

2015

# DISCOVERY SUMMIT

EXPLORING DATA  
INSPIRING INNOVATION

# All Graphs Are Wrong, but Some Are Useful

Xan Gregg  
JMP Development

*esse quam videri*

*esse quam videri*

to be rather than to seem

All models are wrong, but some are useful.

*George E. P. Box (1979)*



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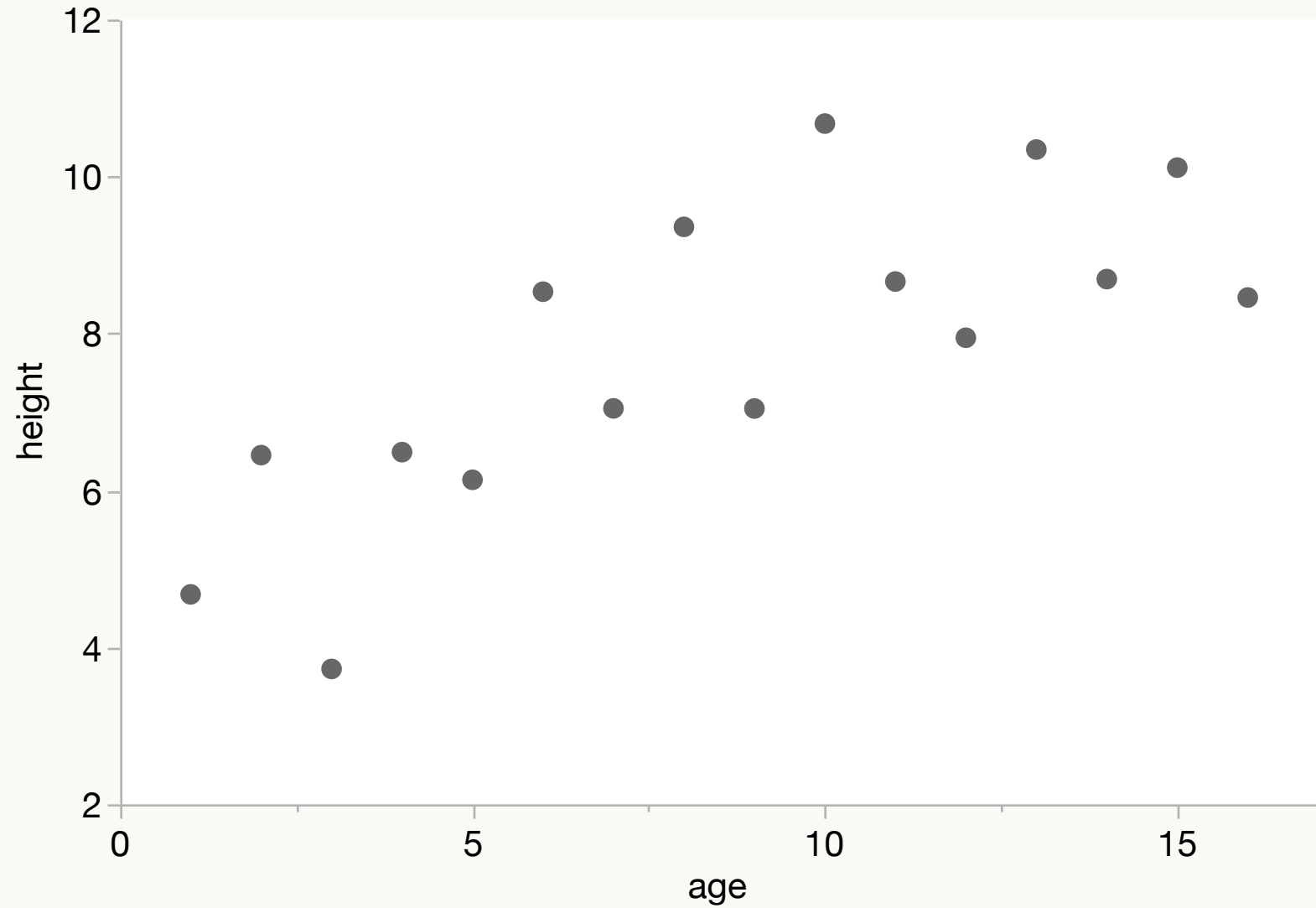


Since all models are wrong the scientist cannot obtain a “correct” one by excessive elaboration. ... overelaboration and overparameterization is often the mark of mediocrity.

