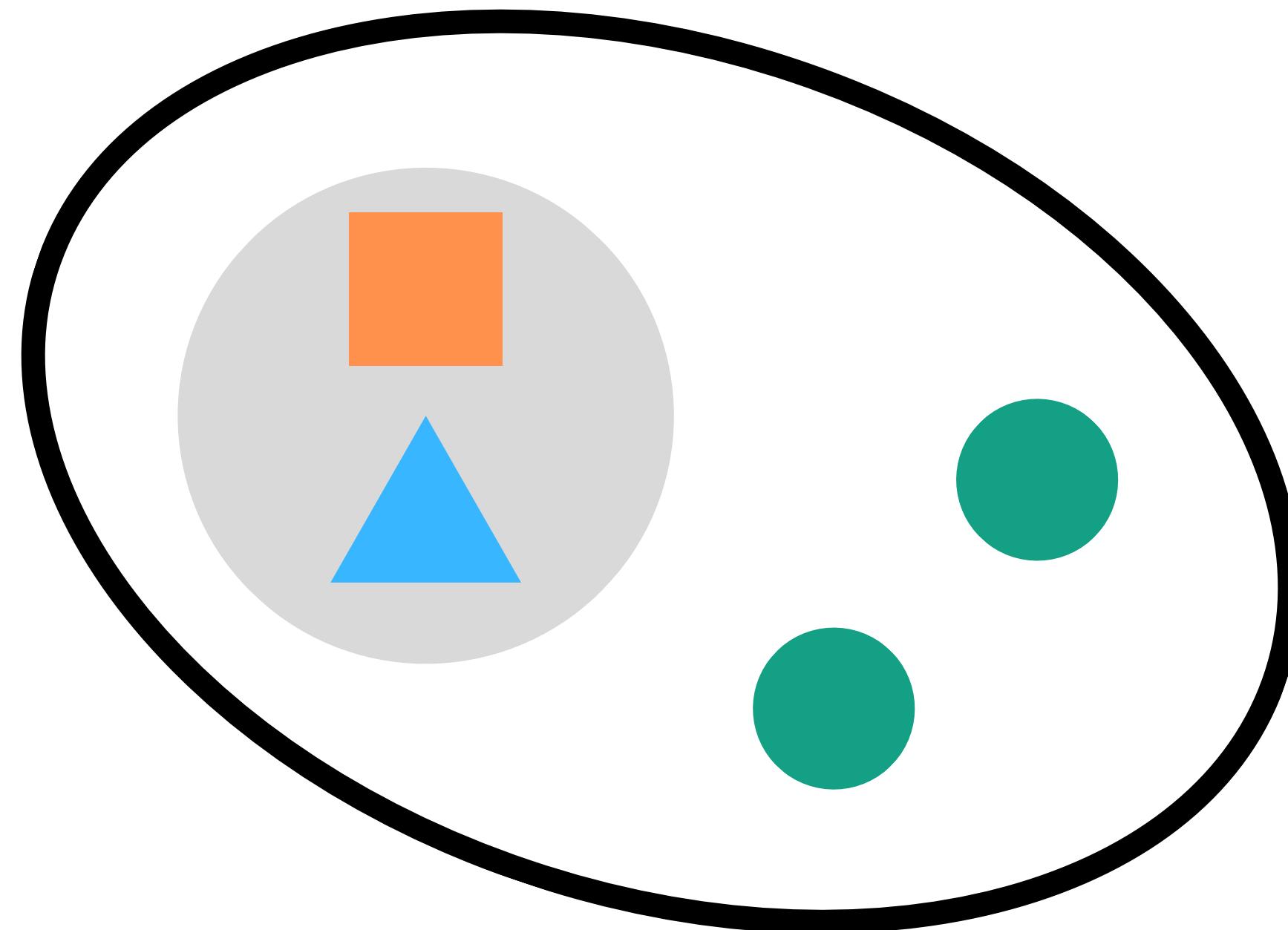
Encoding Semantics

Shapes that are enclosed are perceived as encoding related information



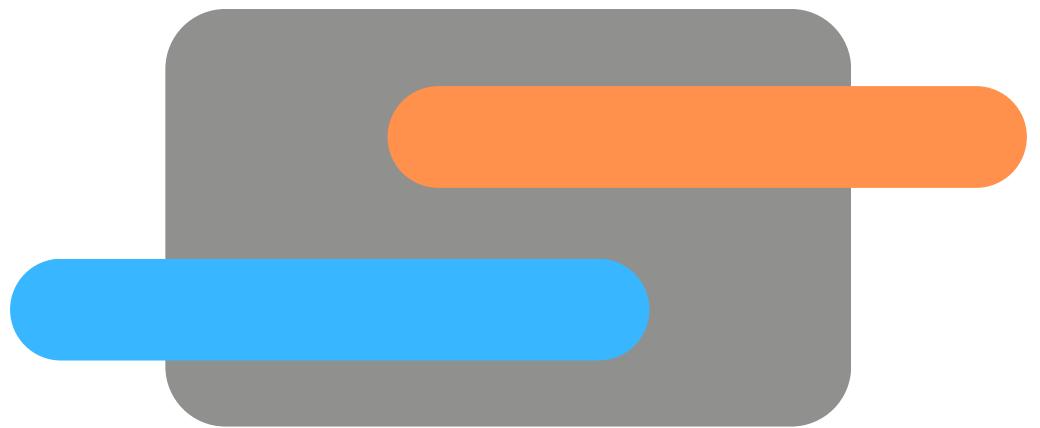
Encoding Semantics

Nested/partitioned regions imply hierarchy



Encoding Semantics

Closed-shape marks that are attached are perceived as part of the same conceptual structure



Expressiveness and Effectiveness

