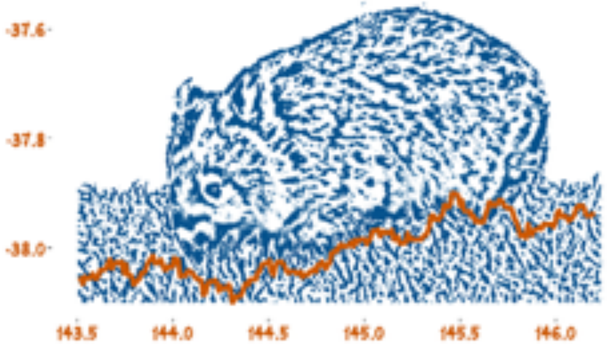
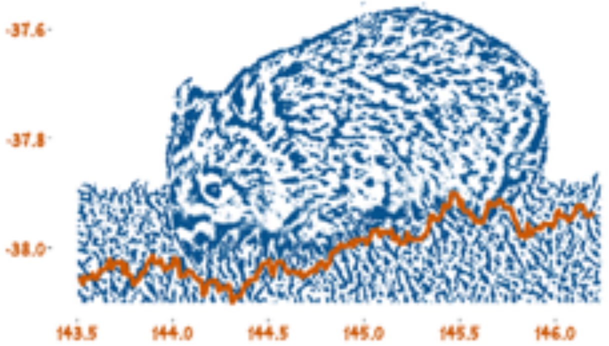
Making data analysis easier



Feature Hierarchy in Graphical Displays

Heike Hofmann*, Susan VanderPlas
Iowa State University

*currently visiting Monash



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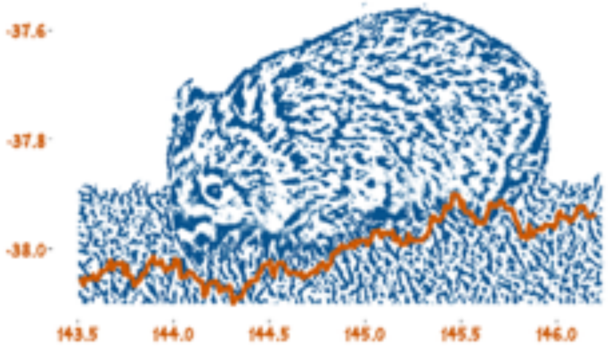
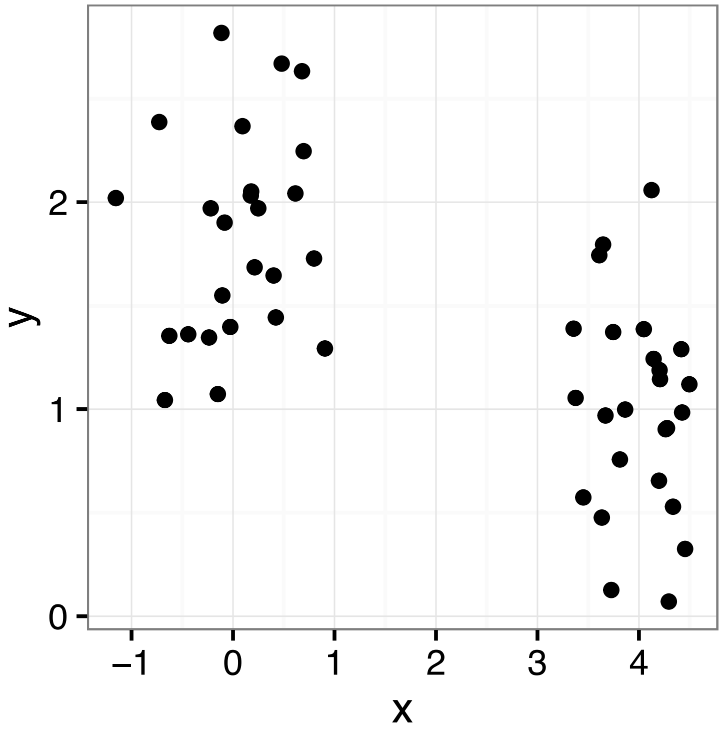
Outline

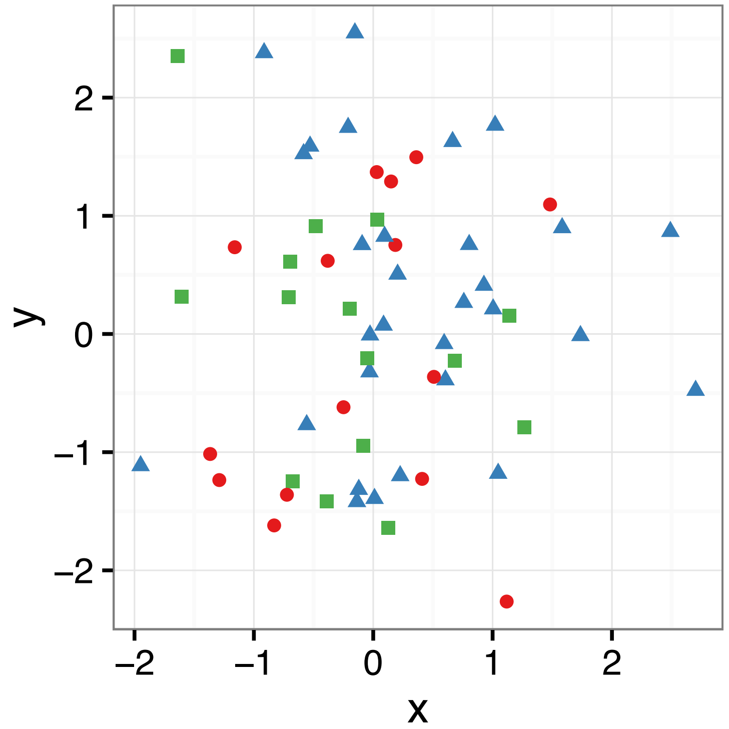


- Cognition and Statistical Graphics
- Lineup Protocol
- Study Design
- Results

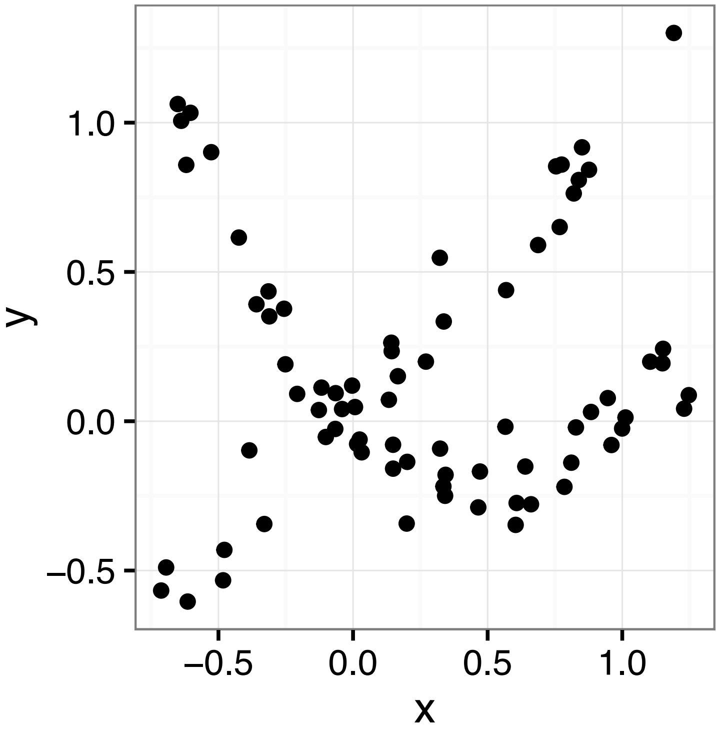
Finding patterns in data



Proximity



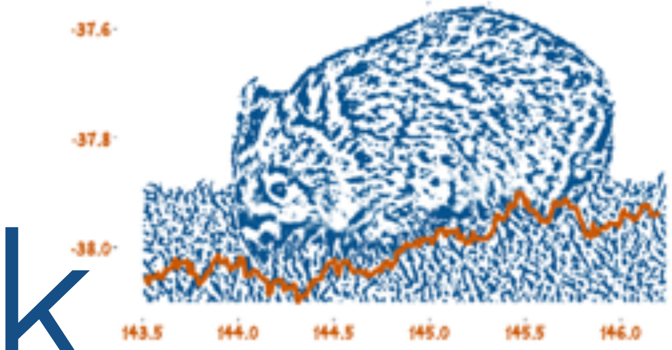
Similarity



Continuity

Cognitive principles for grouping

Missing link

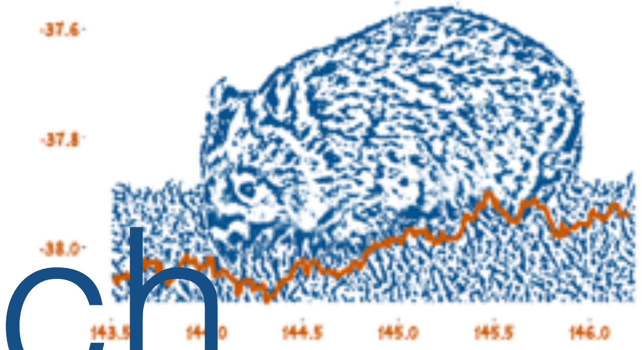


- Cleveland & McGill (1984): hierarchy of basic visual tasks: comparisons along common axis, lengths, area, …