*George E. P. Box (1976)*

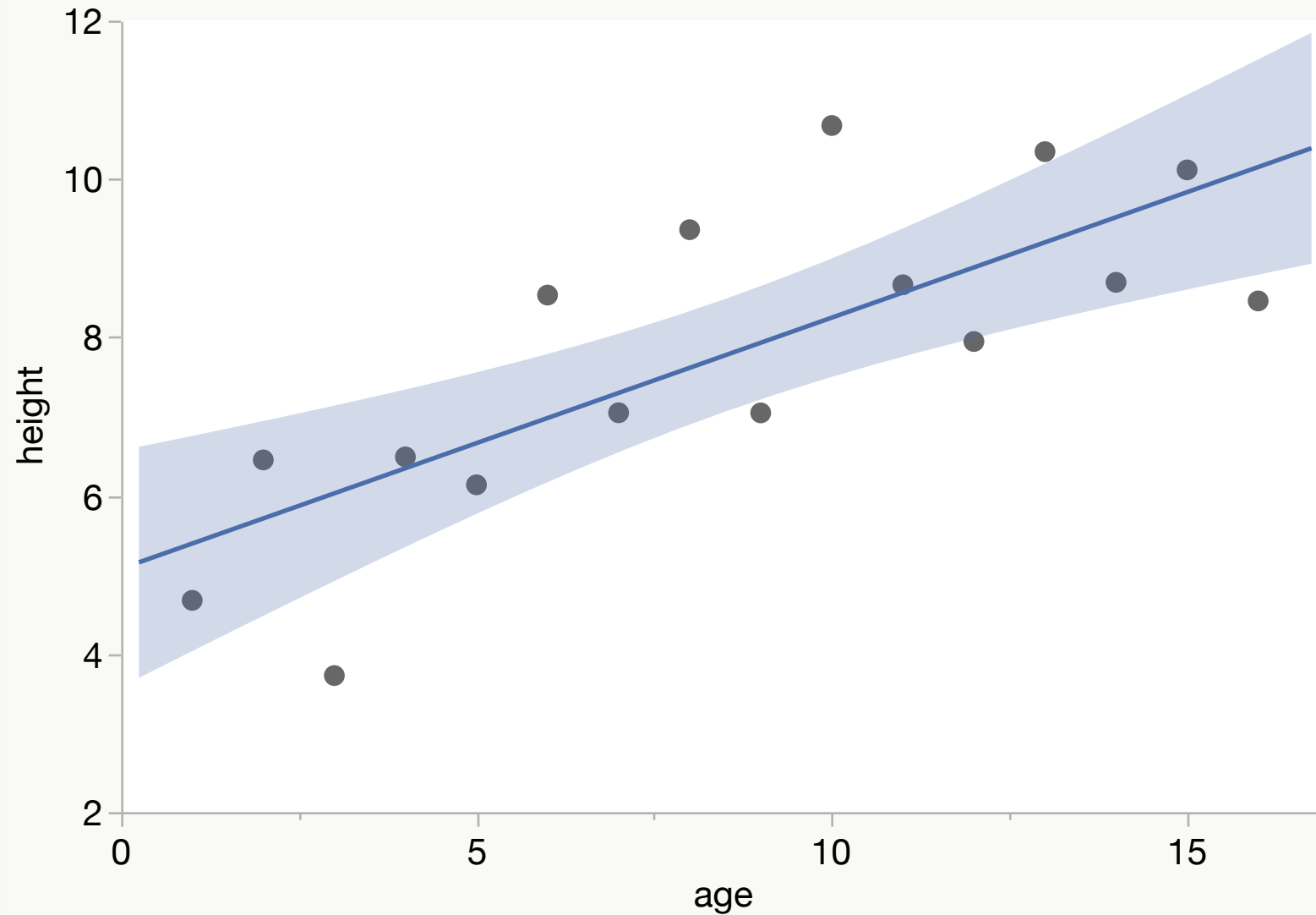
# Overelaboration in Modeling

# Overlaboration in Modeling

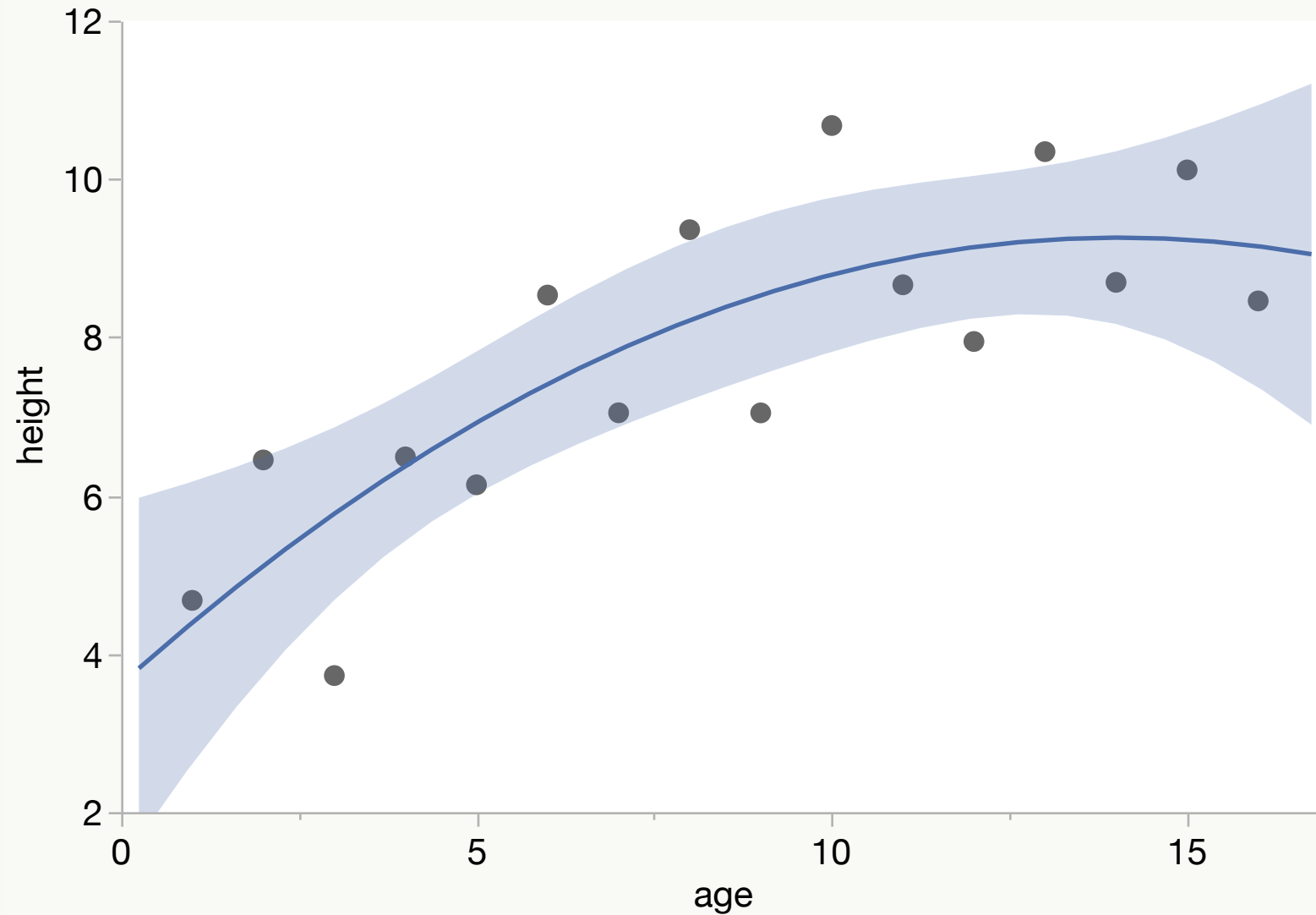




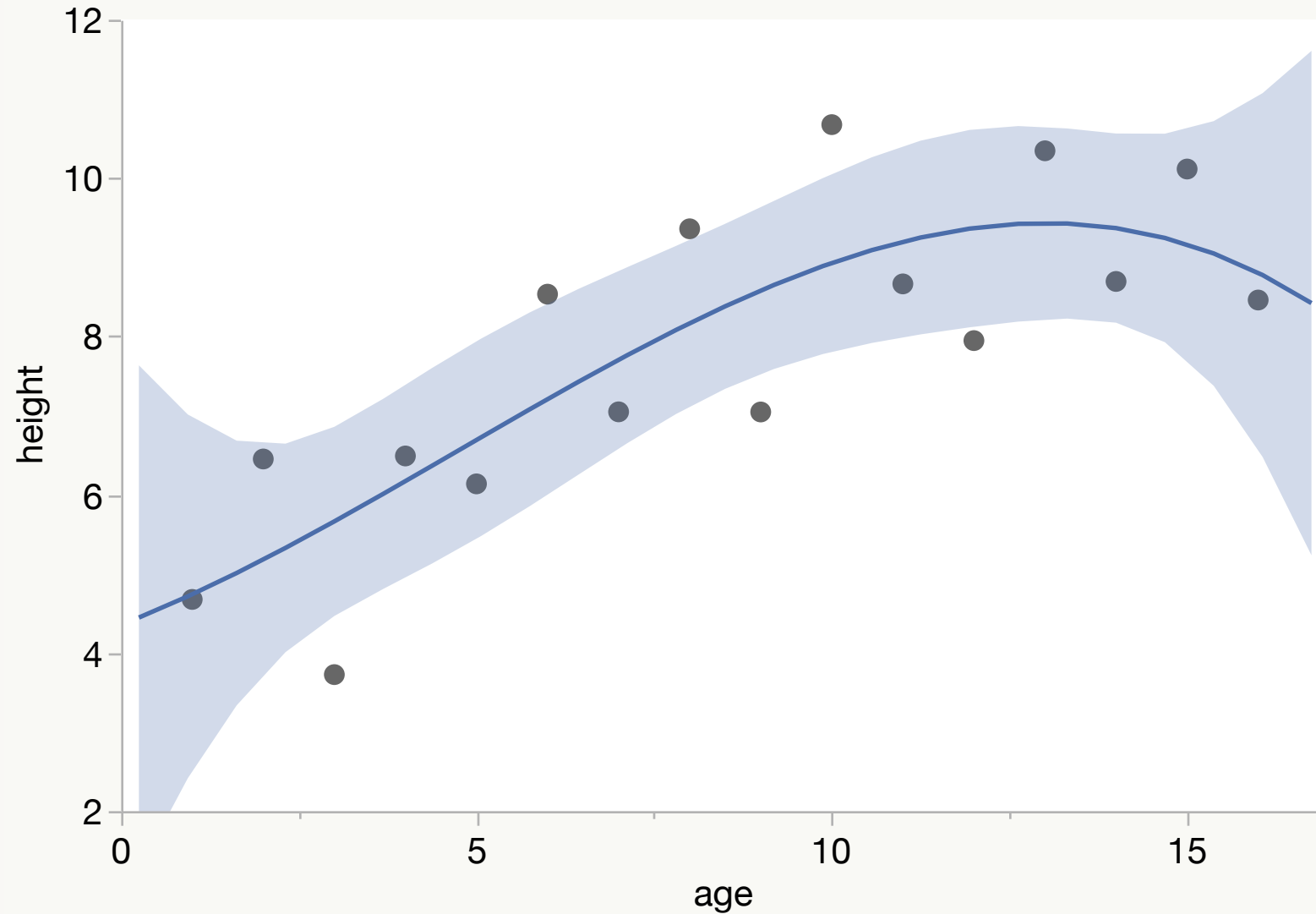
# Overlaboration in Modeling



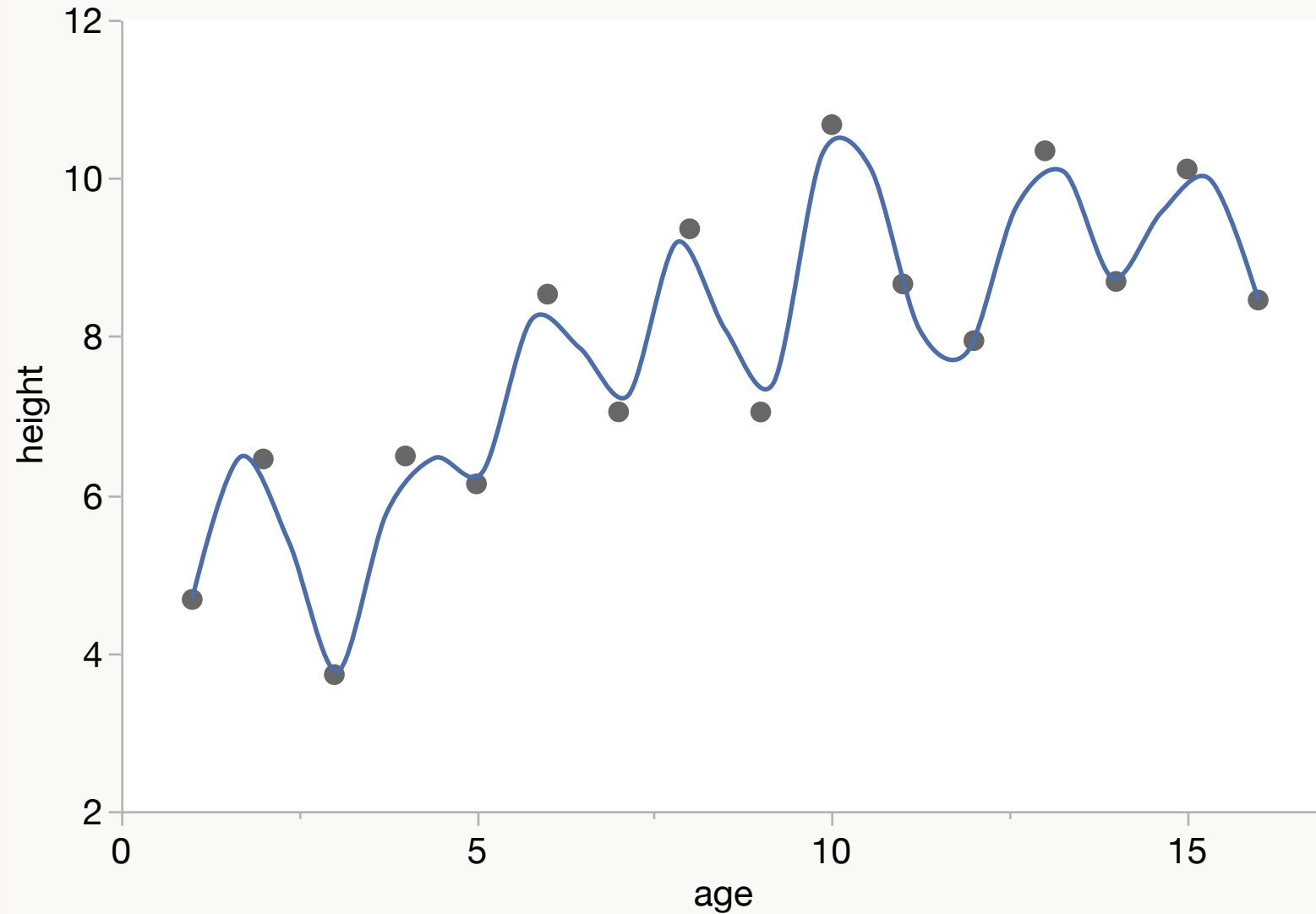
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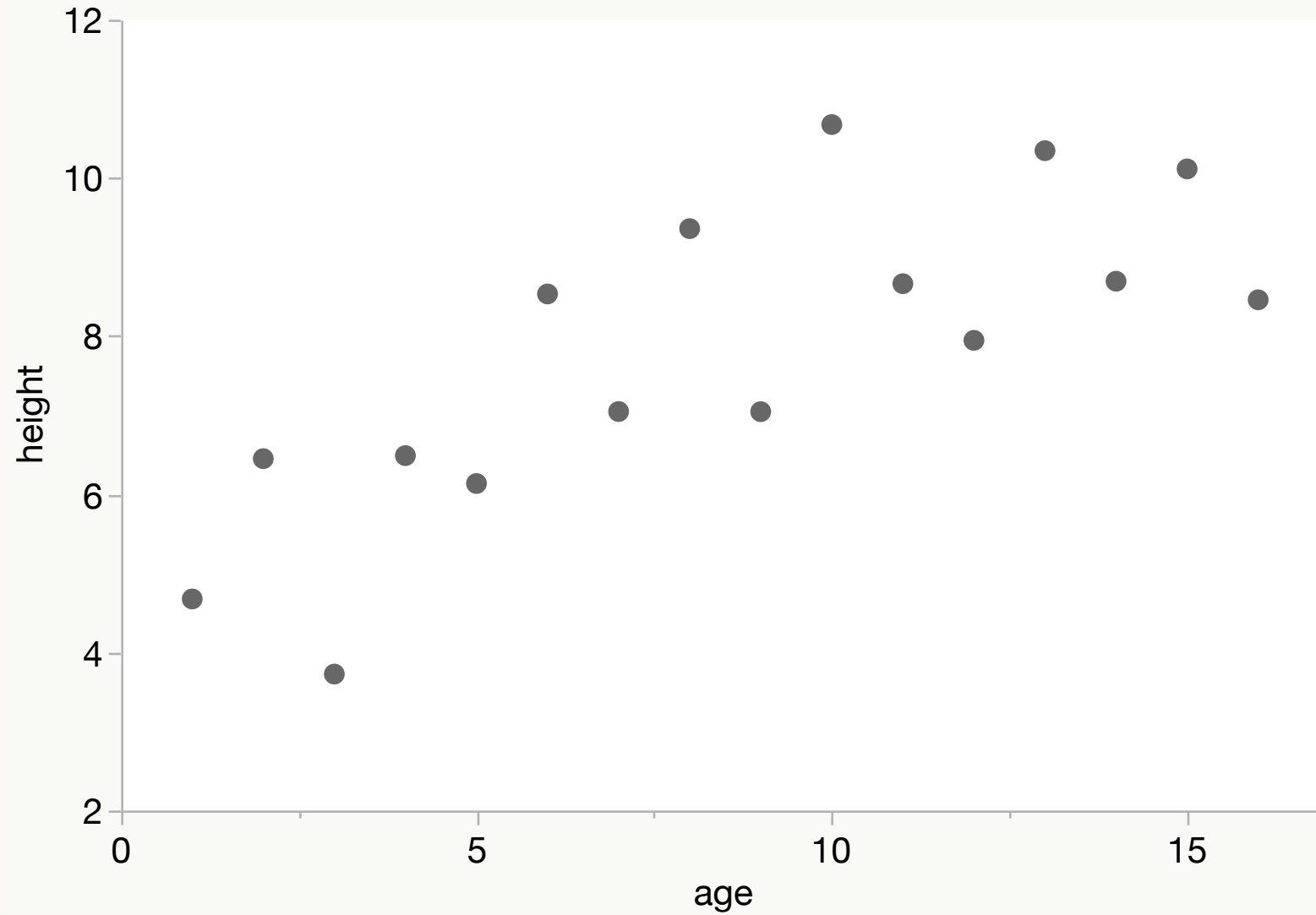


# Overelaboration in Modeling

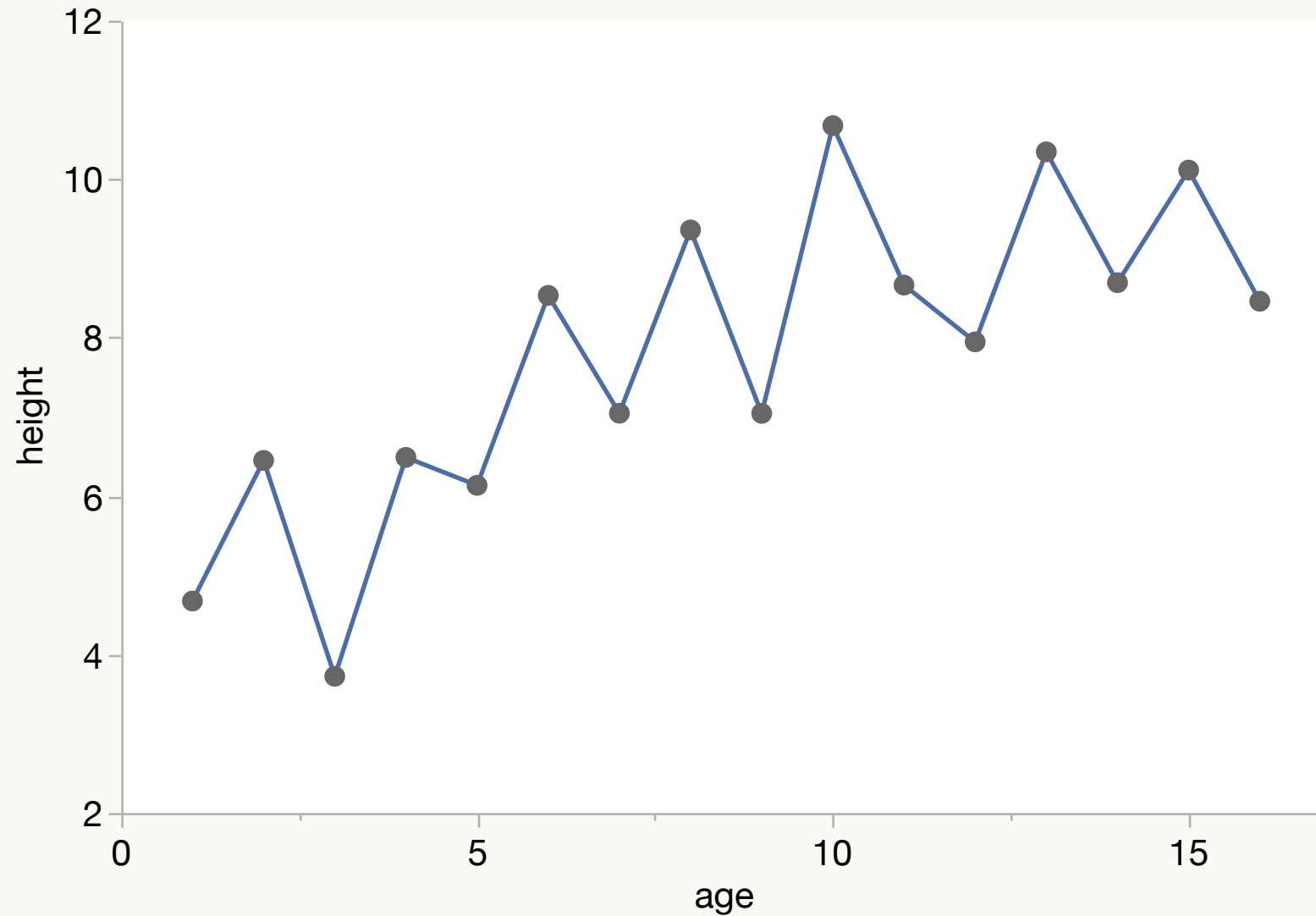


# Overelaboration in Graphing

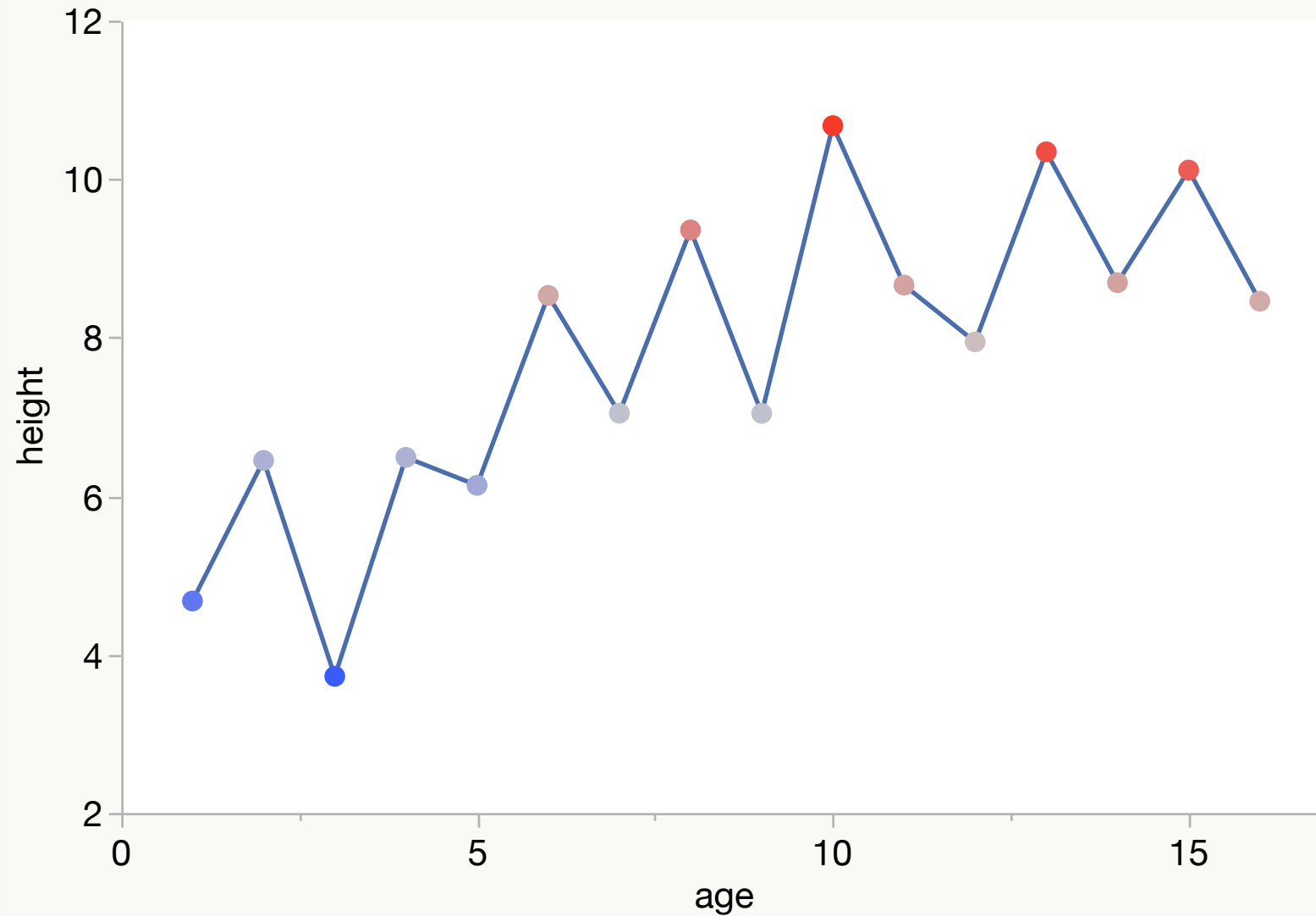
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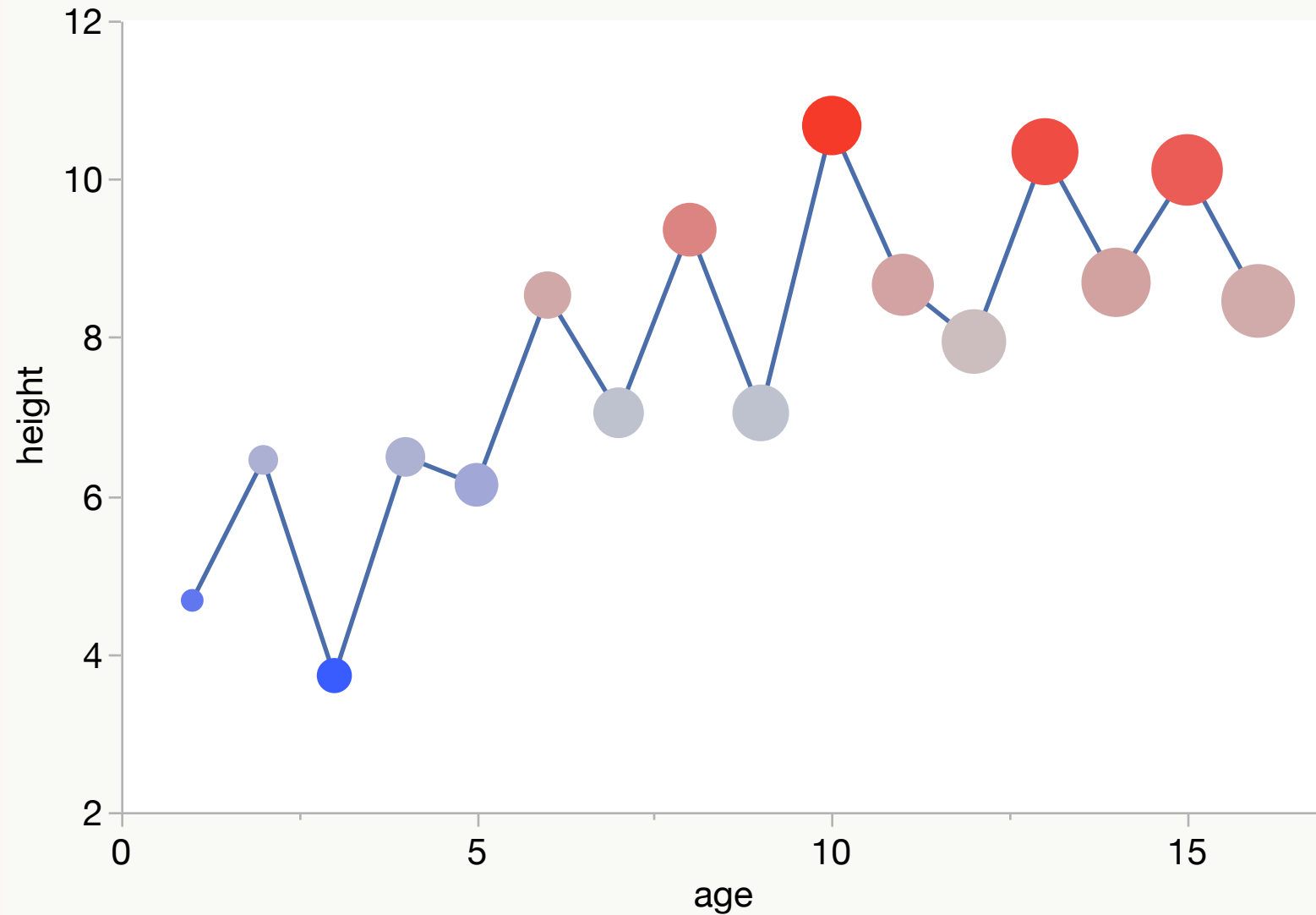