The **effectiveness principle** states that we should use the most salient (noticeable) channels to encode the most important attributes

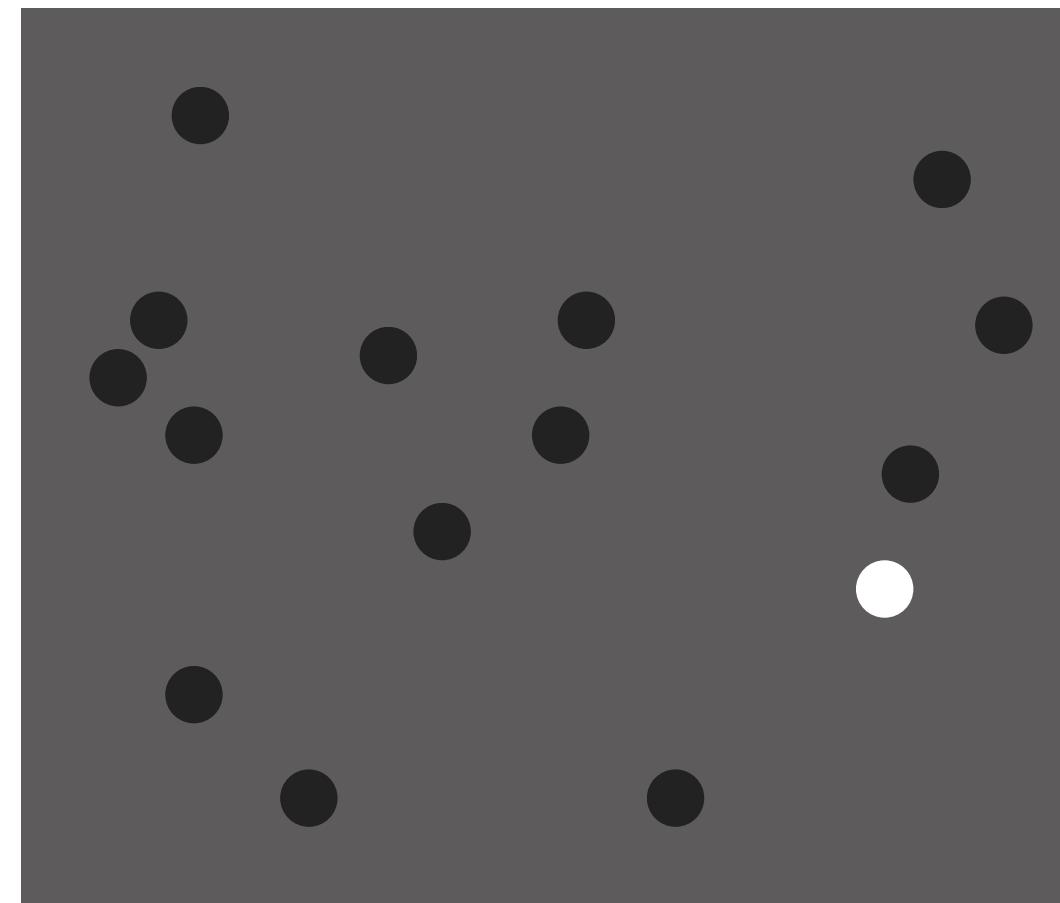
Factors that influence **effectiveness**:

- accuracy
- discriminability
- separability vs integrality
- encoding semantics
- other perceptual effects
 - popout, weber's law, gestalt principles

From the Perception and Cognition Lecture...