- Hierarchy of pre-attentive features (Healey & Enns, 1999): color, shape, angle, …

- Pre-attentiveness of features does not directly translate to understanding charts … need more direct validation

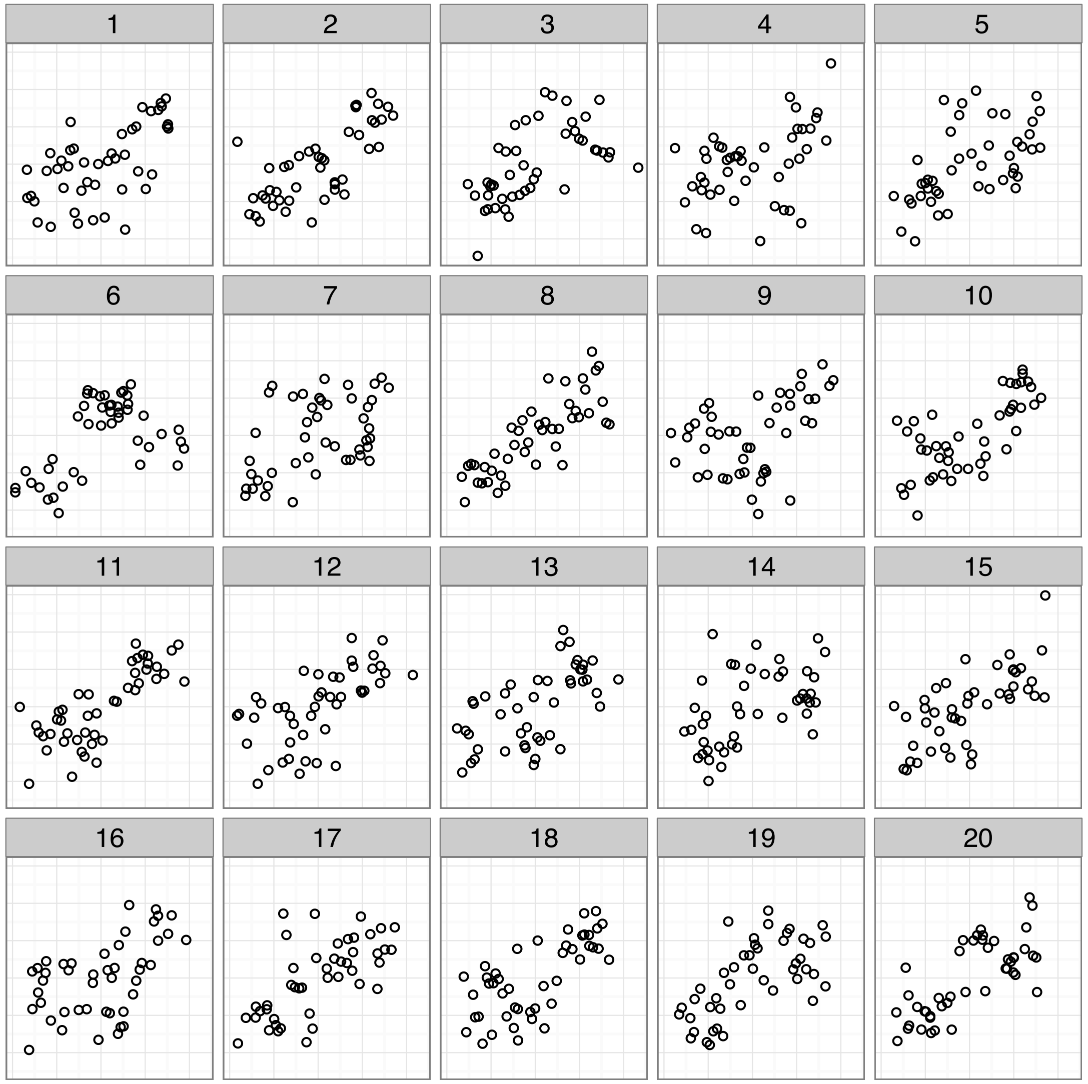
Our approach



- use lineup protocol to investigate charts `in their natural habitat’
- want to quantify how strongly aesthetics such as color and shape and additional features (lines, ellipses) influence pattern detection

The Lineup Protocol

- Buja et al (2009):
  data embedded among a set of 'null' plots
- Visual test of null hypothesis: "data and nulls are generated by the same mechanism"
- Human evaluator: "Which of these plots is the most different?"
- Data plot identification is evidence against the null hypothesis
- p-value based on #data identifications



Which of these plots is the most different?