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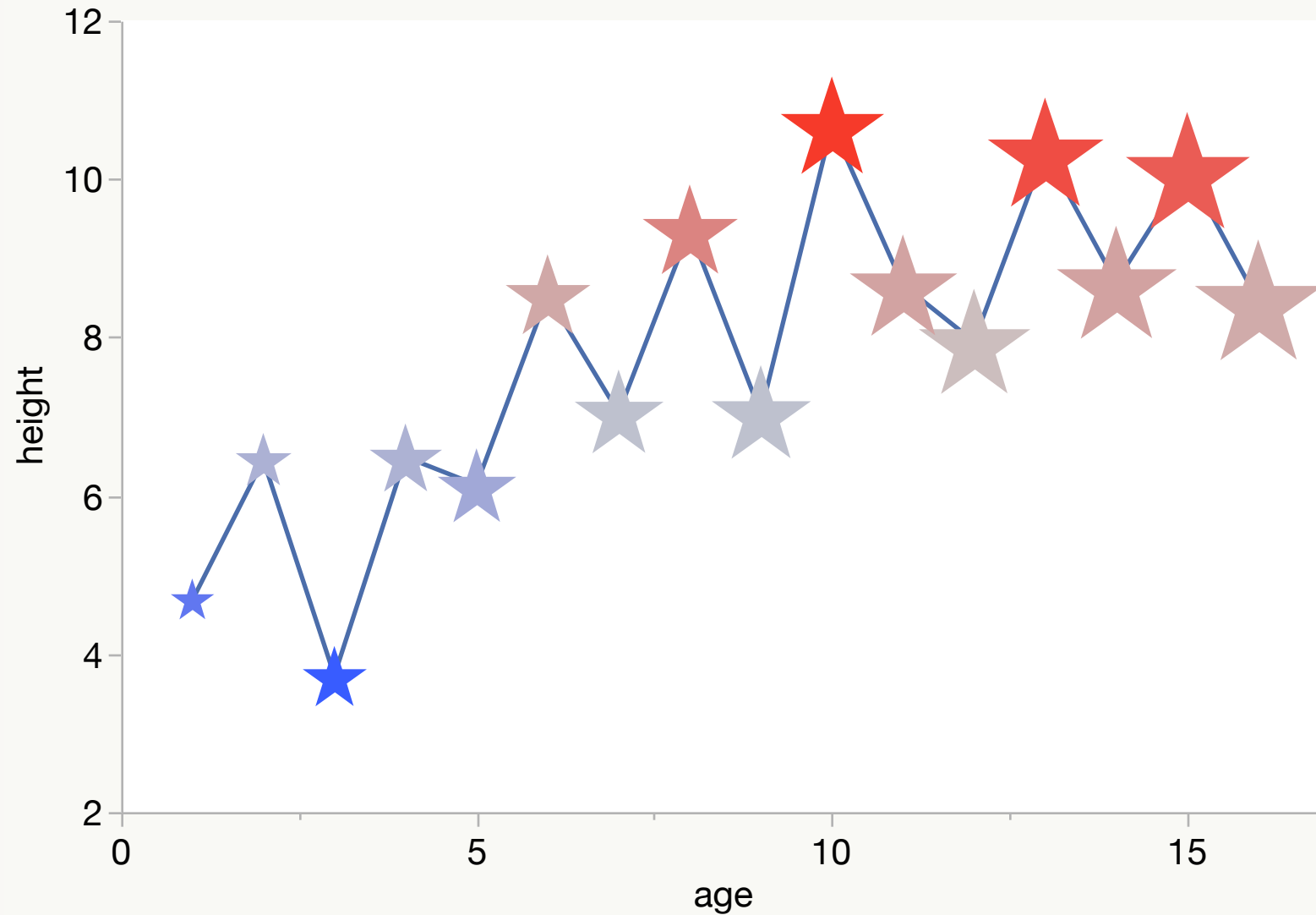




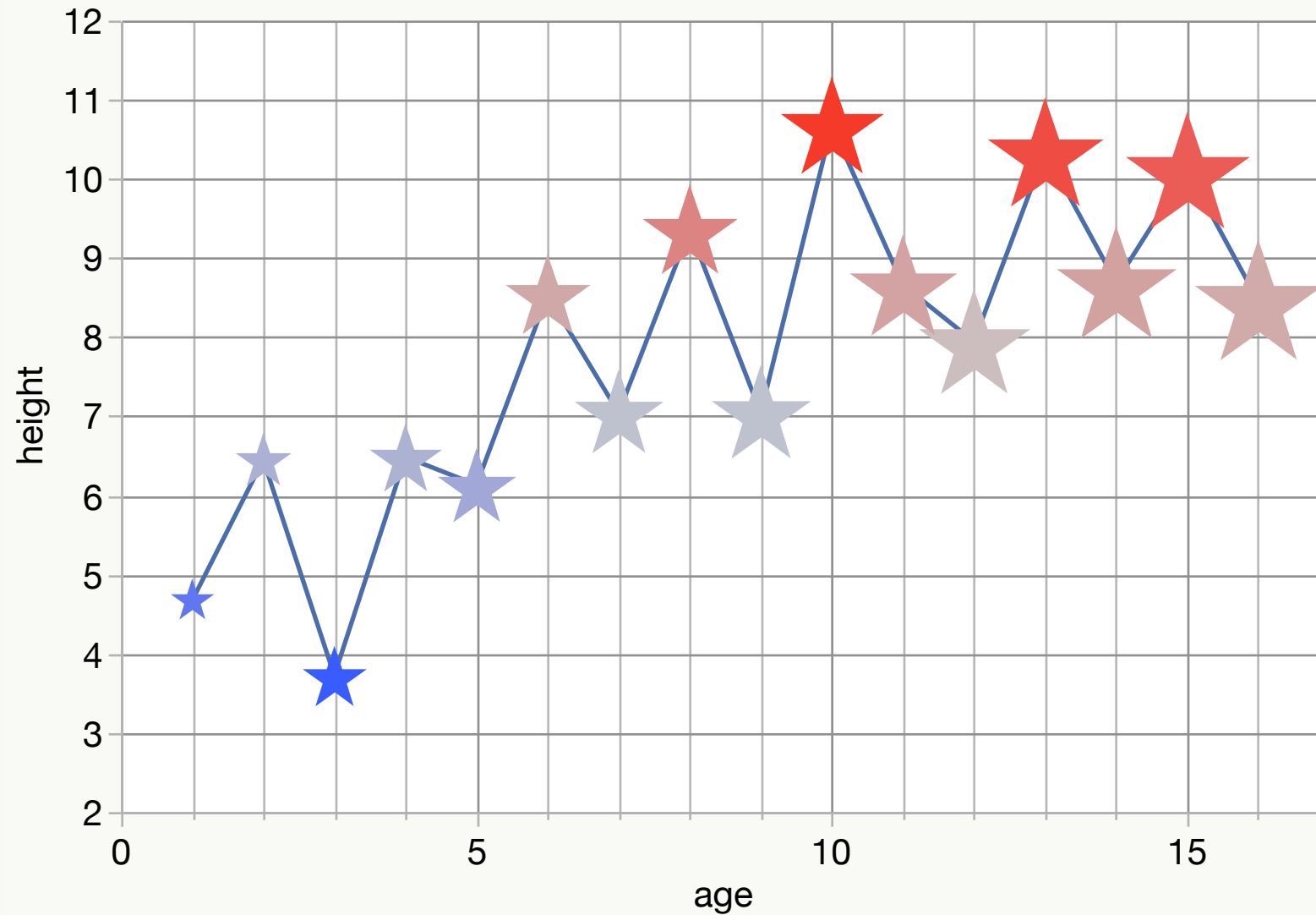
# Overelaboration in Graphing



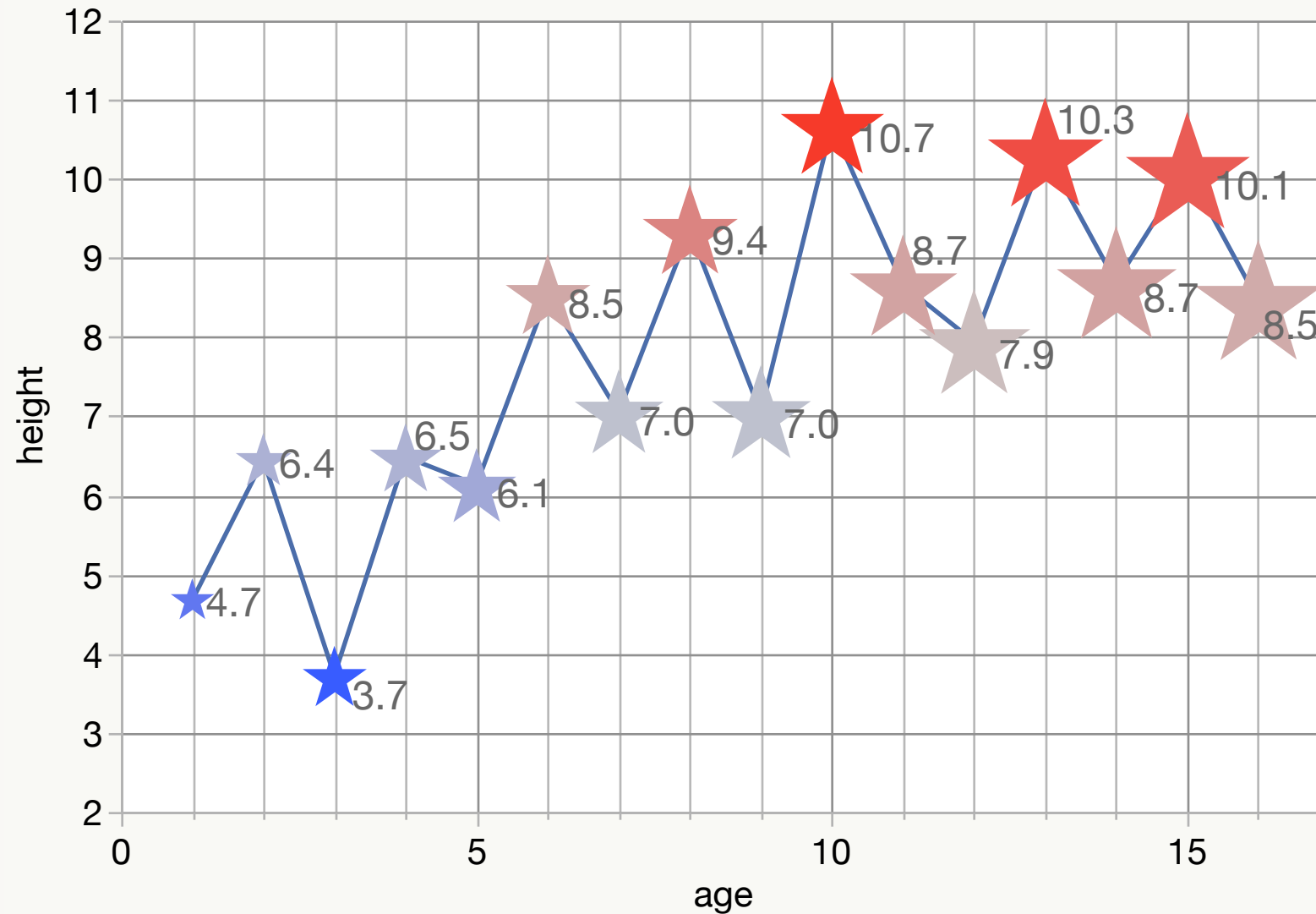
# Overlaboration in Graphing



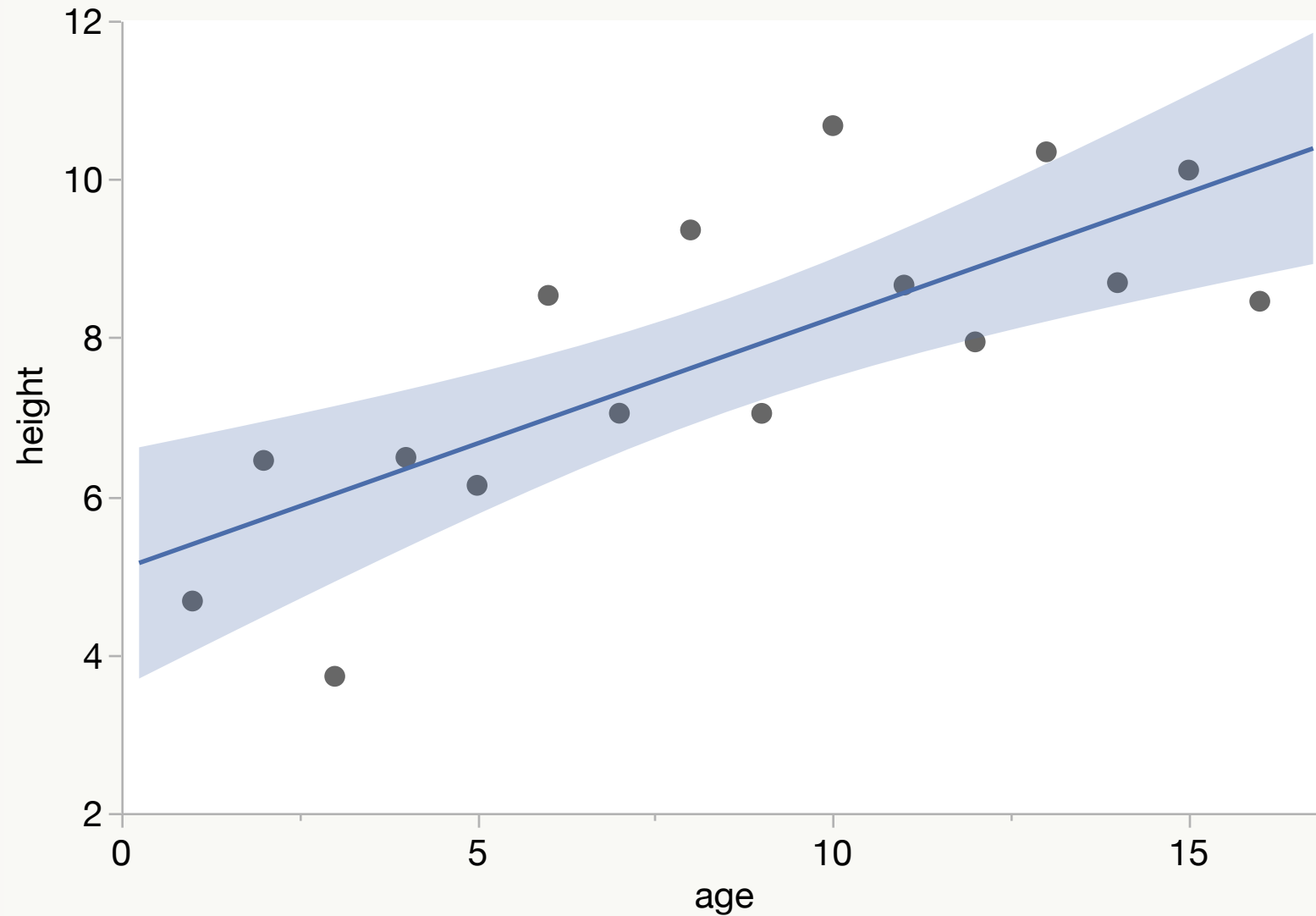
# Overelaboration in Graphing



# Overelaboration in Graphing



# Information rather than Data



# Statistical Discovery



# Statistical Discovery

## Collect

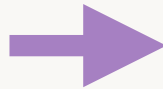
x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
290	1.08	0.39	0.08	2.08	A
742	3.28	2.41	2.28	4.28	A
379	-2.31	-2.05	-3.31	-1.31	A
646	1.05	2.10	0.05	2.05	A
178	4.22	3.28	3.22	5.22	A
272	1.27	2.18	0.27	2.27	A
670	2.00	1.21	1.00	3.00	A
689	2.41	2.15	1.41	3.41	A
233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
18	0.78	1.84	-0.22	1.78	A
439	-3.86	-3.88	-4.86	-2.86	A
167	3.94	3.06	2.94	4.94	A
463	-3.59	-2.83	-4.59	-2.59	A
180	3.79	3.07	2.79	4.79	A
69	2.25	2.90	1.25	3.25	A
848	3.13	3.08	2.13	4.13	A
585	-1.49	-0.58	-2.49	-0.49	A
276	1.28	1.81	0.28	2.28	A
340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B



# Statistical Discovery

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x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
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742	3.28	2.41	2.28	4.28	A
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## Analyze

Linear Fit				
height = 5.10 + 0.293*age				
Summary of Fit				
RSquare				0.89
RSquare Adj				0.887
Root Mean Square Error				0.982
Mean of Response				9.95
Observations (or Sum Wgts)				32
Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	235.01	235.012	243.7541
Error	30	28.92	0.964	Prob > F
C. Total	31	263.94		<.0001*
Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	5.10	0.355	14.36	<.0001*
age	0.294	0.0188	15.61	<.0001*

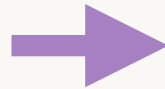




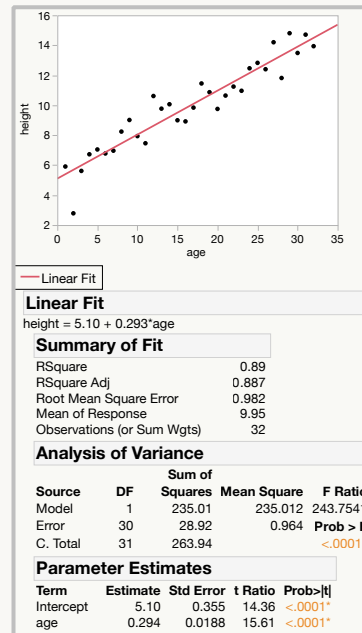
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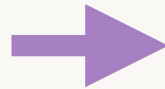
## Analyze



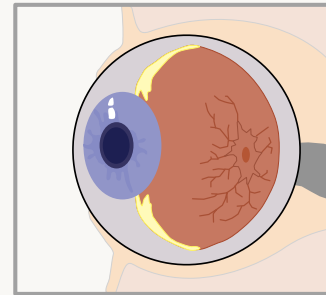
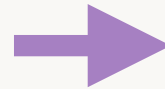
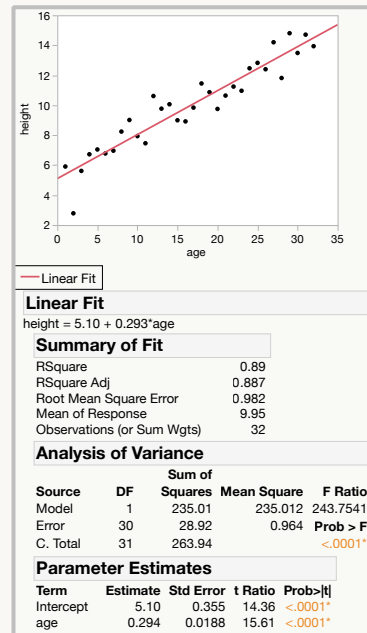
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585	-1.49	-0.58	-2.49	-0.49	A
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969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B