Basic Popout Channels

Color (Lightness)



From the Perception and Cognition Lecture...

Gestalt Principles

“Gestalt” (from German, meaning form)

patterns transcend the visual stimuli that produced them

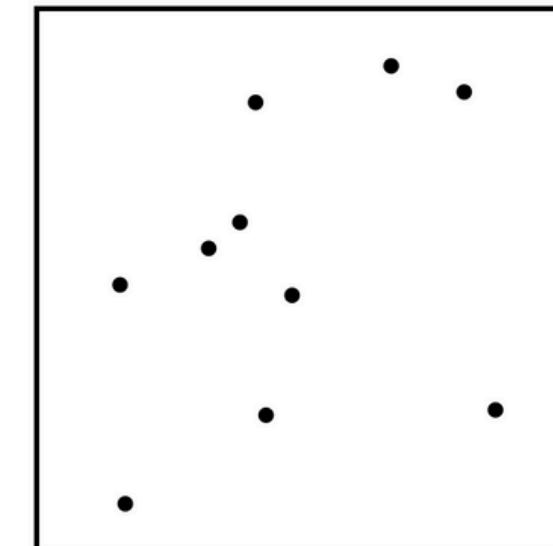
7 principles:

- similarity
- proximity
- connectedness
- continuity
- closure
- figure/ground
- common fate

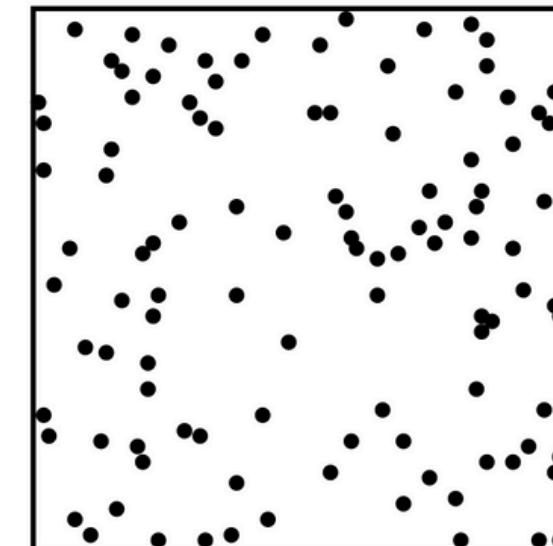
From the Perception and Cognition Lecture...

Weber's Law

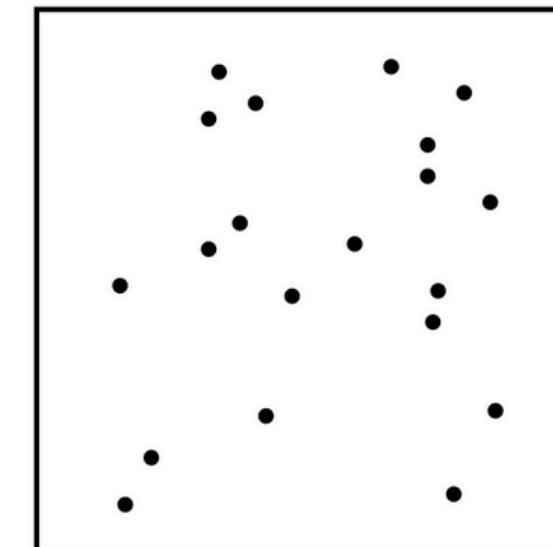
We judge based on relative differences
(not absolute differences)



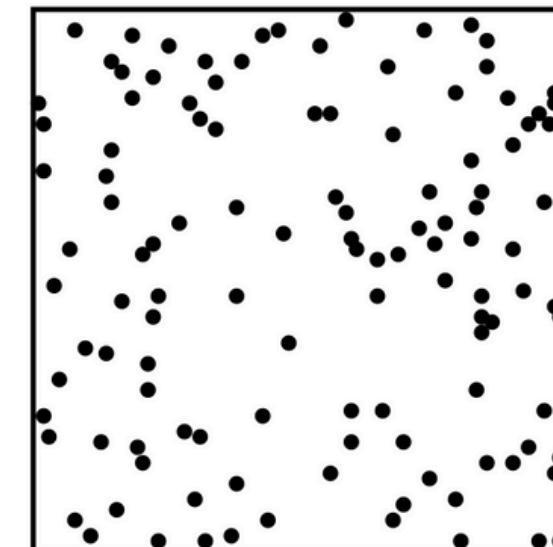
10



110



20



120

Source: Wikipedia

FIN