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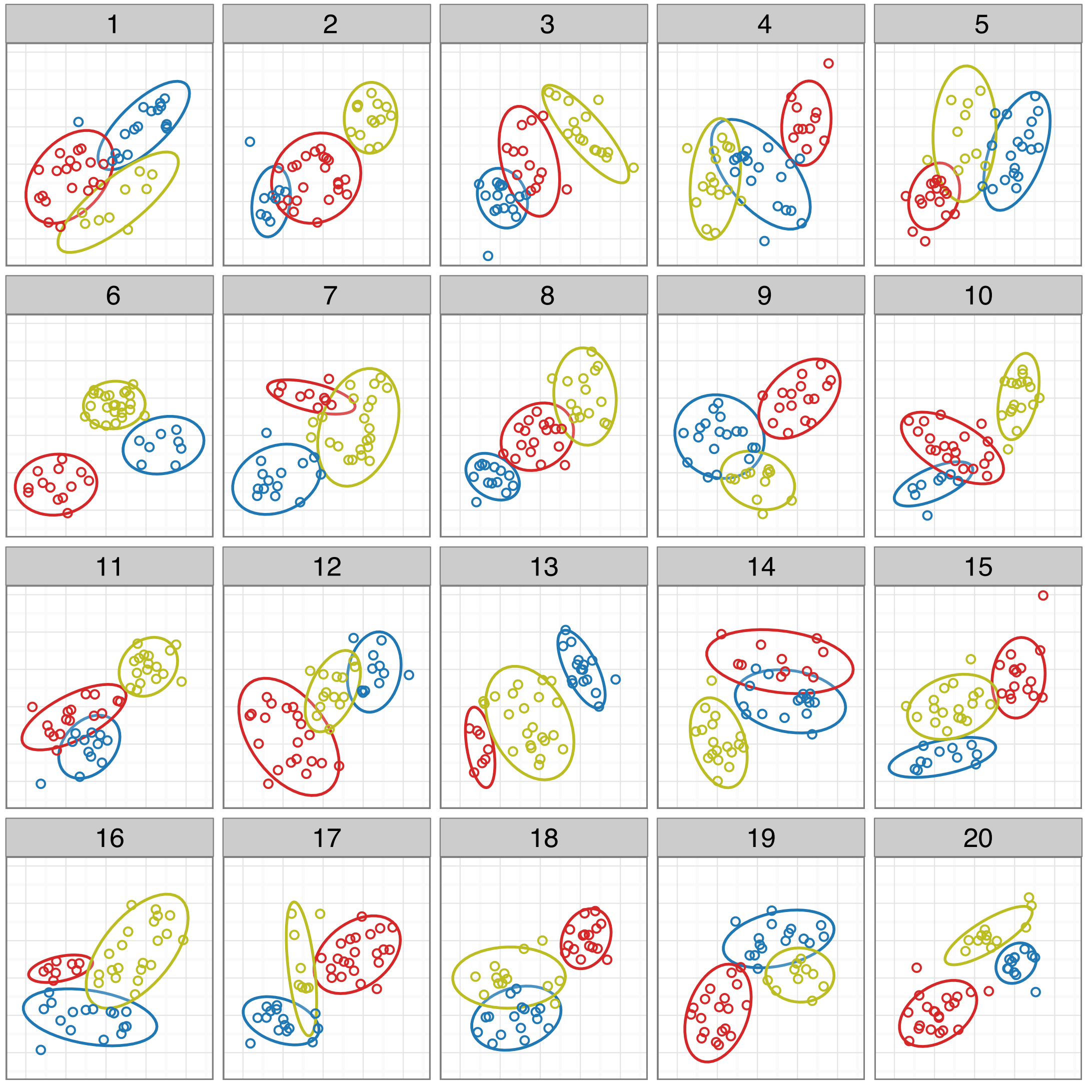
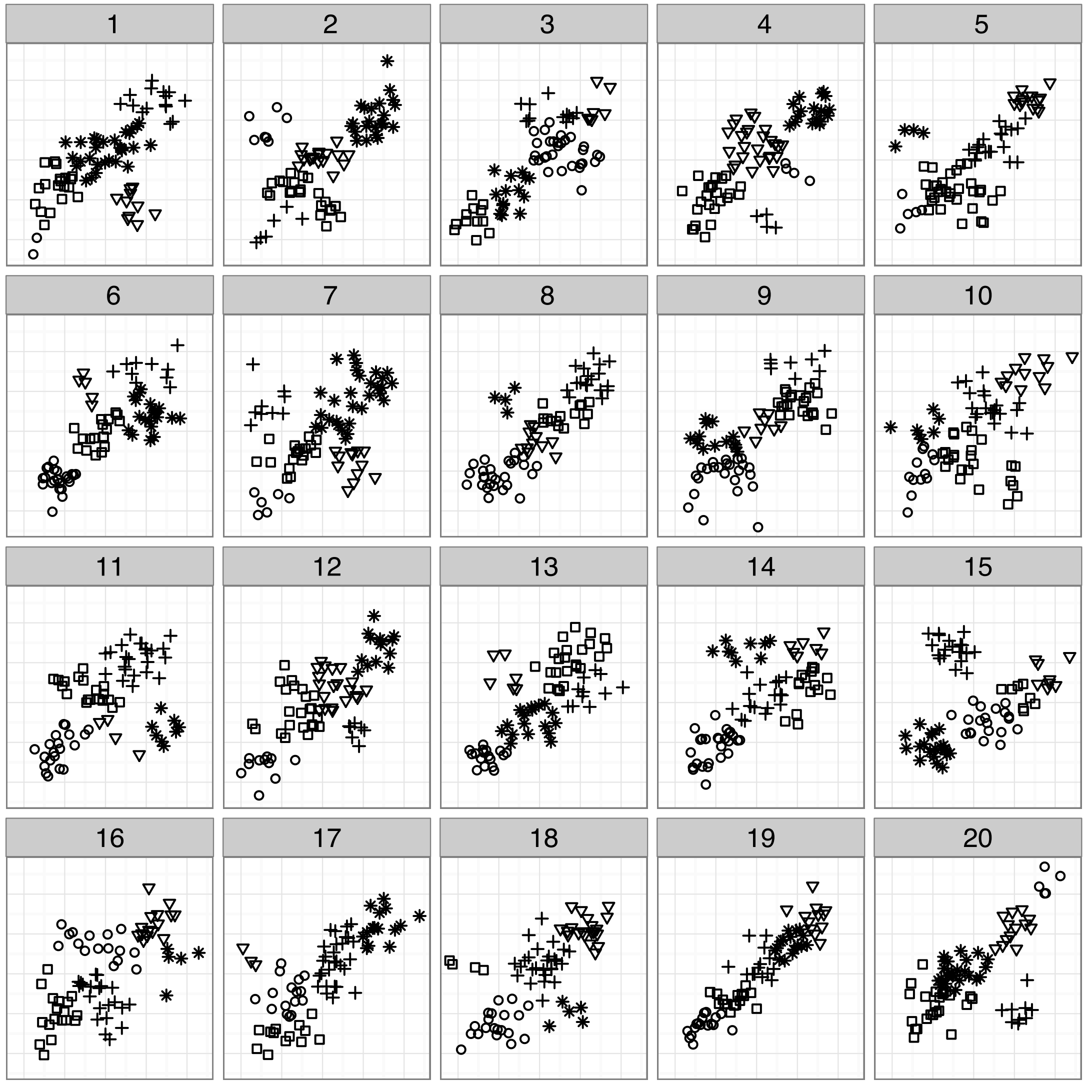


Which of these plots is the most different?

Another Example



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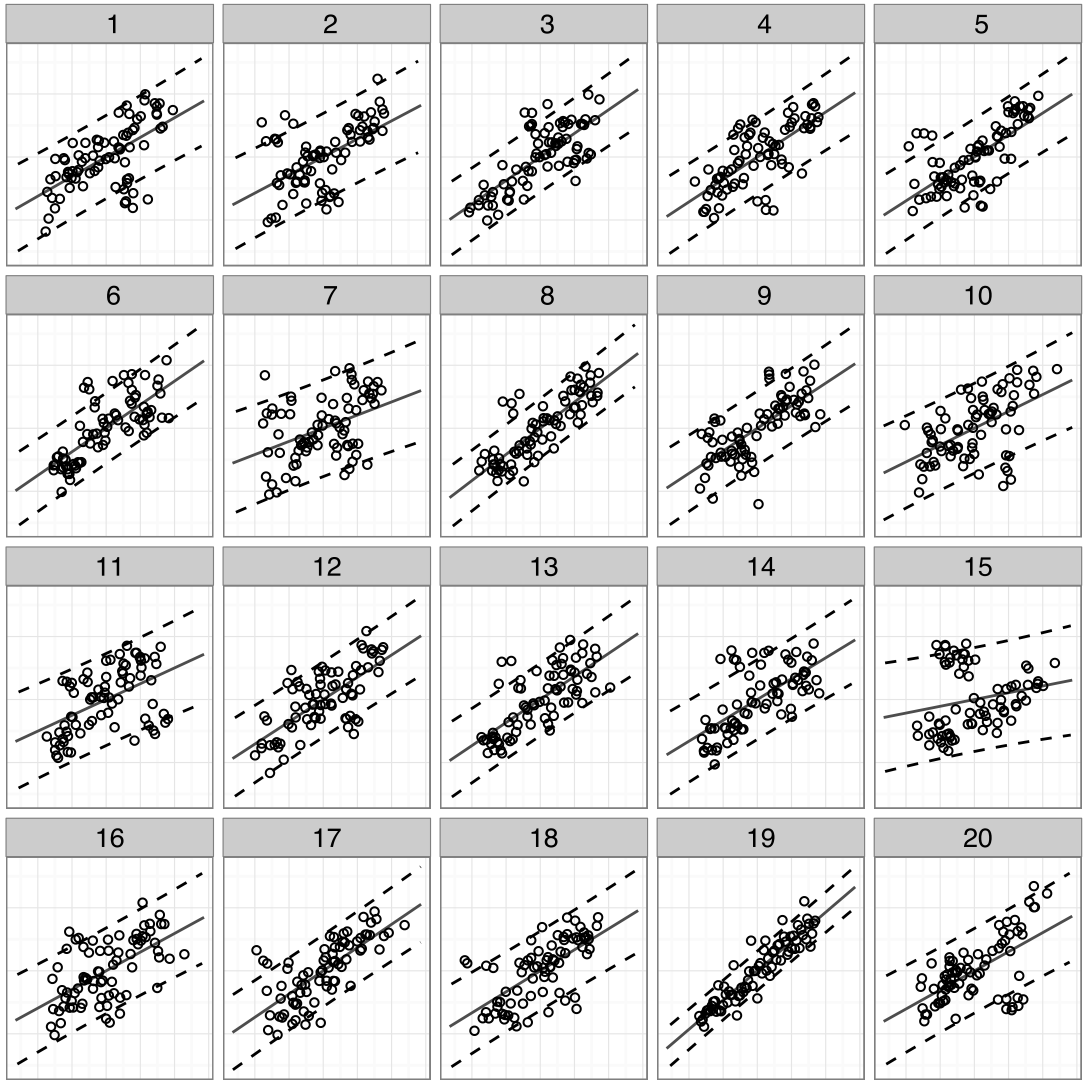