## Analyze

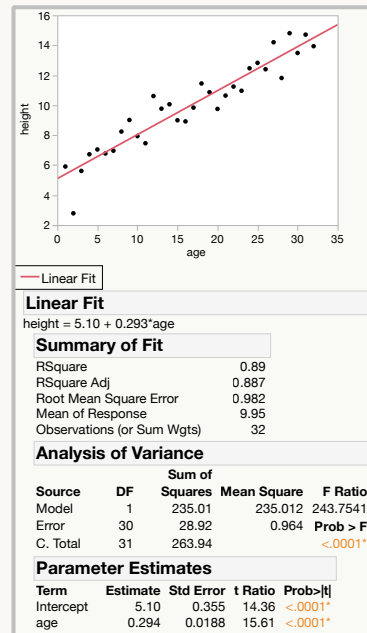


# Statistical Discovery

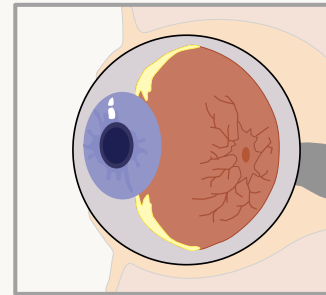
Collect

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84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
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233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
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340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



See



Understand

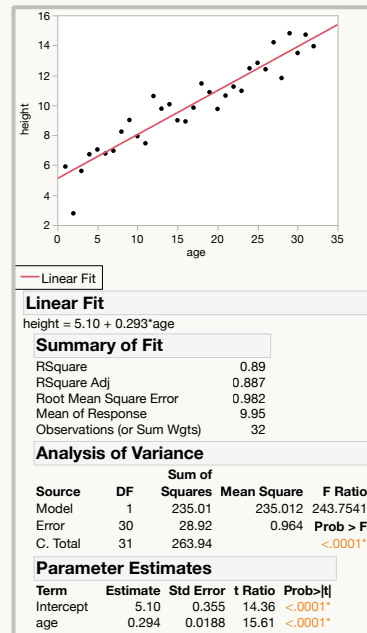


# Statistical Discovery

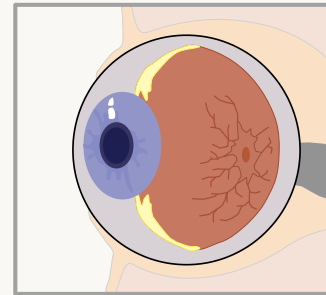
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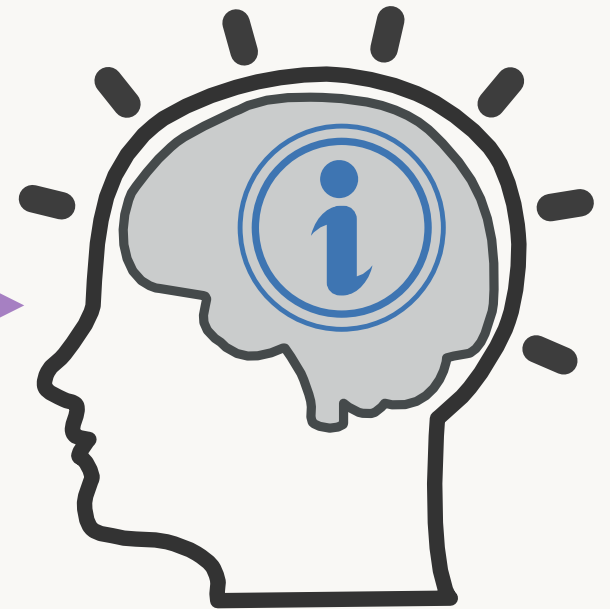
Analyze



See



Understand

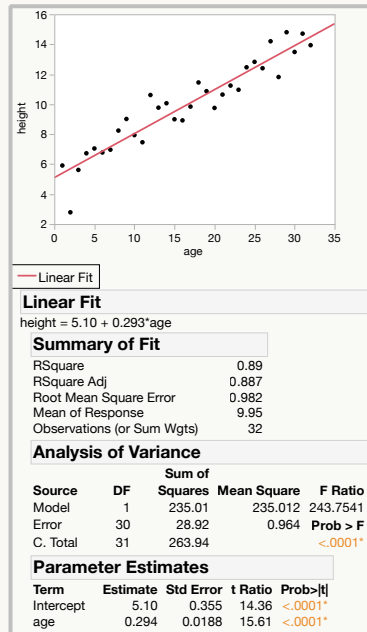


# Statistical Discovery

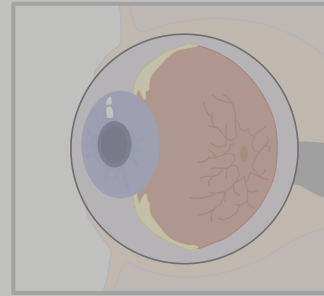
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379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



See



Understand



# Why graph? Anscombe's Quartet

	<b>X1</b>	<b>Y1</b>	
	10	8.04	
	8	6.95	
	13	7.58	
	9	8.81	
	11	8.33	
	14	9.96	
	6	7.24	
	4	4.26	
	12	10.84	
	7	4.82	
	5	5.68	

	<b>X2</b>	<b>Y2</b>	
	10	9.14	
	8	8.14	
	13	8.74	
	9	8.77	
	11	9.26	
	14	8.1	
	6	6.13	
	4	3.1	
	12	9.13	
	7	7.26	
	5	4.74	

	<b>X3</b>	<b>Y3</b>	
	10	7.46	
	8	6.77	
	13	12.74	
	9	7.11	
	11	7.81	
	14	8.84	
	6	6.08	
	4	5.39	
	12	8.15	
	7	6.42	
	5	5.73	

	<b>X4</b>	<b>Y4</b>	
	8	6.58	
	8	5.76	
	8	7.71	
	8	8.84	
	8	8.47	
	8	7.04	
	8	5.25	
	19	12.5	
	8	5.56	
	8	7.91	
	8	6.89	

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Term	Estimate	Std Error	Prob> t
Intercept	3.00	1.125	0.0257*
X1	0.50	0.118	0.0022*

Term	Estimate	Std Error	Prob> t
Intercept	3.00	1.125	0.0258*
X2	0.50	0.118	0.0022*

Term	Estimate	Std Error	Prob> t
Intercept	3.00	1.124	0.0256*
X3	0.50	0.118	0.0022*

Term	Estimate	Std Error	Prob> t
Intercept	3.00	1.124	0.0256*
X4	0.50	0.118	0.0022*

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X3	0.50	0.118	0.0022*

Term	Estimate	Std Error	Prob> t
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X4	0.50	0.118	0.0022*

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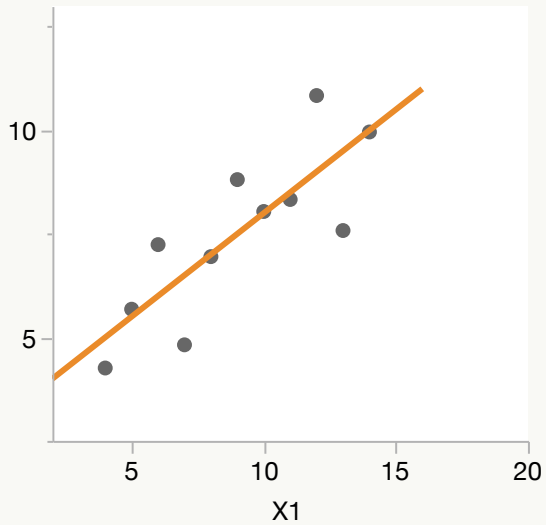
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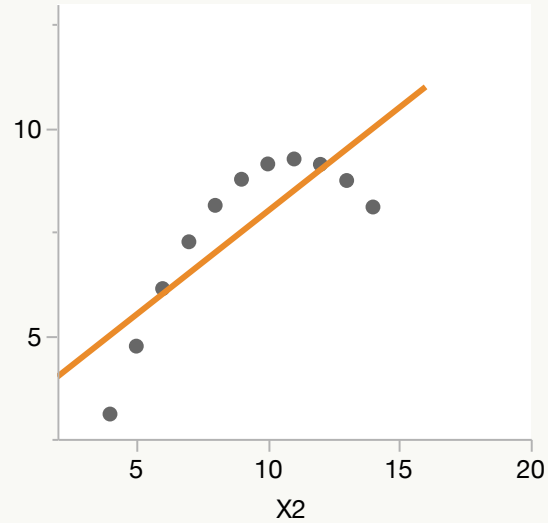
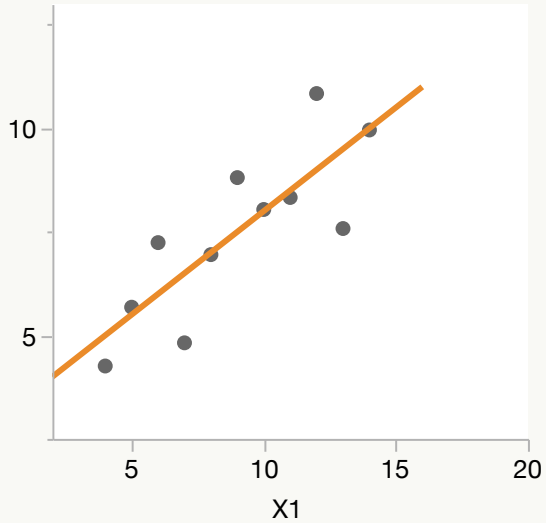
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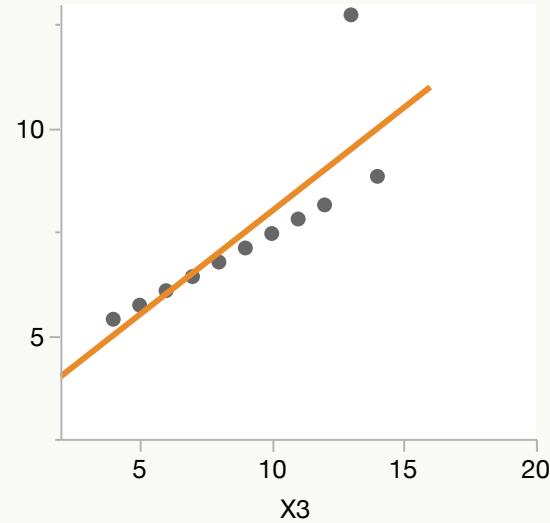
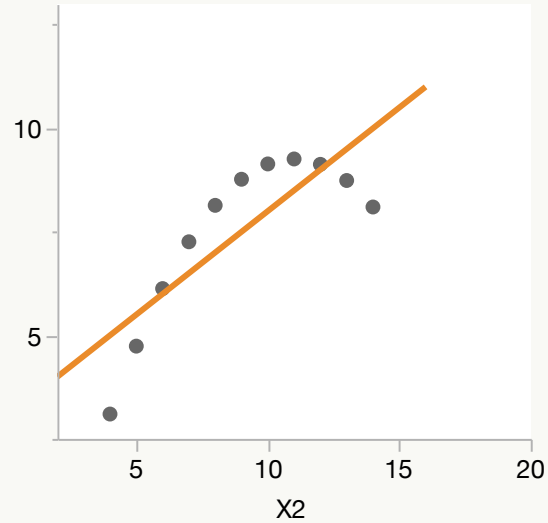
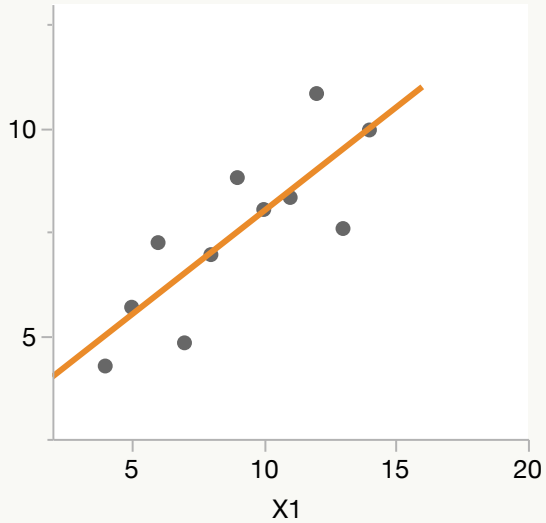
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# Why graph? Anscombe's Quartet



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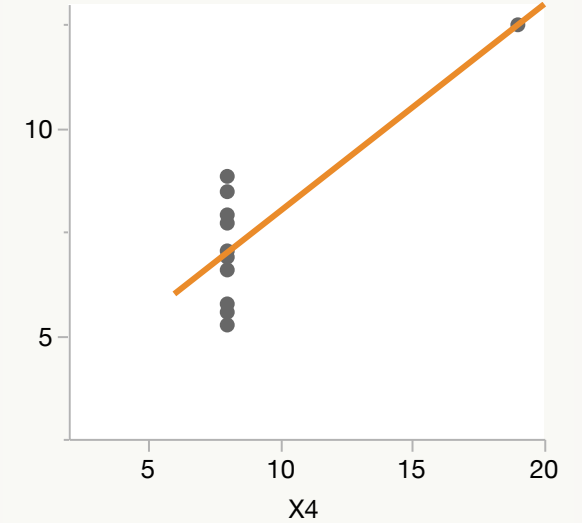
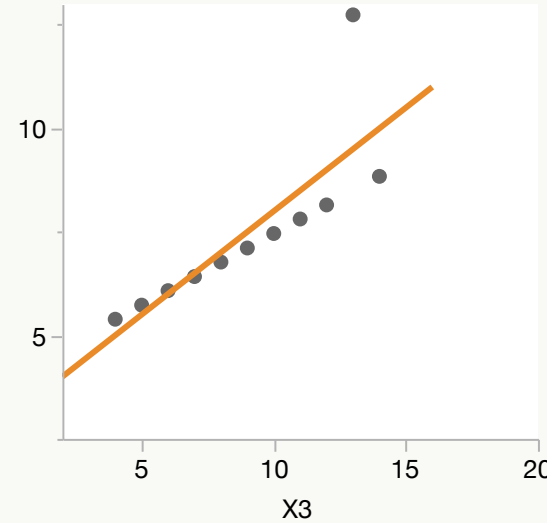
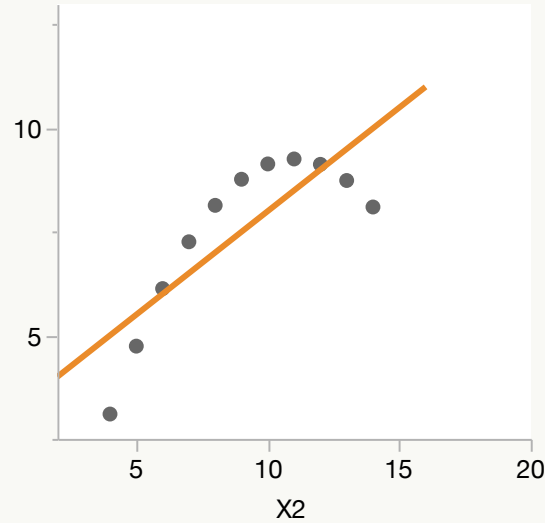
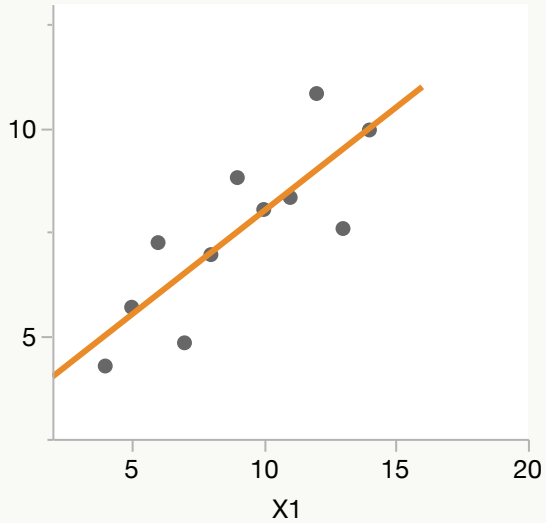
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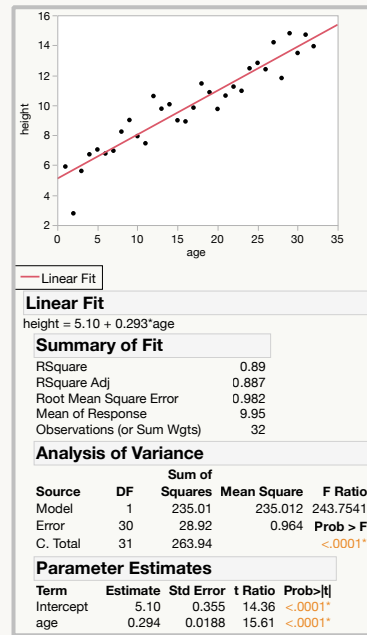
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# Statistical Discovery

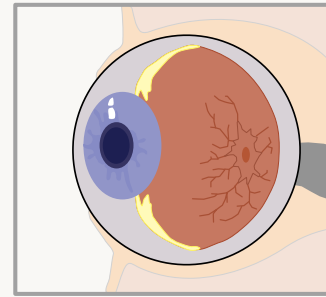
Collect

x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
290	1.08	0.39	0.08	2.08	A
742	3.28	2.41	2.28	4.28	A
379	-2.31	-2.05	-3.31	-1.31	A
646	1.05	2.10	0.05	2.05	A
178	4.22	3.28	3.22	5.22	A
272	1.27	2.18	0.27	2.27	A
670	2.00	1.21	1.00	3.00	A
689	2.41	2.15	1.41	3.41	A
233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
18	0.78	1.84	-0.22	1.78	A
439	-3.86	-3.88	-4.86	-2.86	A
167	3.94	3.06	2.94	4.94	A
463	-3.59	-2.83	-4.59	-2.59	A
180	3.79	3.07	2.79	4.79	A
69	2.25	2.90	1.25	3.25	A
848	3.13	3.08	2.13	4.13	A
585	-1.49	-0.58	-2.49	-0.49	A
276	1.28	1.81	0.28	2.28	A
340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