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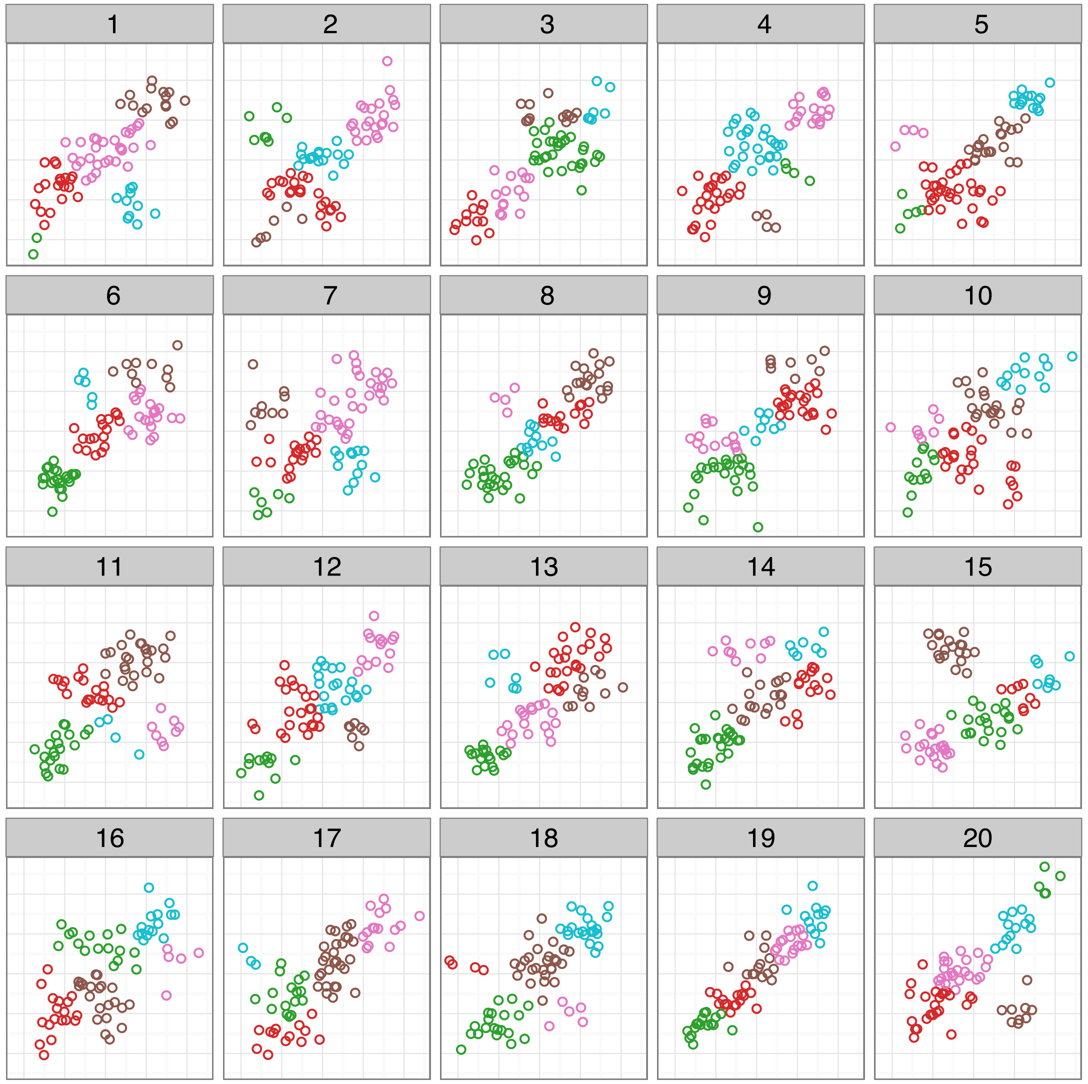

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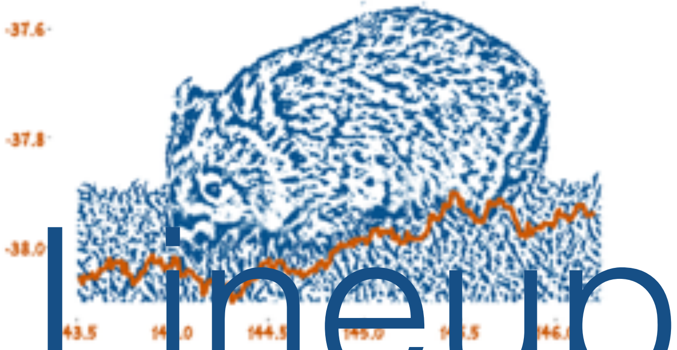
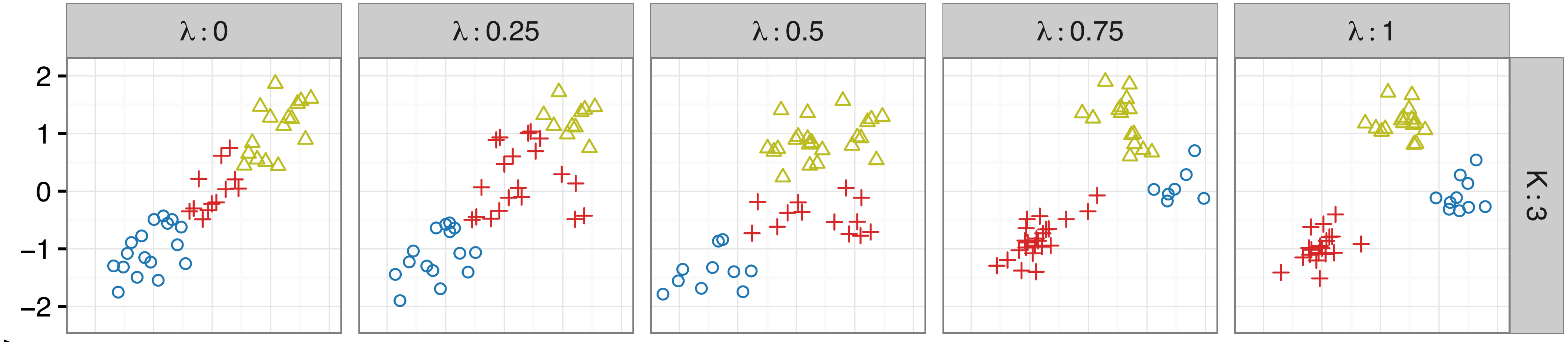
Modified Lineup



trend target

nulls

cluster target



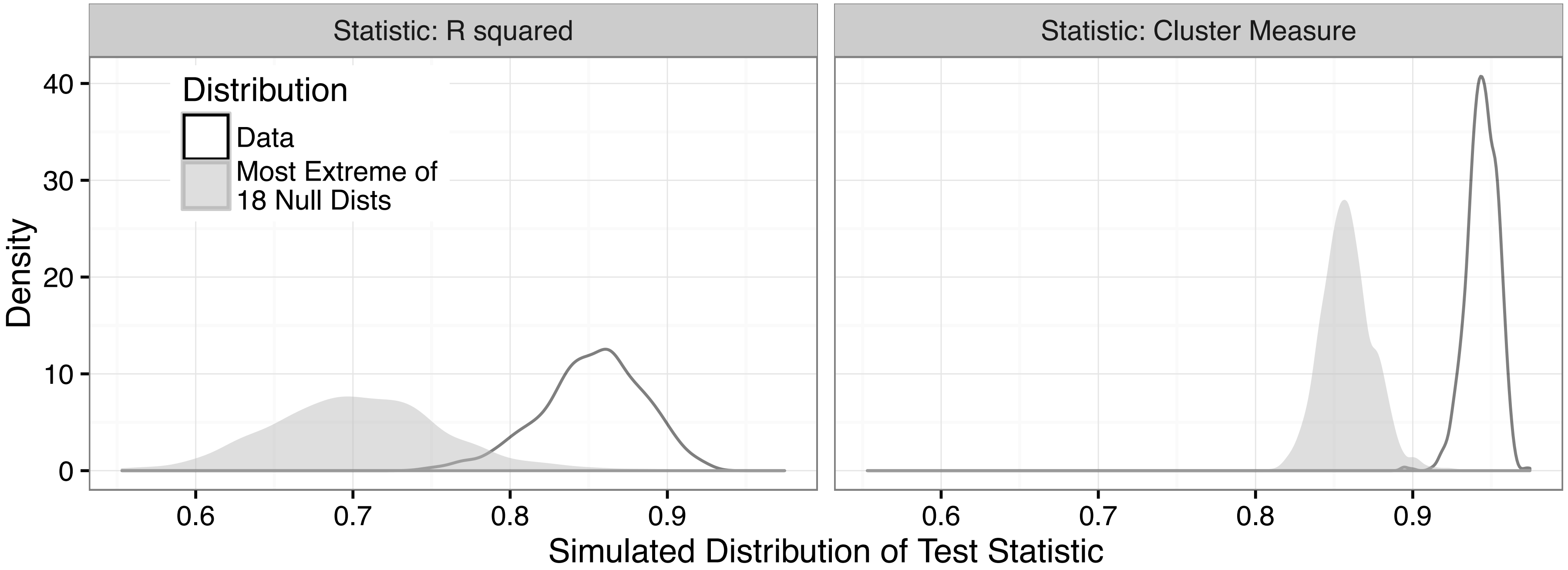
Model M_T
with parameter s_T

mixture

Model M_C
with parameter s_C

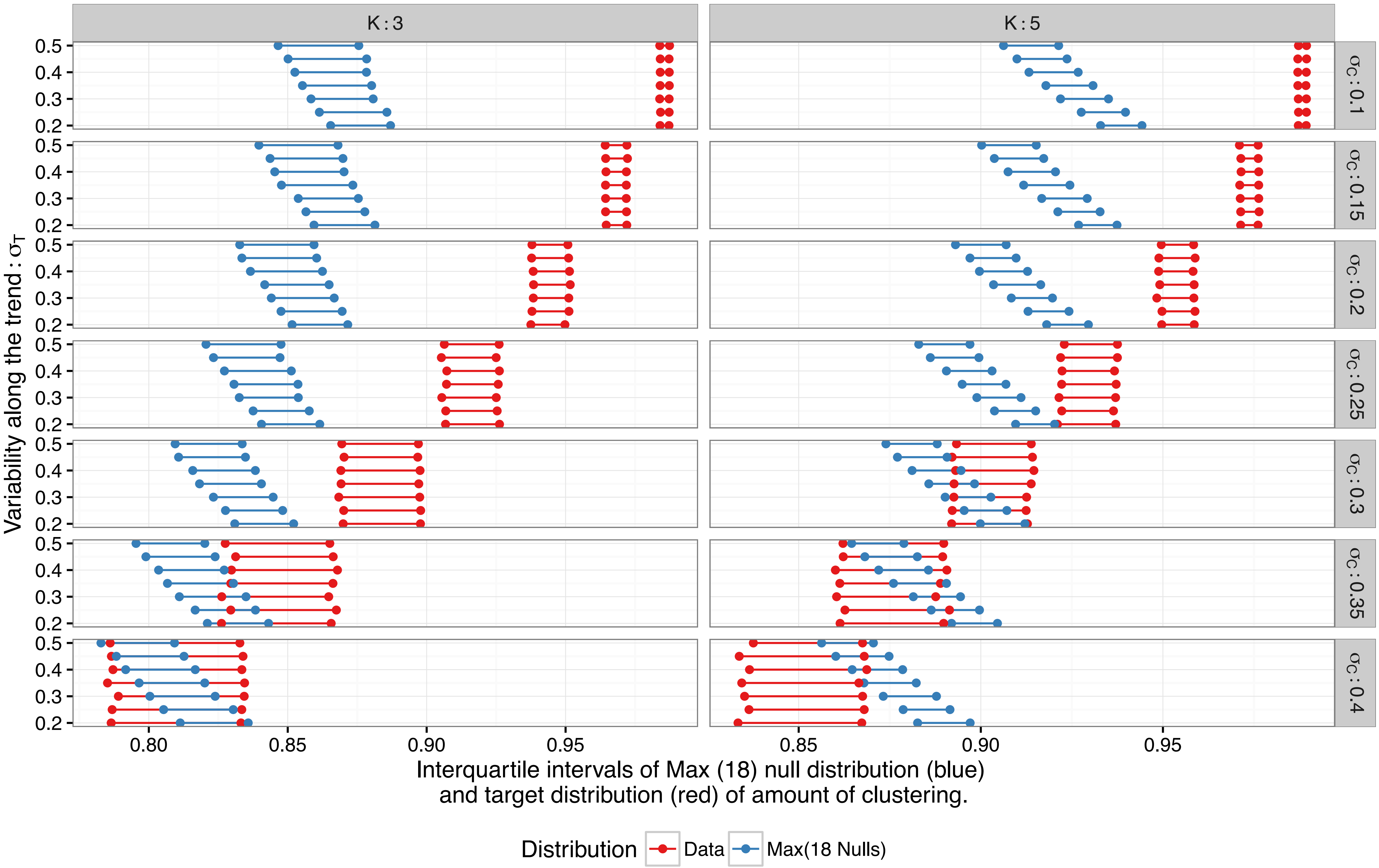
- two targets embedded in the lineup
- allows head-to-head evaluation of signal strength (satisfaction of search, Fleck et al 2010)
- choice of model parameters is tricky

Parameter settings



- Simulation: simulate 1000 data sets for s_T=0.25 and s_C = 0.2
- compute R^2 and cluster measure for data and max null
- we have a good chance of ‘seeing’ the targets in a lineup

Parameter space

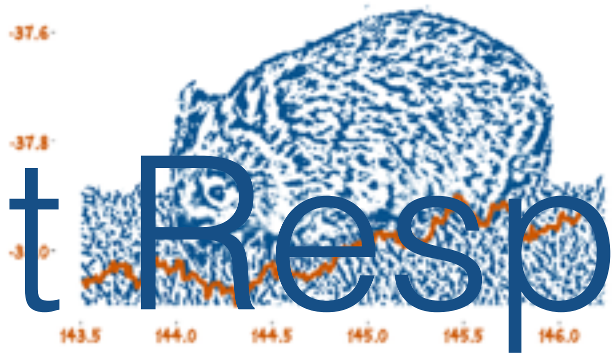


Designs: Cluster vs Trend

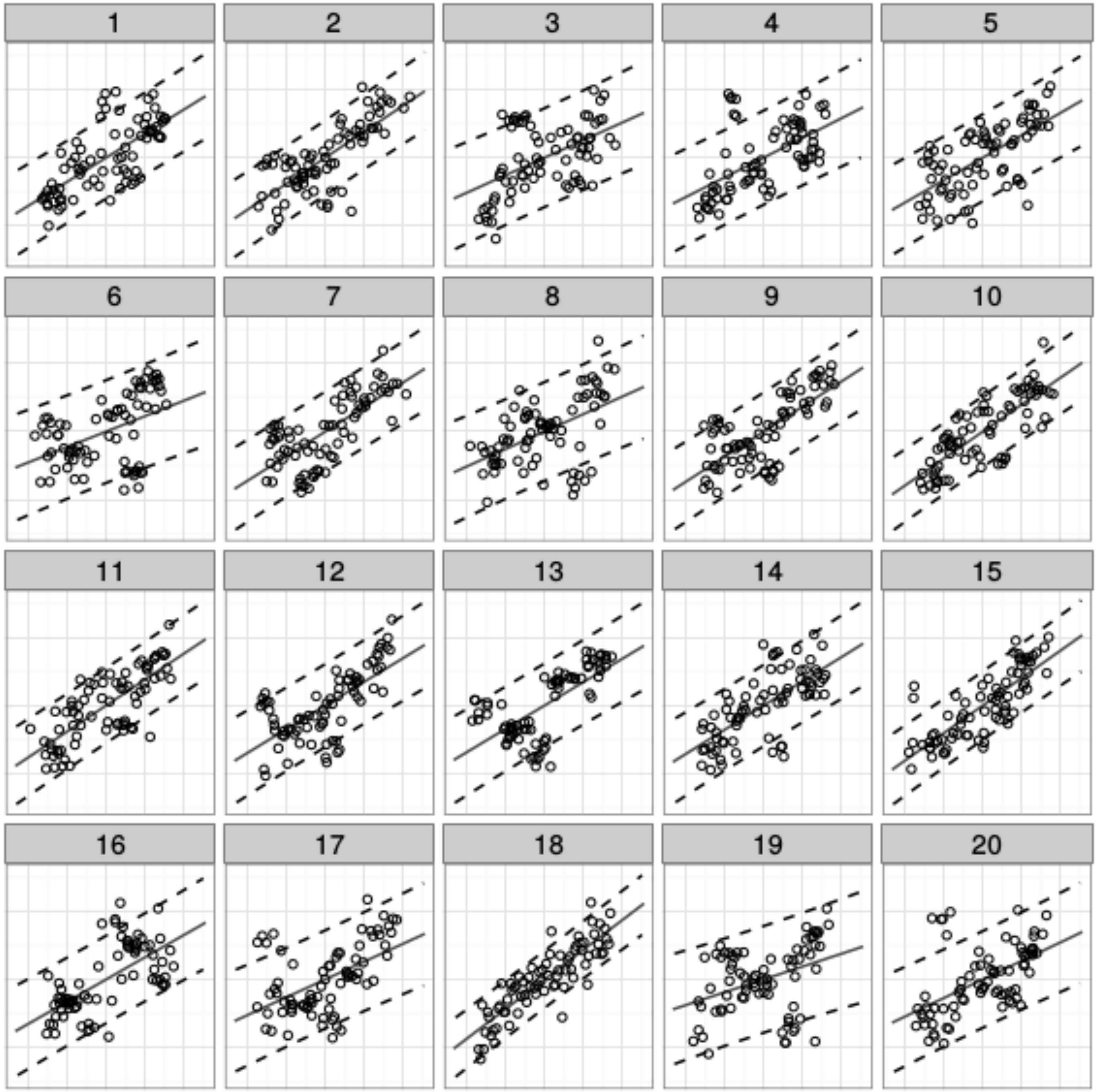
		Trend Emphasis		
	Strength	0	1	2
Cluster Emphasis	0	None	Trend	Trend + Error
	1	Color Shape	Color + Trend	
	2	Color + Shape Color + Ellipse		Color + Ellipse + Trend + Error
	3	Color + Shape + Ellipse		