See



Understand



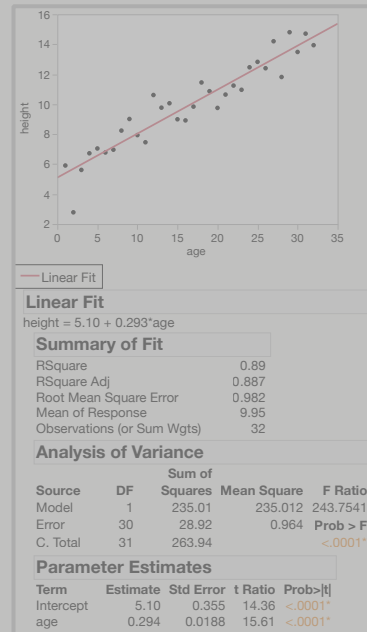


# Statistical Discovery

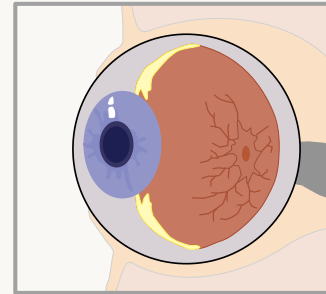
Collect

x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
290	1.08	0.39	0.08	2.08	A
742	3.28	2.41	2.28	4.28	A
379	-2.31	-2.05	-3.31	-1.31	A
646	1.05	2.10	0.05	2.05	A
178	4.22	3.28	3.22	5.22	A
272	1.27	2.18	0.27	2.27	A
670	2.00	1.21	1.00	3.00	A
689	2.41	2.15	1.41	3.41	A
233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
18	0.78	1.84	-0.22	1.78	A
439	-3.86	-3.88	-4.86	-2.86	A
167	3.94	3.06	2.94	4.94	A
463	-3.59	-2.83	-4.59	-2.59	A
180	3.79	3.07	2.79	4.79	A
69	2.25	2.90	1.25	3.25	A
848	3.13	3.08	2.13	4.13	A
585	-1.49	-0.58	-2.49	-0.49	A
276	1.28	1.81	0.28	2.28	A
340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



See



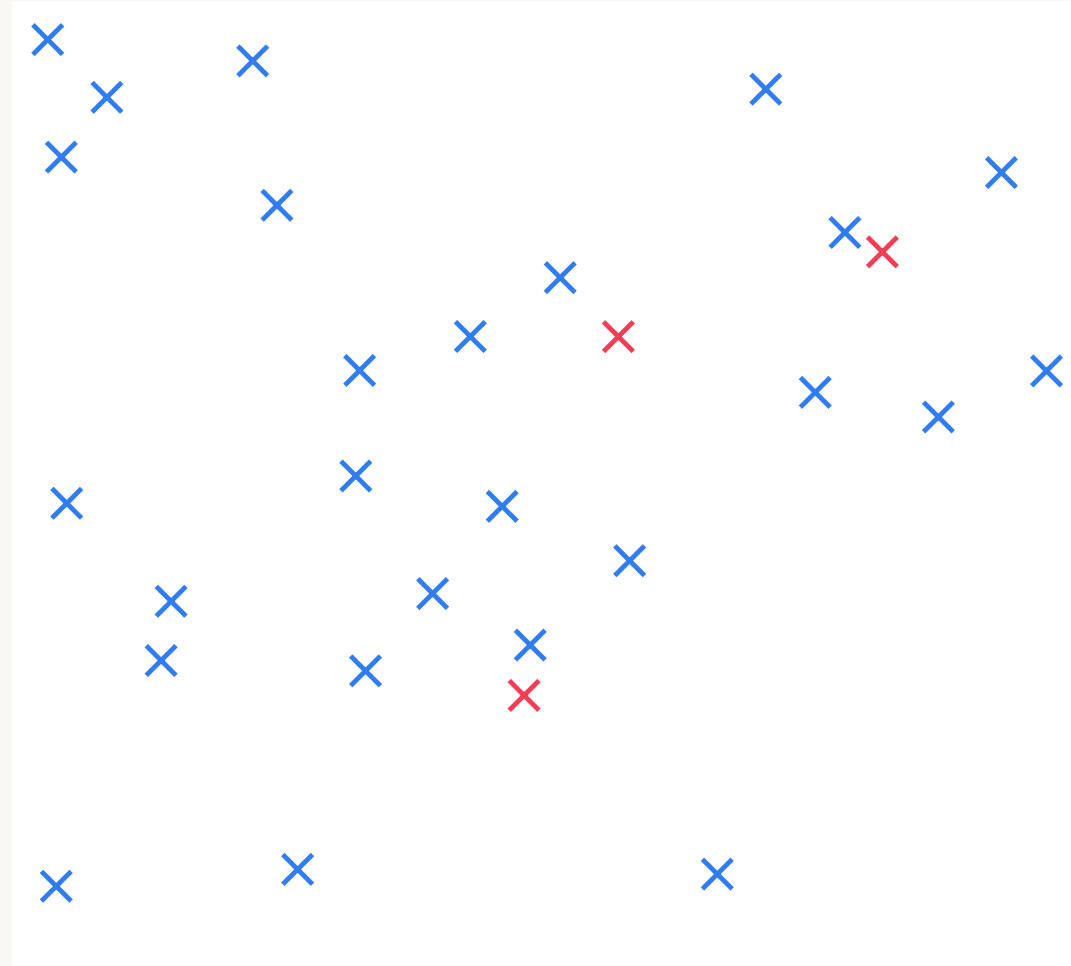
Understand



# Pre-attentive Processing

# Pre-attentive Processing

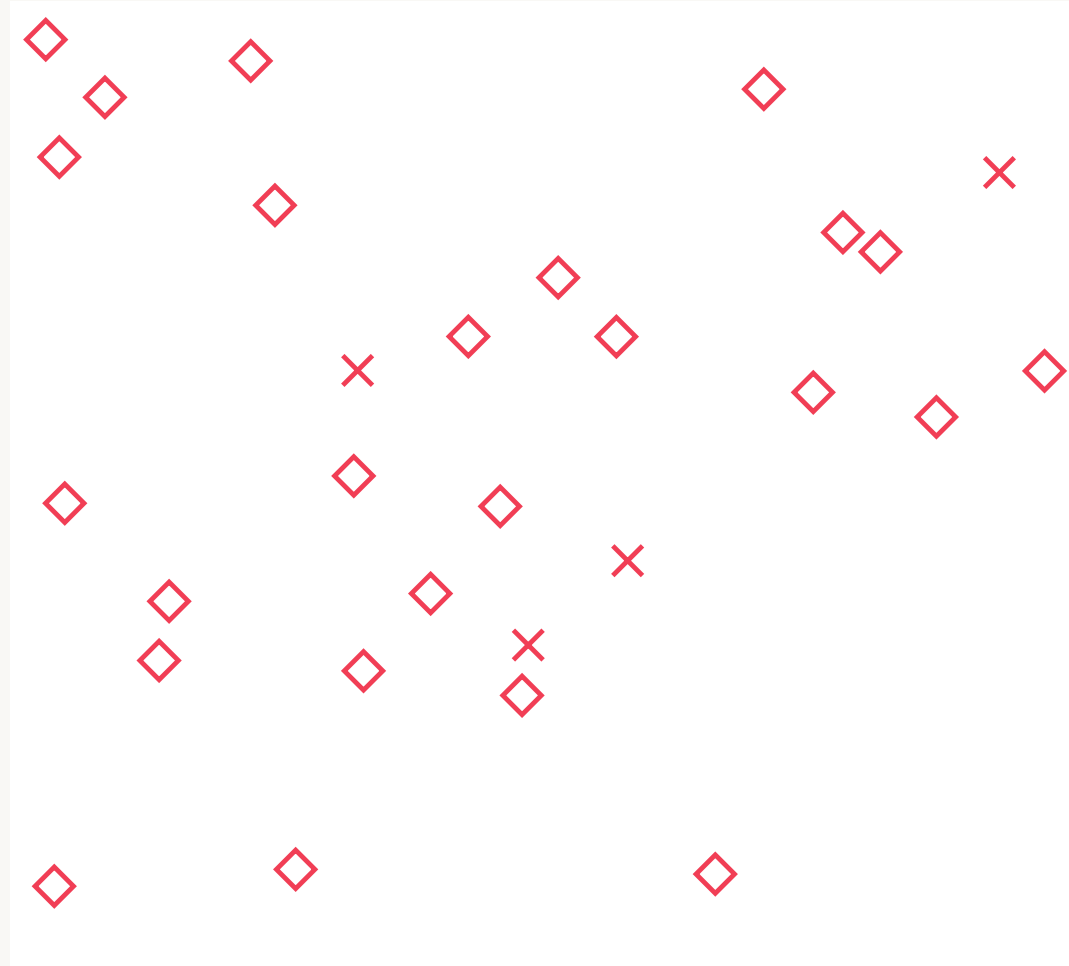
# Pre-attentive Processing



# Pre-attentive Processing

# Pre-attentive Processing

# Pre-attentive Processing

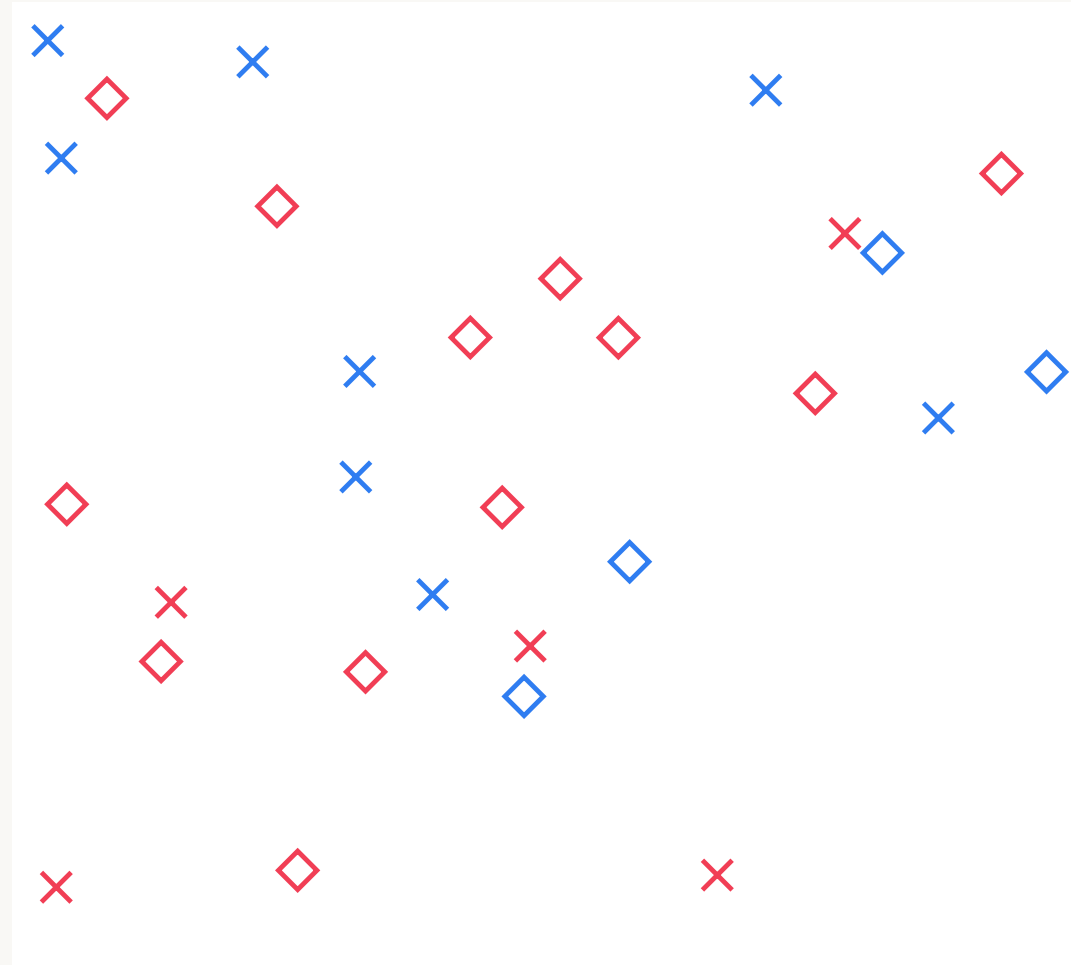


# Pre-attentive Processing

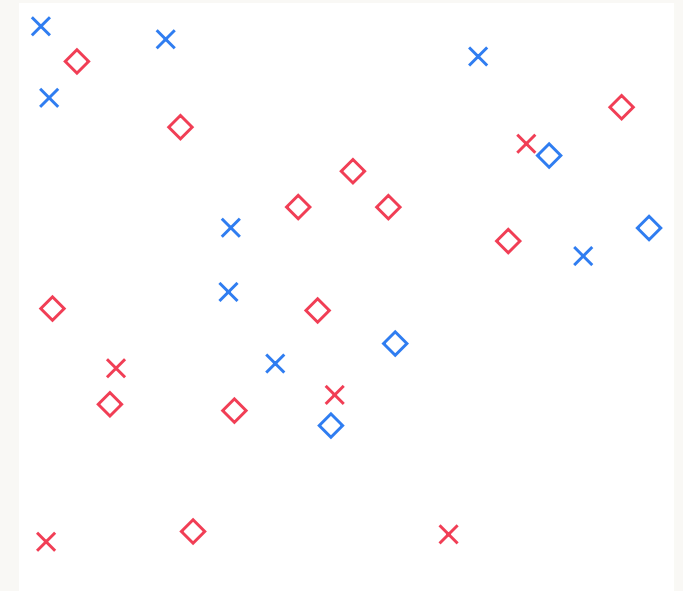
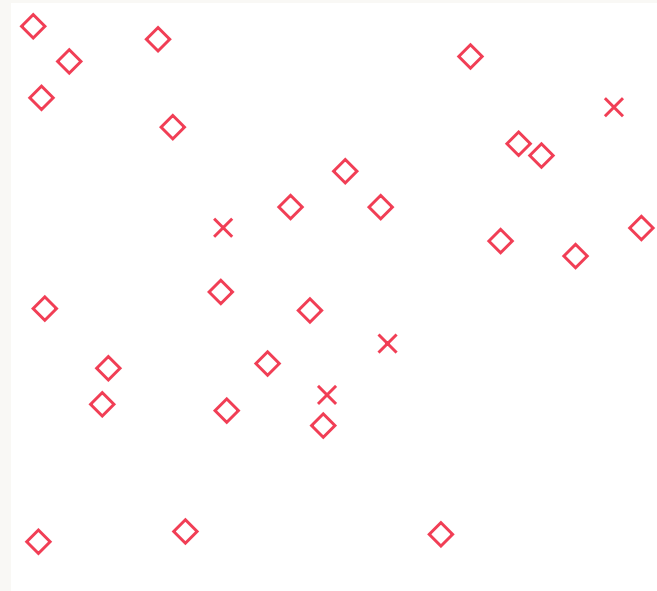
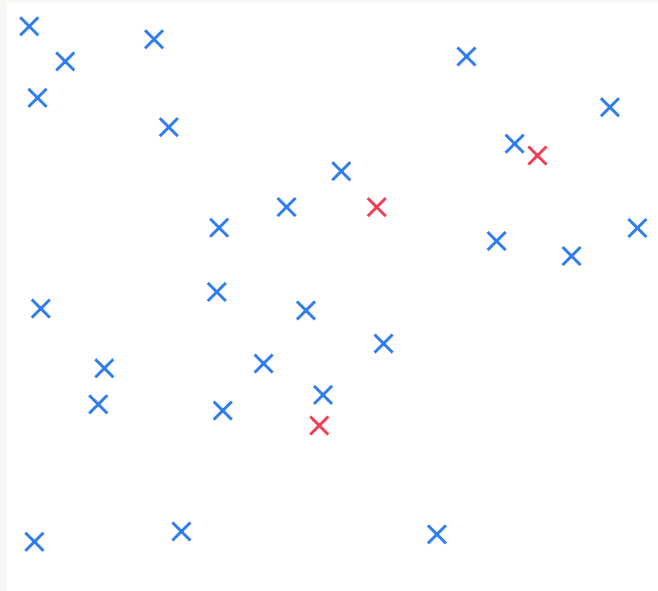


# Pre-attentive Processing

# Pre-attentive Processing



# Pre-attentive Processing

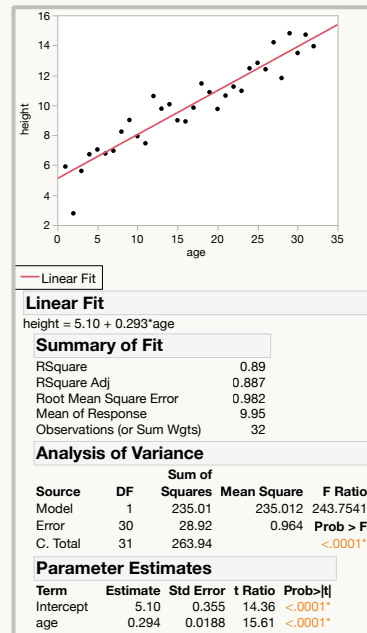


# Statistical Discovery

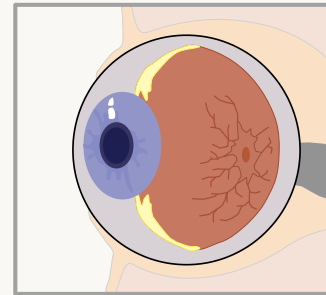
Collect

x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
290	1.08	0.39	0.08	2.08	A
742	3.28	2.41	2.28	4.28	A
379	-2.31	-2.05	-3.31	-1.31	A
646	1.05	2.10	0.05	2.05	A
178	4.22	3.28	3.22	5.22	A
272	1.27	2.18	0.27	2.27	A
670	2.00	1.21	1.00	3.00	A
689	2.41	2.15	1.41	3.41	A
233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
18	0.78	1.84	-0.22	1.78	A
439	-3.86	-3.88	-4.86	-2.86	A
167	3.94	3.06	2.94	4.94	A
463	-3.59	-2.83	-4.59	-2.59	A
180	3.79	3.07	2.79	4.79	A
69	2.25	2.90	1.25	3.25	A
848	3.13	3.08	2.13	4.13	A
585	-1.49	-0.58	-2.49	-0.49	A
276	1.28	1.81	0.28	2.28	A
340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