AMT study

- Using AMT for recruiting participants (https://erichare.shinyapps.io/lineups/)
- requirements: at least 100 HITS, 95% success rate
- two successful pre-trial lineup evaluations
- Ten evaluations:
  one of each design,
  one of each of the nine parameter settings
- Result: 12010 lineup evaluations from 1201 participants

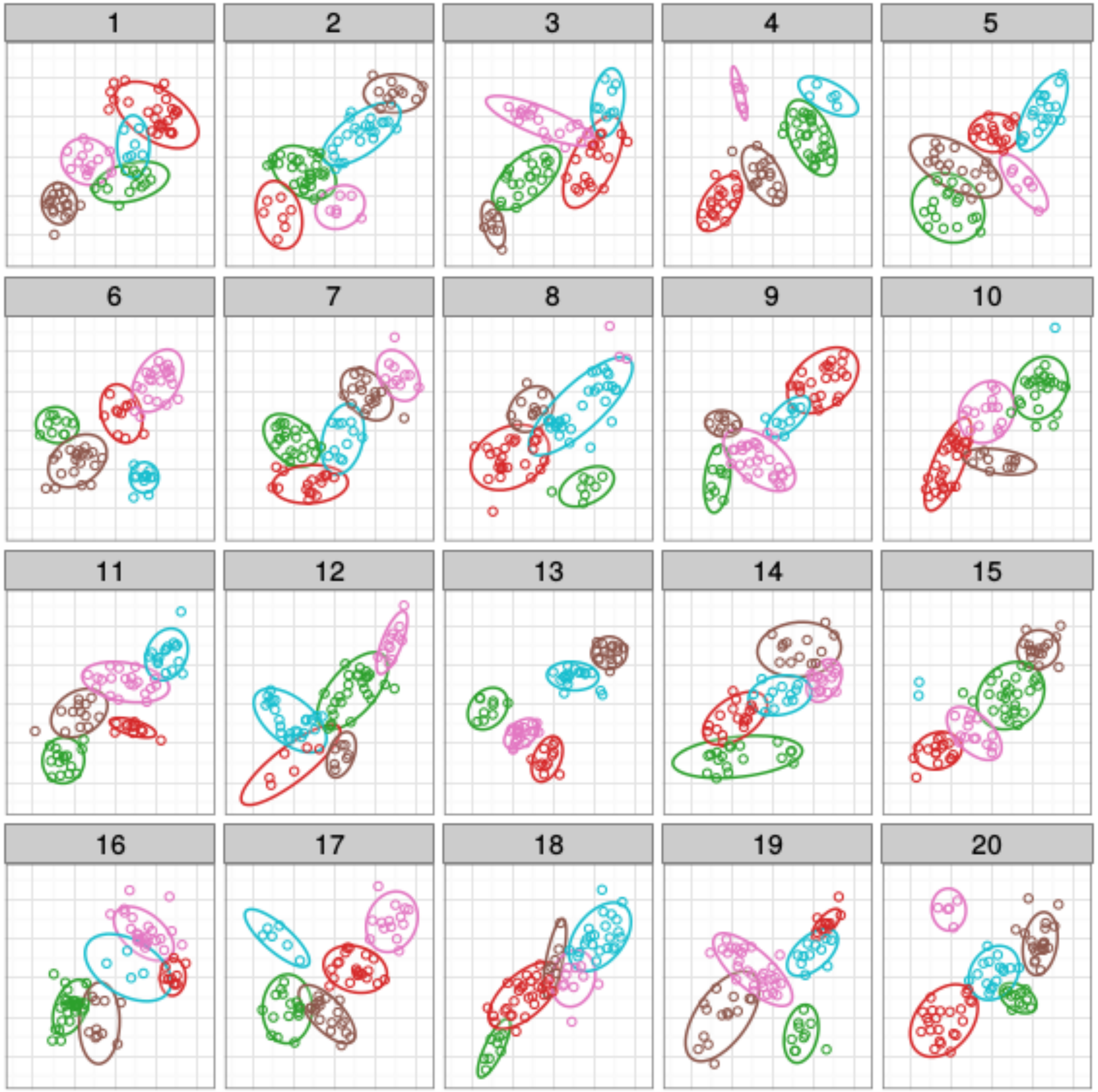


Participant Responses

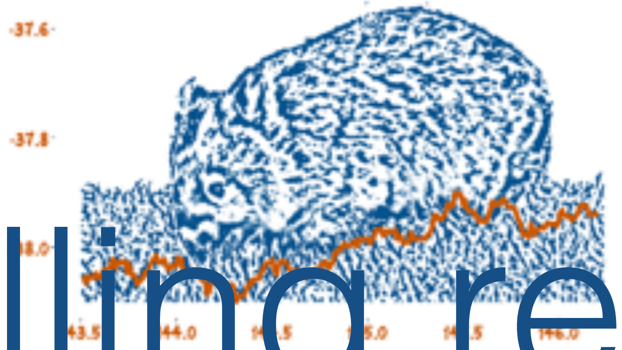


- Sample size: 22
- Trend target: 15
- Cluster target: 2
- Other: 5

Participant Responses



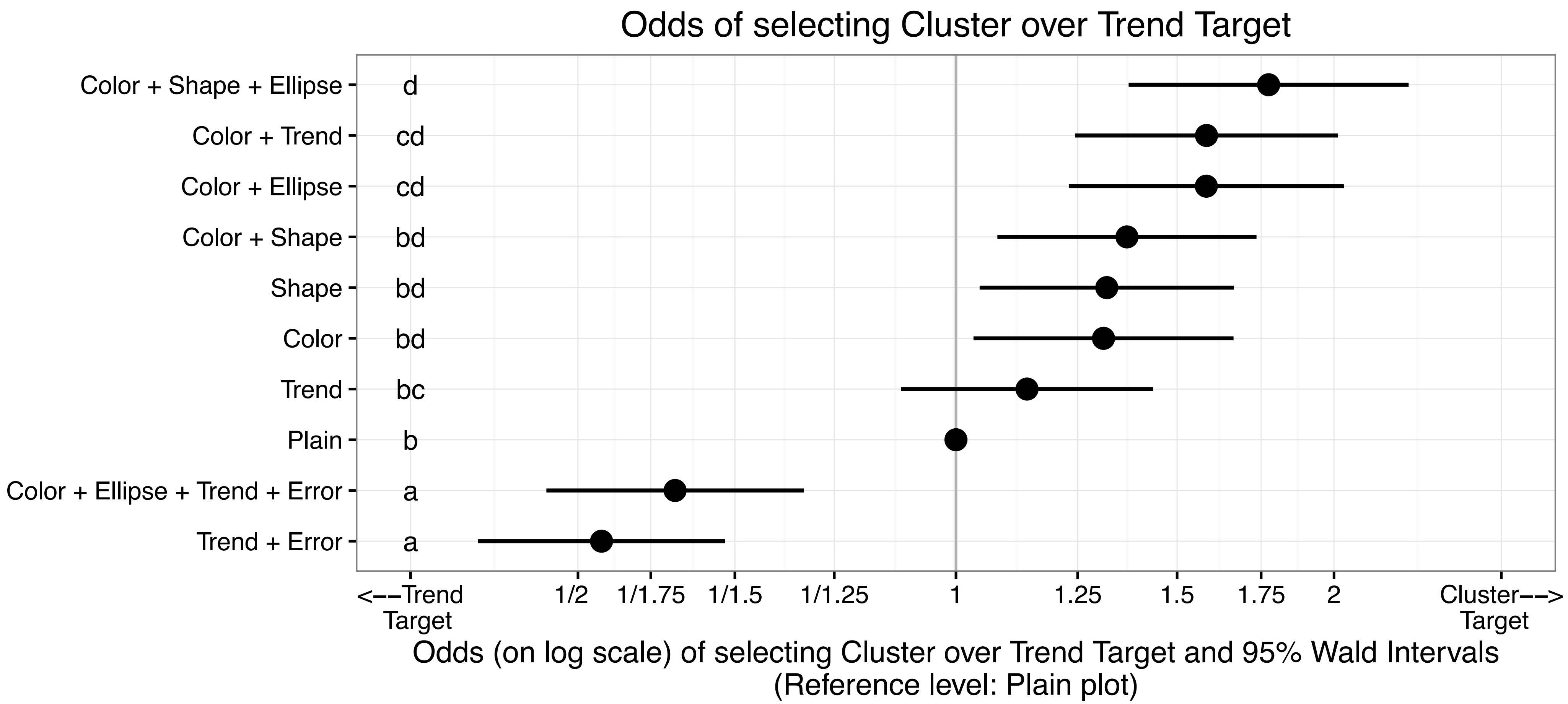
- Sample size: 14
- Trend target: 0
- Cluster target: 11
- Other: 3



Modelling results

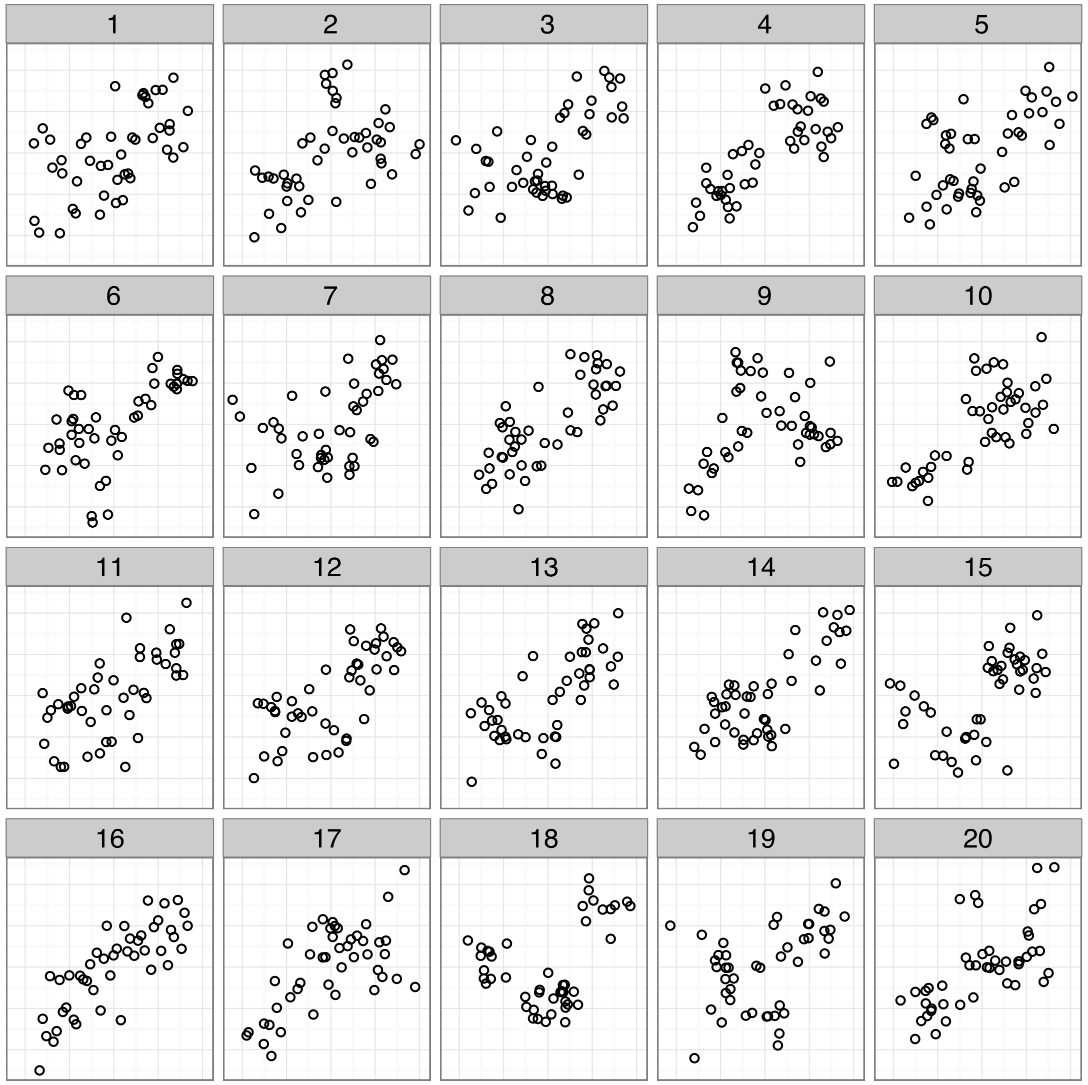
- Modelling balance between targets: subset on lineup evaluations that identified one of the targets (9959 out of 12010 evaluations)
- logistic regression of P(C | C u T)
- with random intercept for individuals' skills
  random intercept for data set difficulty

Cluster vs Trend



- generally the expected result
- mixed signals have mixed results
- control parameters s_T and s_C work as expected

… and a bit of a surprise …



- fairly strong support for cluster target

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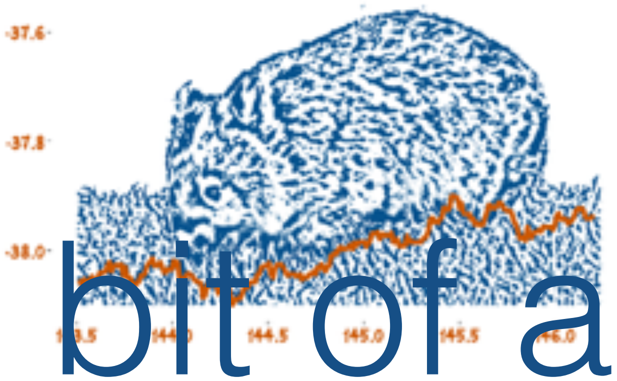
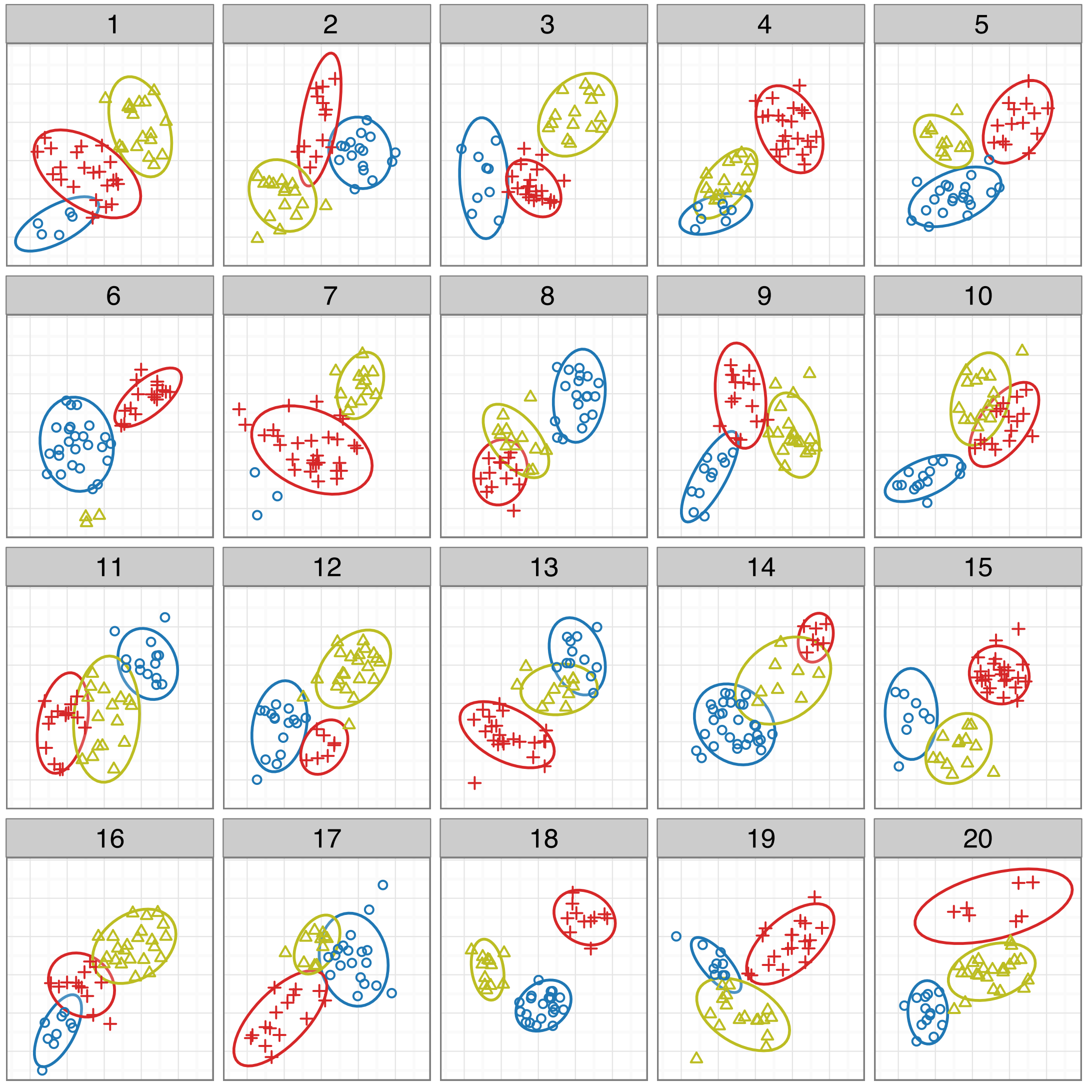
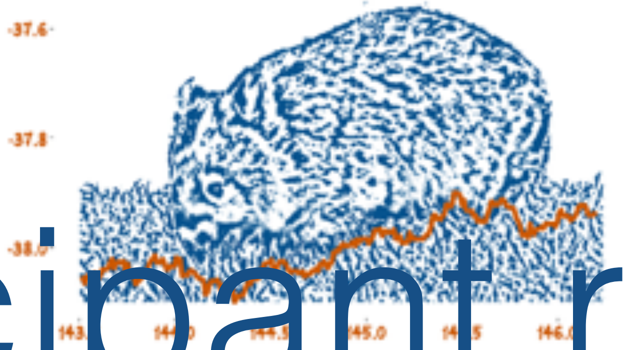