See



Understand

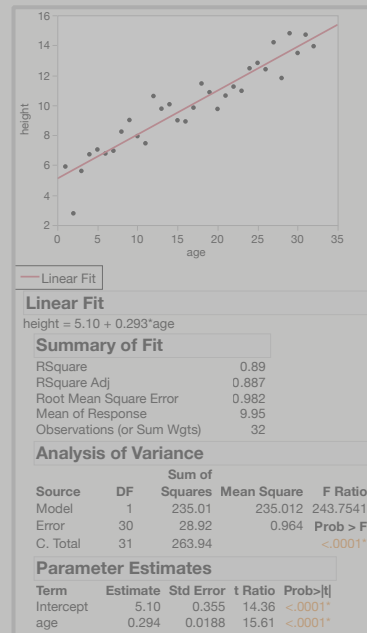


# Statistical Discovery

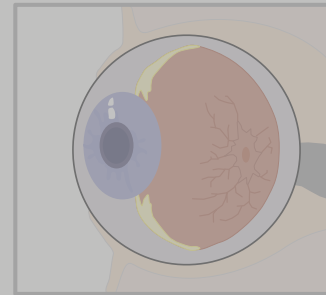
Collect

x	mid	y	lo	hi	sensor
84	2.60	3.43	1.60	3.60	A
990	-1.50	-2.47	-2.50	-0.50	A
203	3.46	4.52	2.46	4.46	A
290	1.08	0.39	0.08	2.08	A
742	3.28	2.41	2.28	4.28	A
379	-2.31	-2.05	-3.31	-1.31	A
646	1.05	2.10	0.05	2.05	A
178	4.22	3.28	3.22	5.22	A
272	1.27	2.18	0.27	2.27	A
670	2.00	1.21	1.00	3.00	A
689	2.41	2.15	1.41	3.41	A
233	3.09	2.07	2.09	4.09	A
593	-1.09	-0.77	-2.09	-0.09	A
295	1.08	0.21	0.08	2.08	A
54	1.77	0.94	0.77	2.77	A
82	2.58	3.52	1.58	3.58	A
484	-3.67	-4.69	-4.67	-2.67	A
2	-0.02	0.22	-1.02	0.98	A
188	3.63	3.62	2.63	4.63	A
18	0.78	1.84	-0.22	1.78	A
439	-3.86	-3.88	-4.86	-2.86	A
167	3.94	3.06	2.94	4.94	A
463	-3.59	-2.83	-4.59	-2.59	A
180	3.79	3.07	2.79	4.79	A
69	2.25	2.90	1.25	3.25	A
848	3.13	3.08	2.13	4.13	A
585	-1.49	-0.58	-2.49	-0.49	A
276	1.28	1.81	0.28	2.28	A
340	-0.71	-0.24	-1.71	0.29	A
379	-2.06	-1.82	-3.06	-1.06	A
546	-2.84	-3.78	-3.84	-1.84	A
969	-3.78	-3.37	-4.78	-2.78	B
226	-0.47	-0.99	-1.47	0.53	B

Analyze



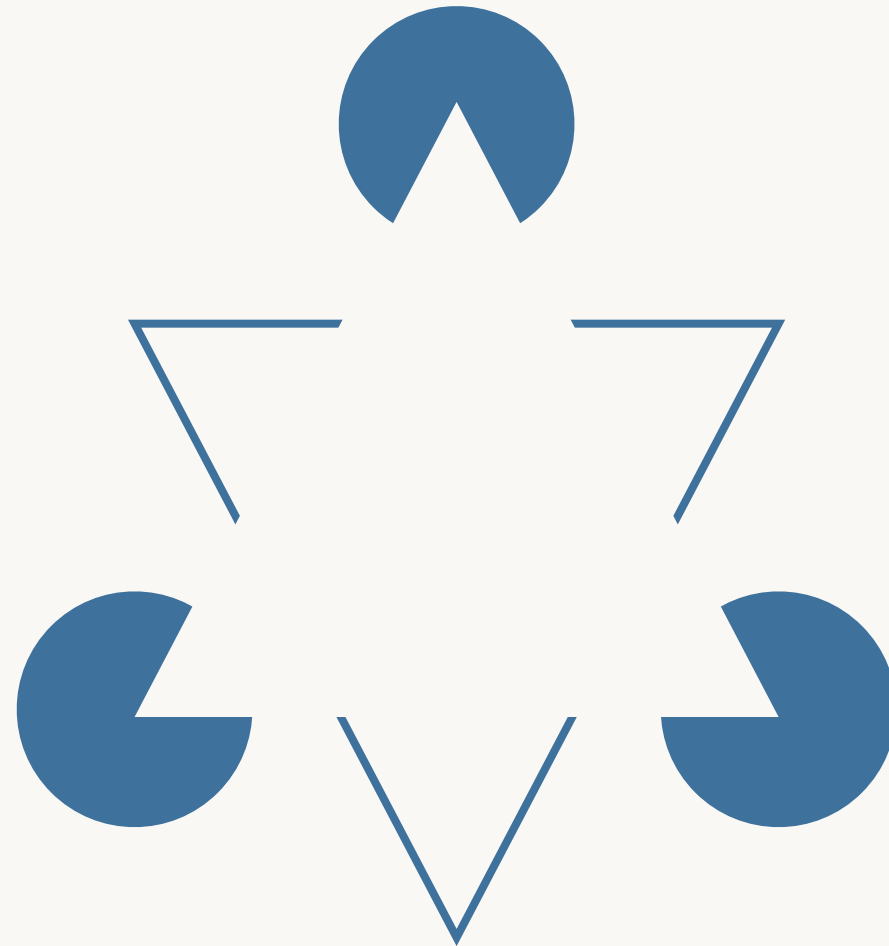
See



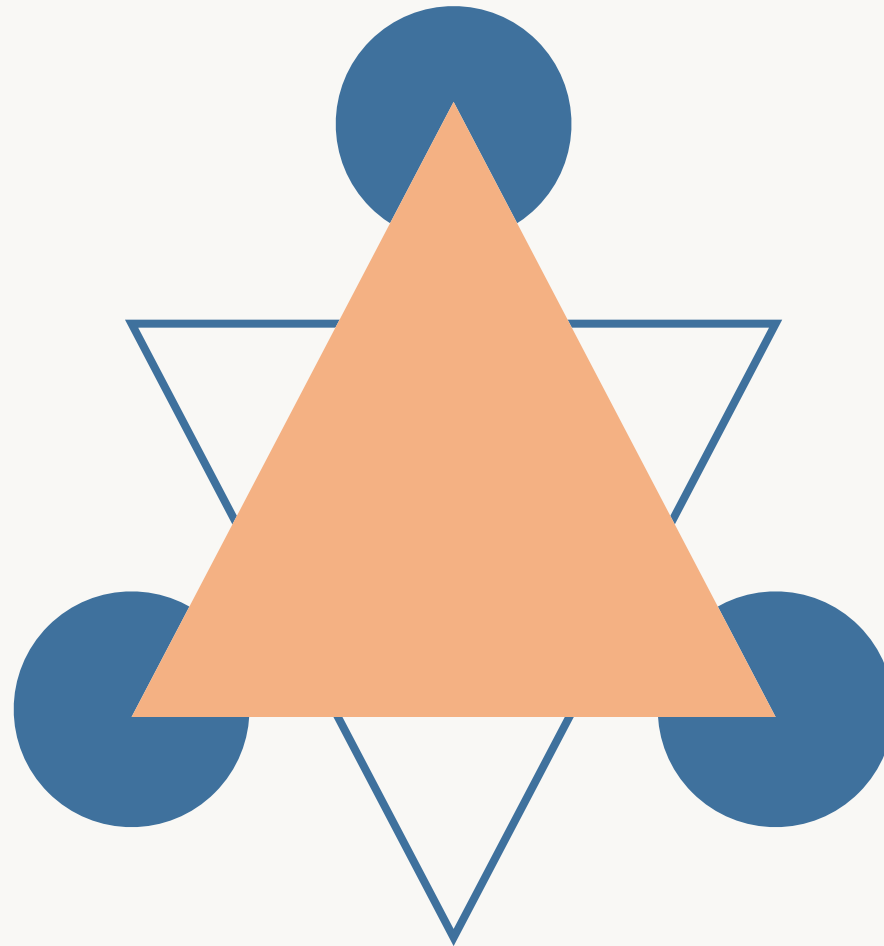
Understand



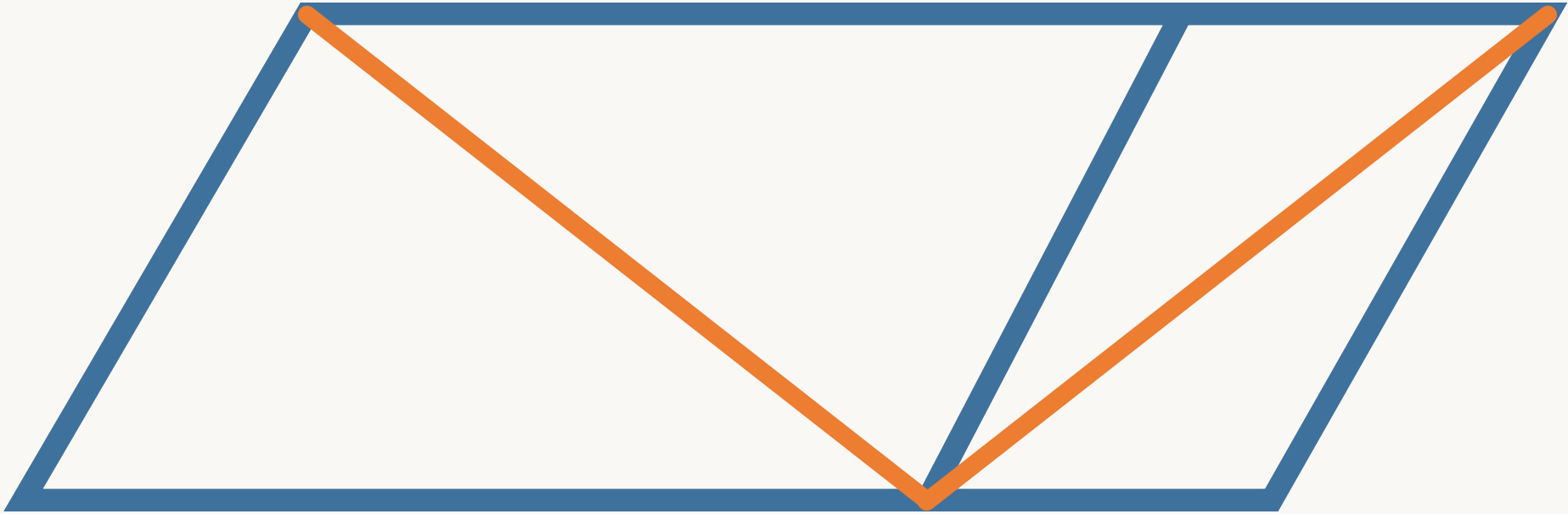
# Kanizsa Triangle



# Kanizsa Triangle

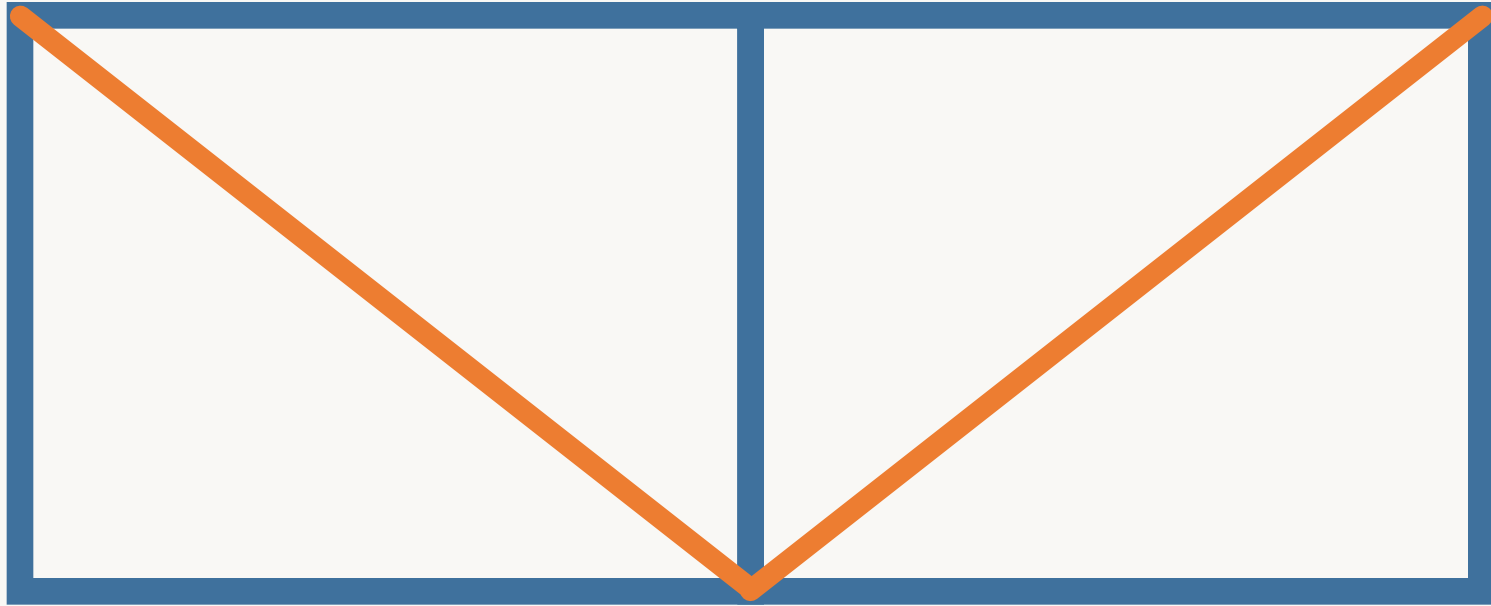


# Sander's Parallelogram

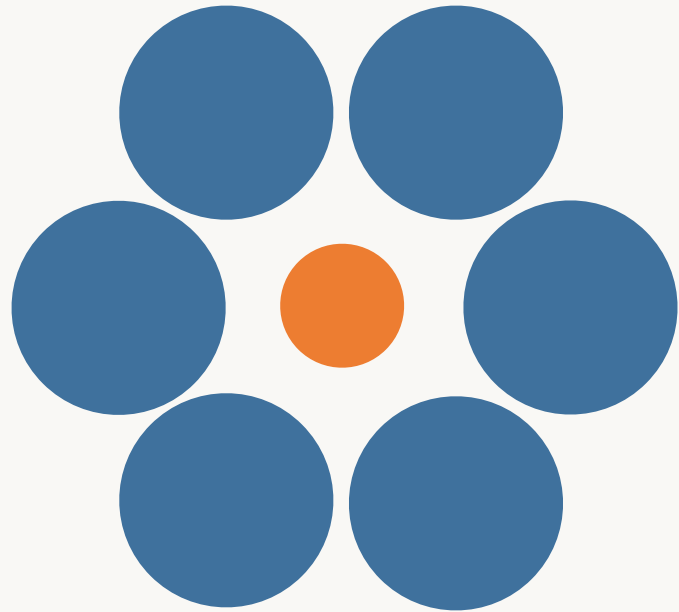




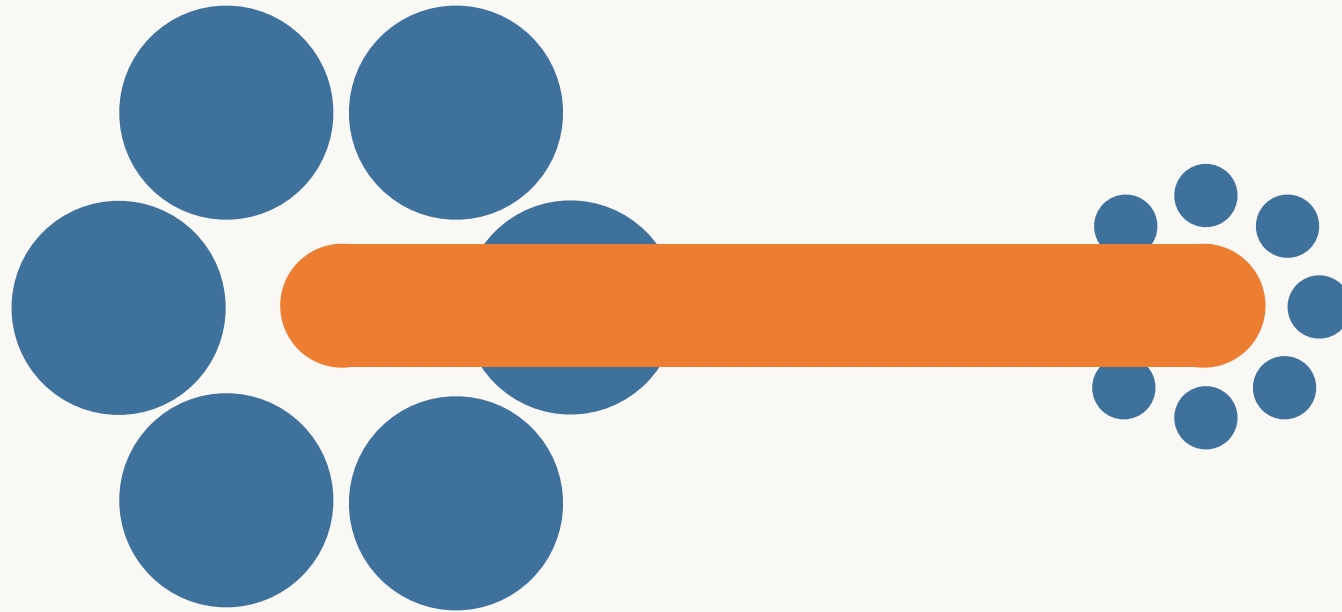
# Sander's Parallelogram



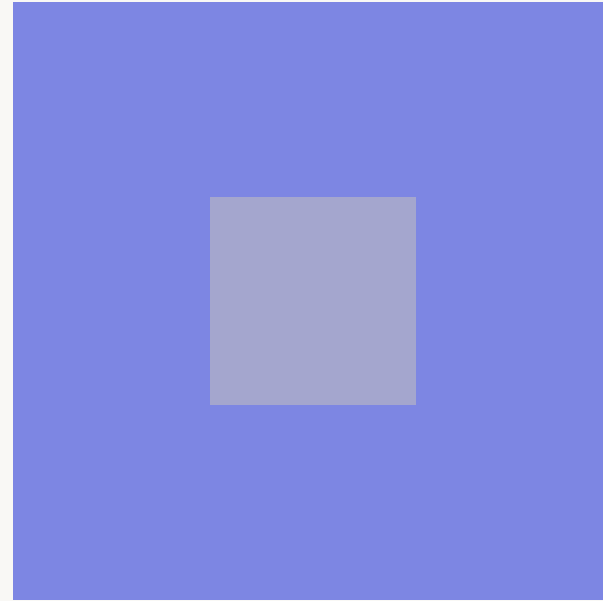
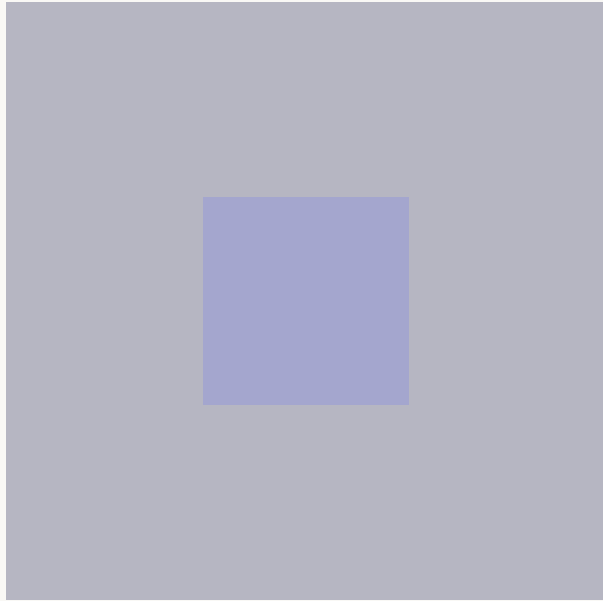
# Ebbinghaus Illusion