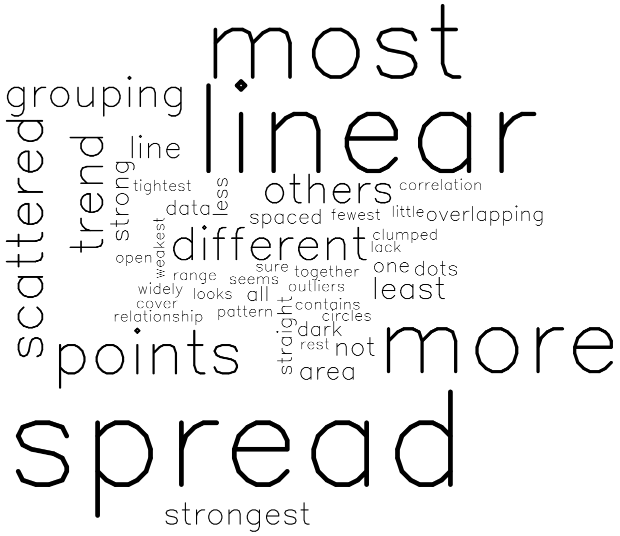
- support for cluster target not as strong???
- instead: #6, #7
- missing ellipses are a strong signal (single missing ellipse cuts probability by 44%)



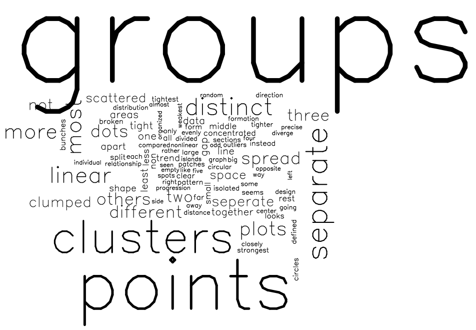
participant reasoning

- word cloud based on reason for choice:

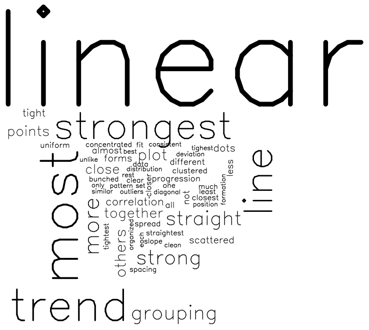
(a) Plain, neither target



(b) Plain, cluster target



(c) Plain, trend target



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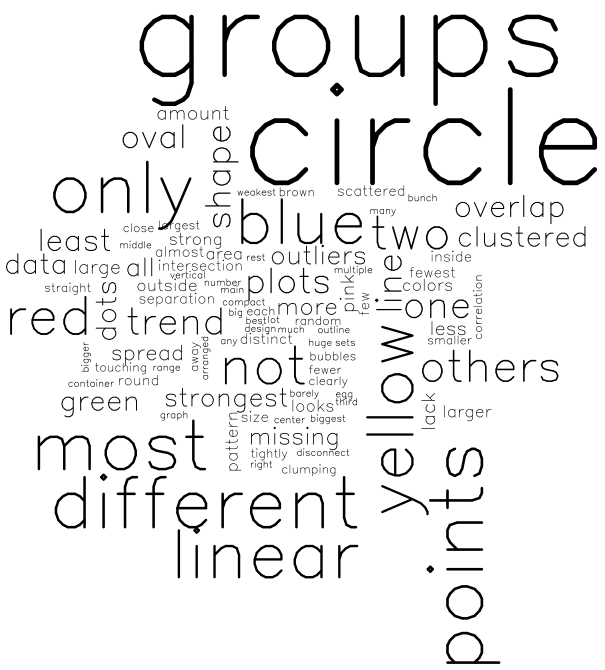
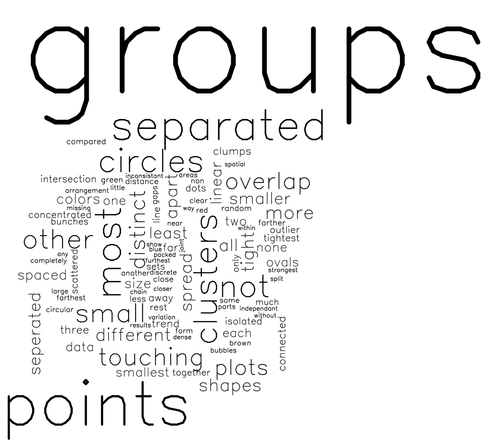
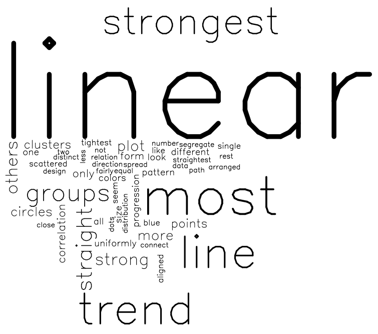


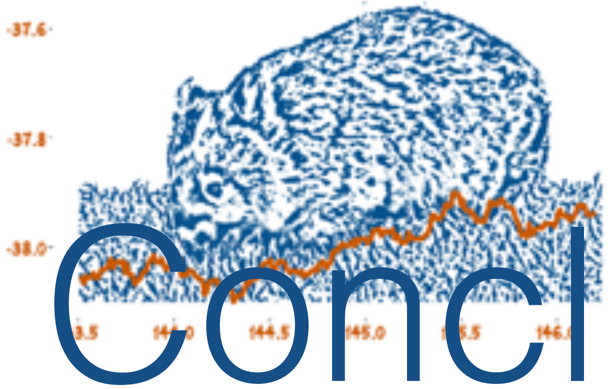
(j) Color + Ellipse, neither



(k) Color + Ellipse, cluster



(l) Color + Ellipse, trend



Conclusions

- Aesthetics matter, while not all significant, the trends follow the expectation:
color, shape and ellipses emphasize clustering
trend-line and predictions emphasize trends

- trend-line by itself might not be a particularly strong signal

- Human observers are extremely good at finding missing groups, if they expected them.