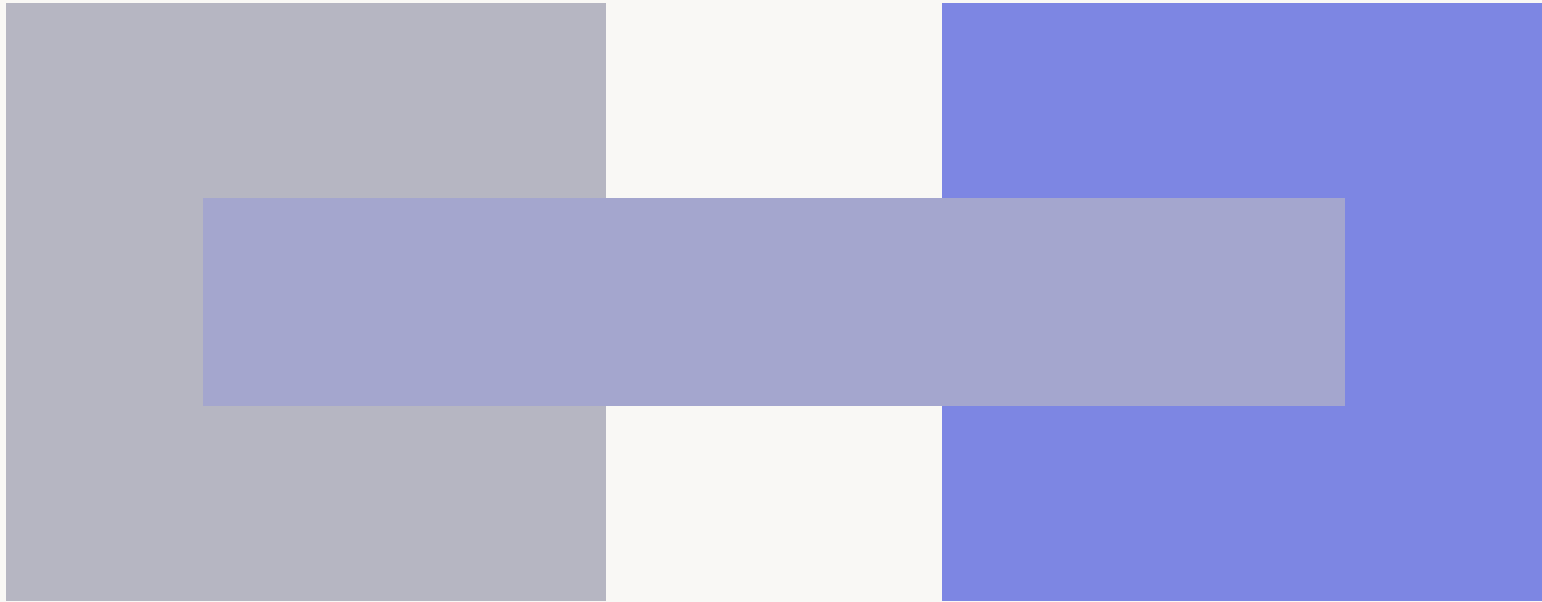
# Ebbinghaus Illusion



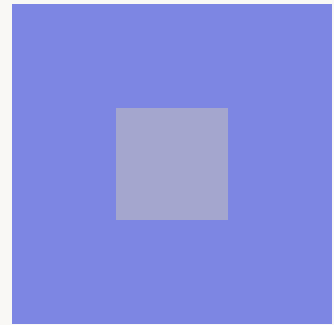
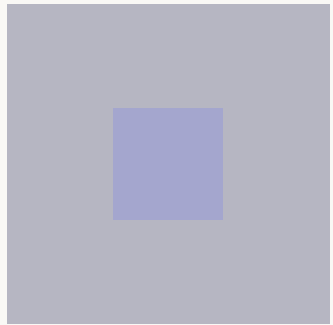
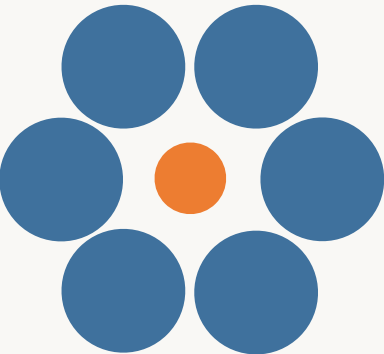
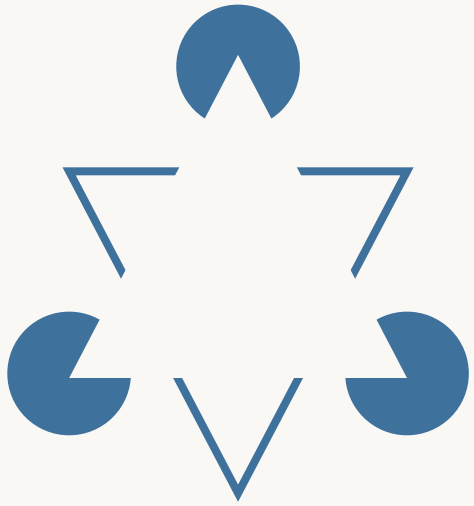
# Chubb Illusion



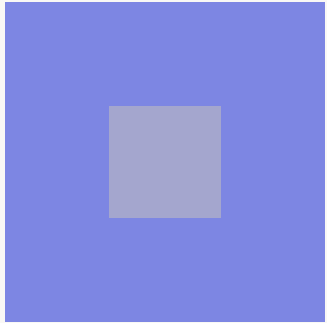
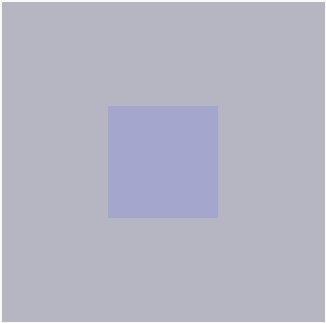
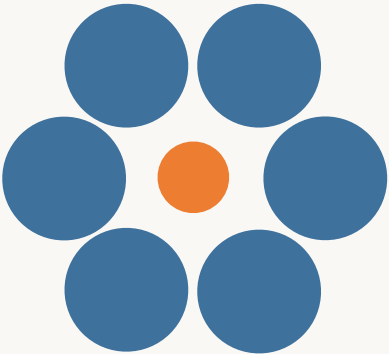
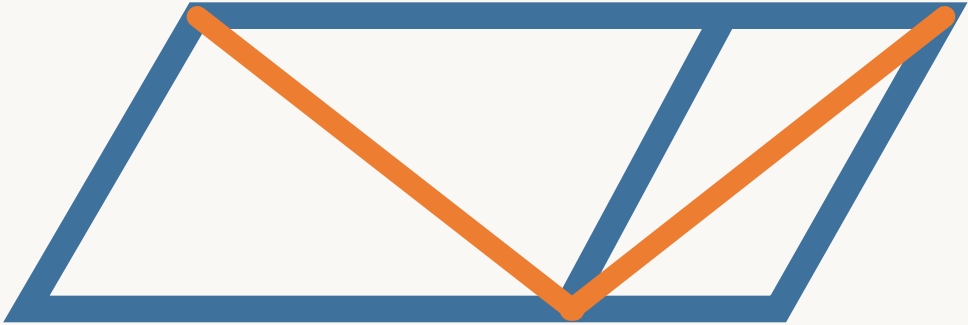
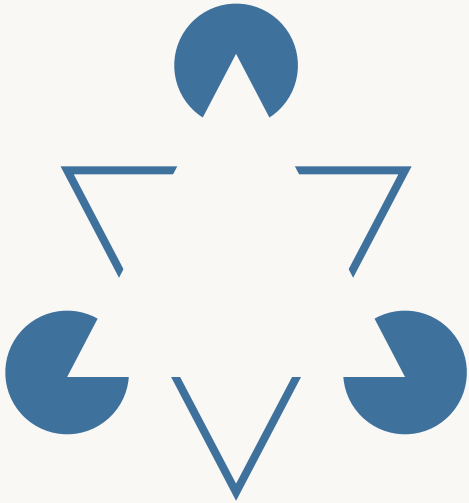
# Chubb Illusion



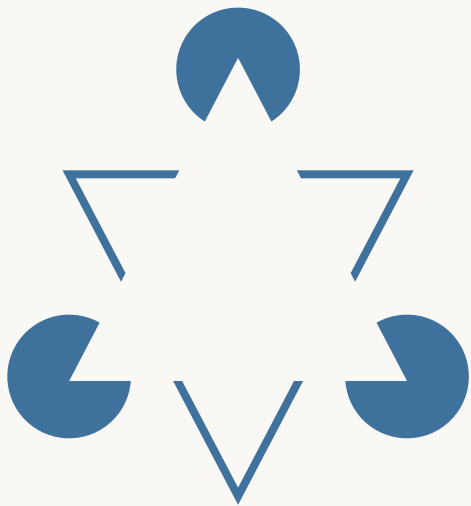
# Features, not Flaws



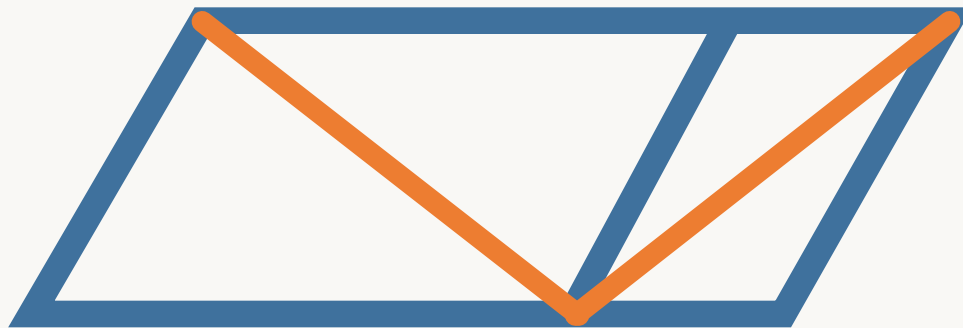
# Resistance to Alternative Denotation



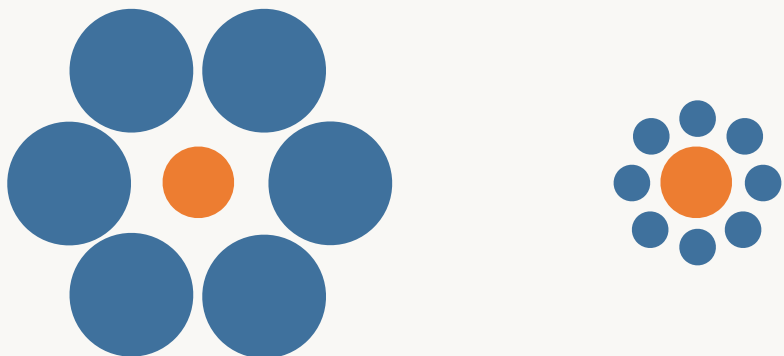
## Shape



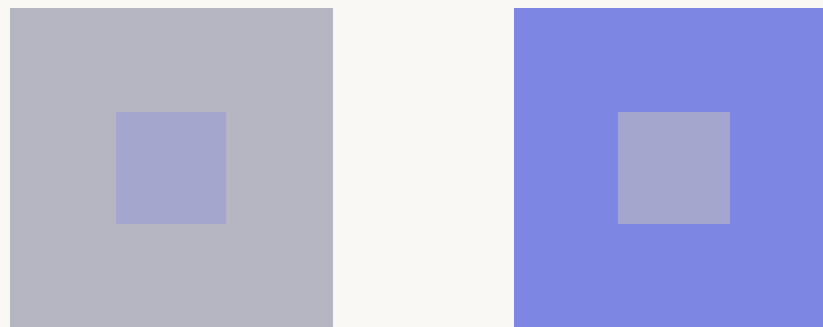
## Length



## Size

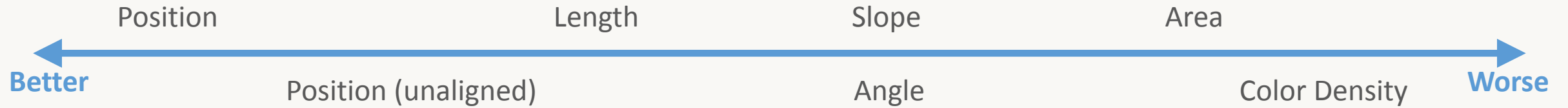


## Color

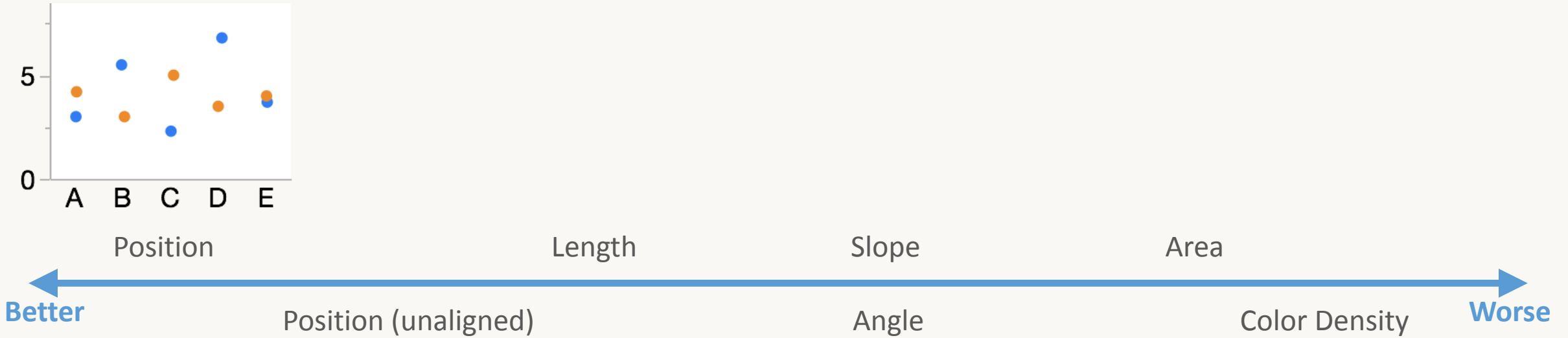




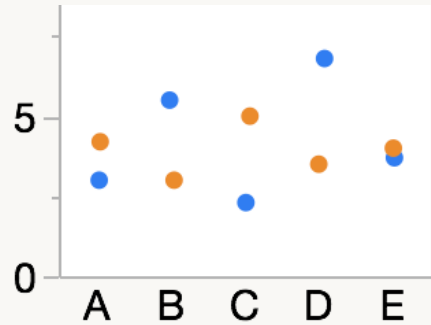
# Graphic Attributes: Quantitative Scales



# Graphic Attributes: Quantitative Scales



# Graphic Attributes: Quantitative Scales



Position

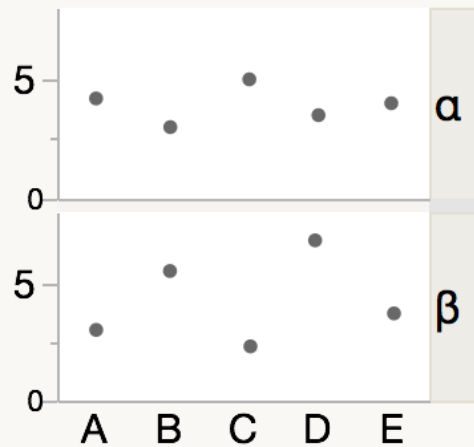
Length

Slope

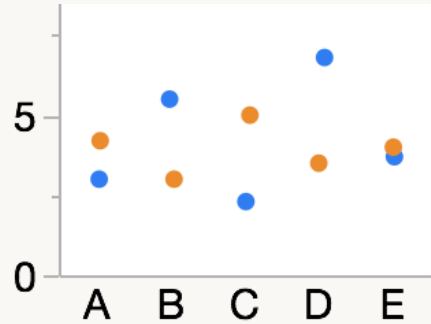
Area



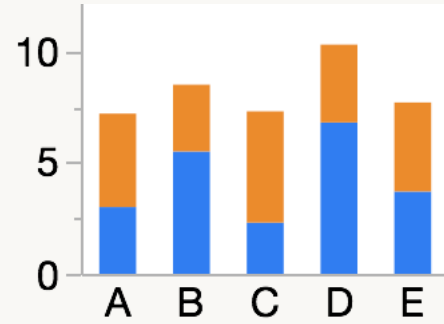
Position (unaligned)



# Graphic Attributes: Quantitative Scales



Position



Length

Slope

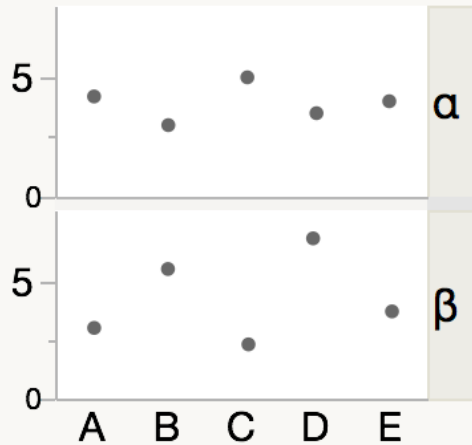
Area



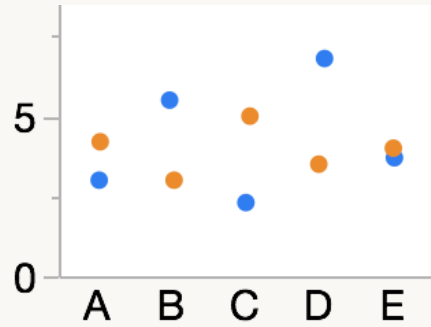
Angle

Color Density

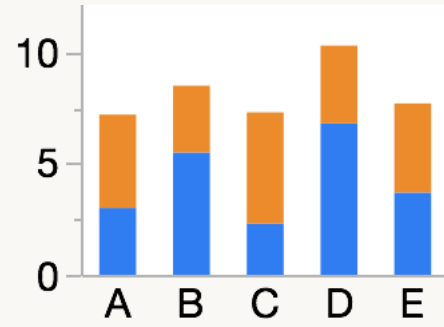
Position (unaligned)



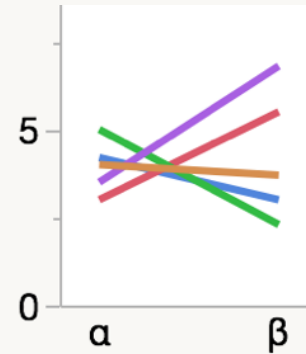
# Graphic Attributes: Quantitative Scales



Position



Length

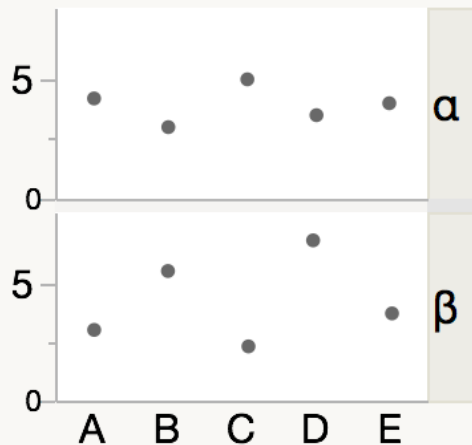


Slope

Area



Position (unaligned)

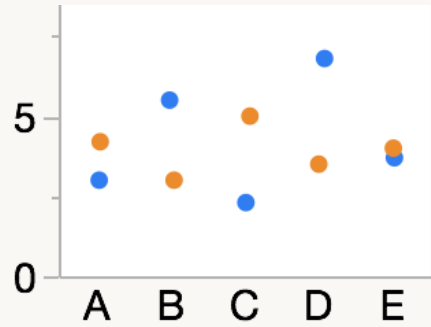


Angle

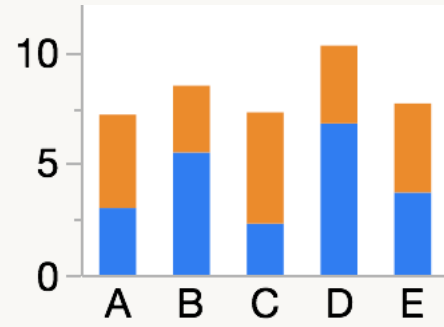
Color Density

Worse

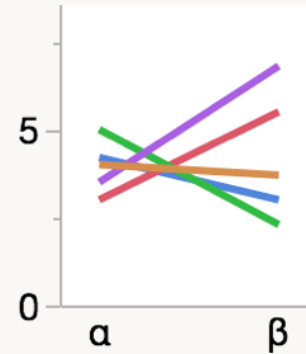
# Graphic Attributes: Quantitative Scales



Position



Length

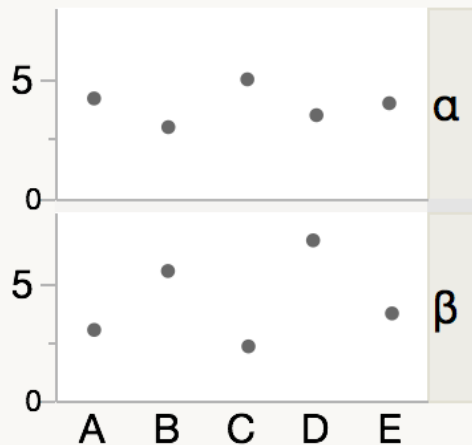


Slope

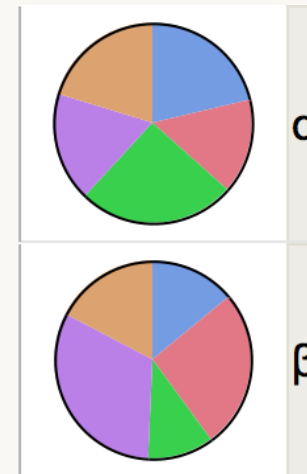
Area



Position (unaligned)



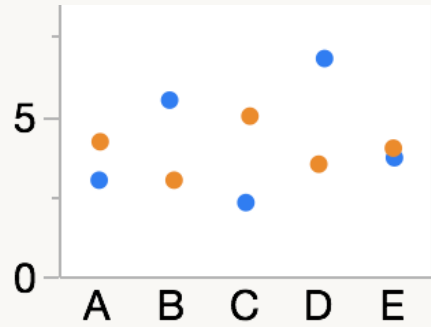
Angle



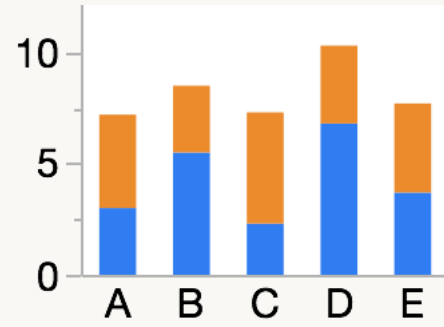
Color Density

Worse

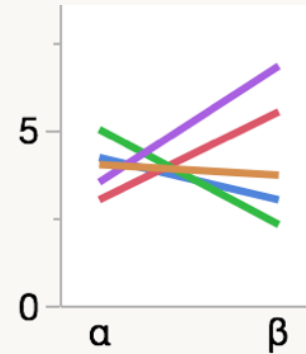
# Graphic Attributes: Quantitative Scales



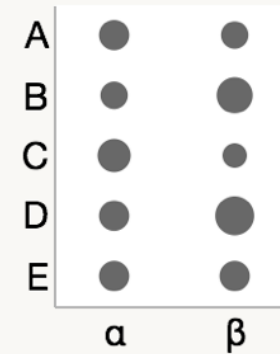
Position



Length



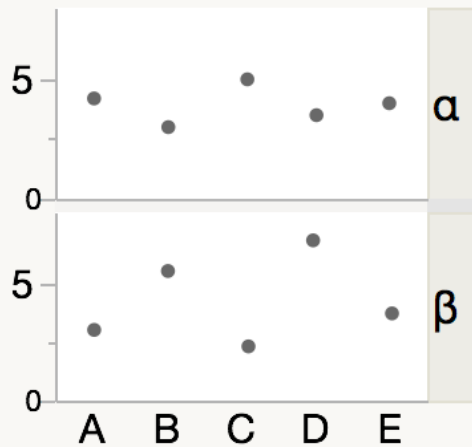
Slope



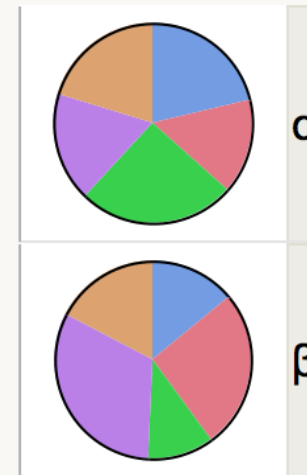
Area



Position (unaligned)

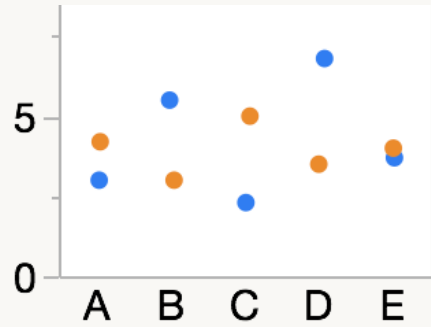


Angle

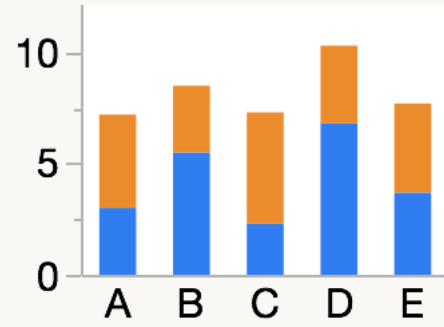


Color Density

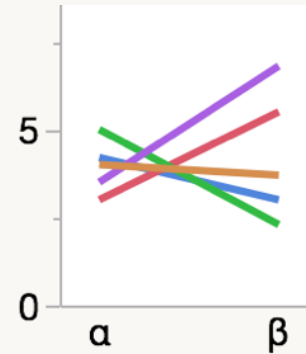
# Graphic Attributes: Quantitative Scales



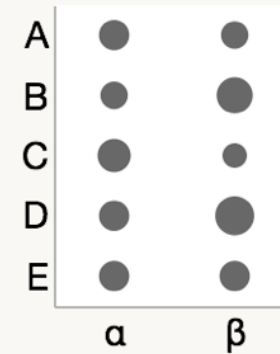
Position



Length



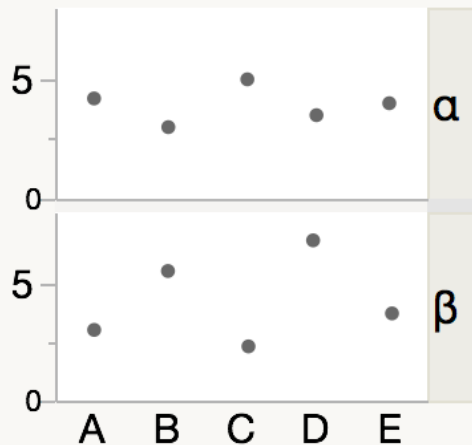
Slope



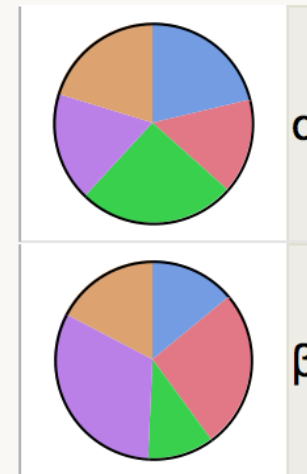
Area



Position (unaligned)



Angle

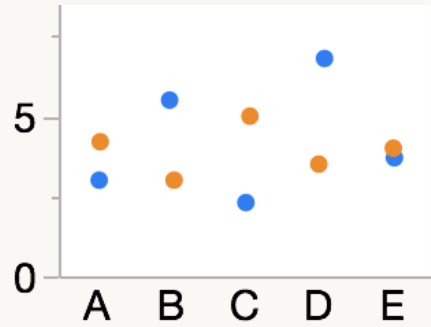


Color Density

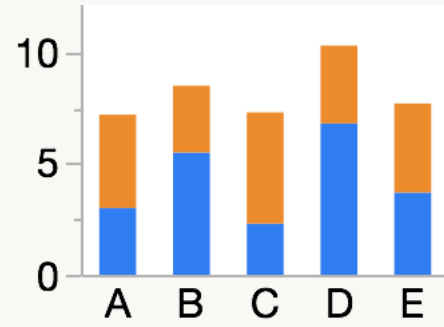




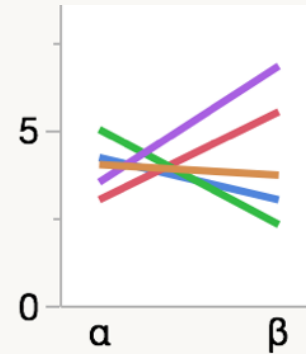
# Graphic Attributes: Quantitative Scales



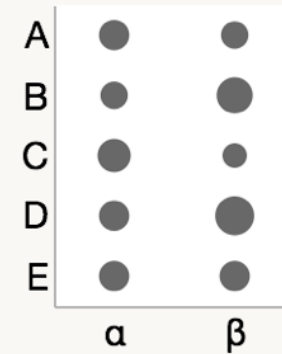
Position



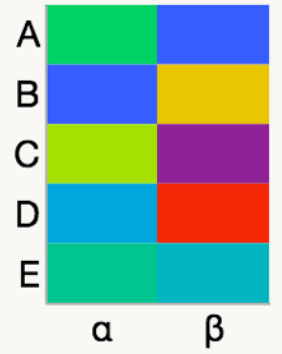
Length



Slope



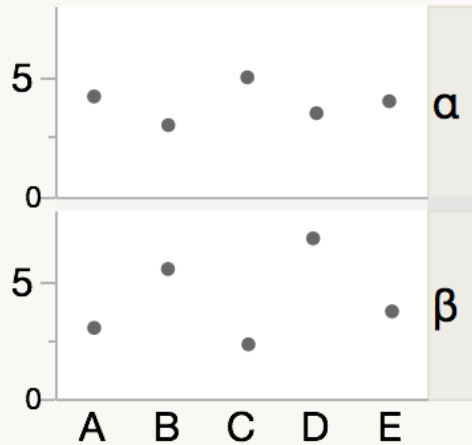
Area



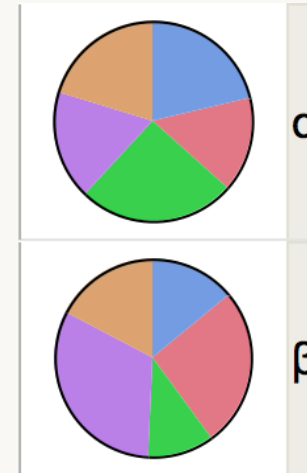
Color Hue



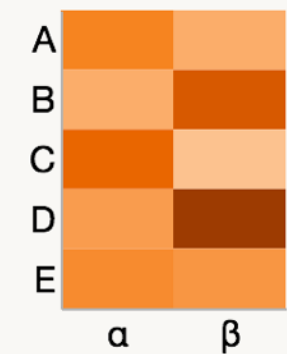
Position (unaligned)



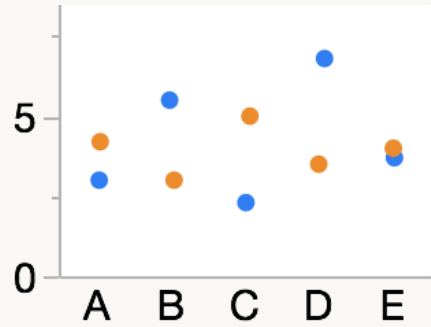
Angle



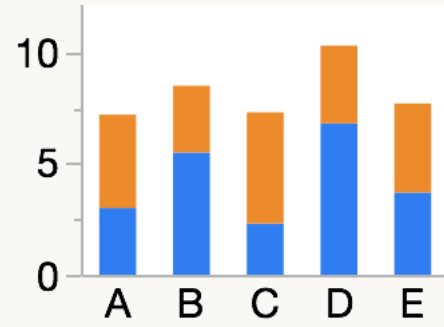
Color Density



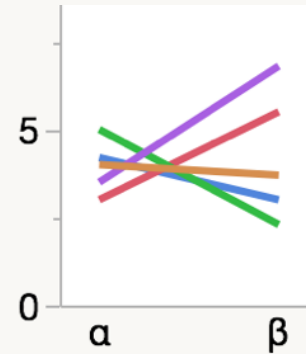
# Graphic Attributes: Quantitative Scales



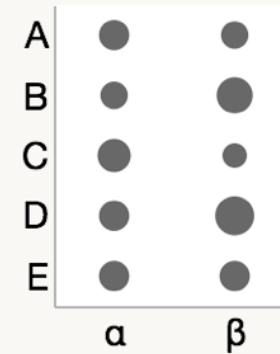
Position



Length



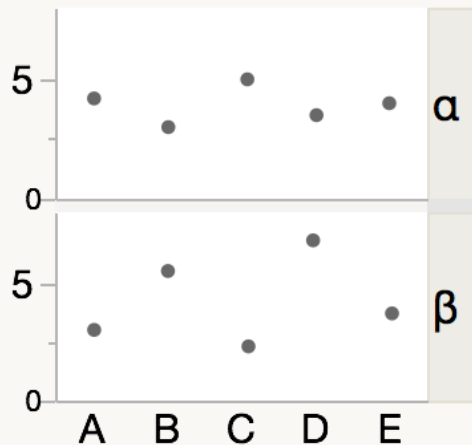
Slope



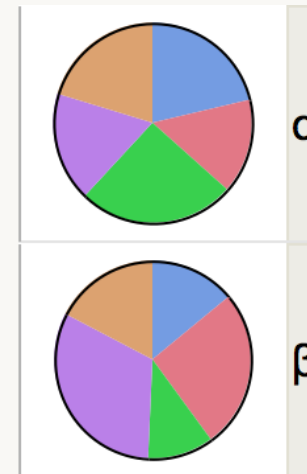
Area



Position (unaligned)



Angle



Color Density



# Putting Theory Into Practice



- Information vs. Data
- Distance perception
- Color perception

- Graph the information
- Use (don't abuse) pre-attentive processing
- Choose appropriate color scales
- Less is more

All Graphs Are Wrong,  
but *Yours* Can Be Useful

2015

# DISCOVERY SUMMIT

EXPLORING DATA  
INSPIRING INNOVATION