Perception in Statistical Graphics

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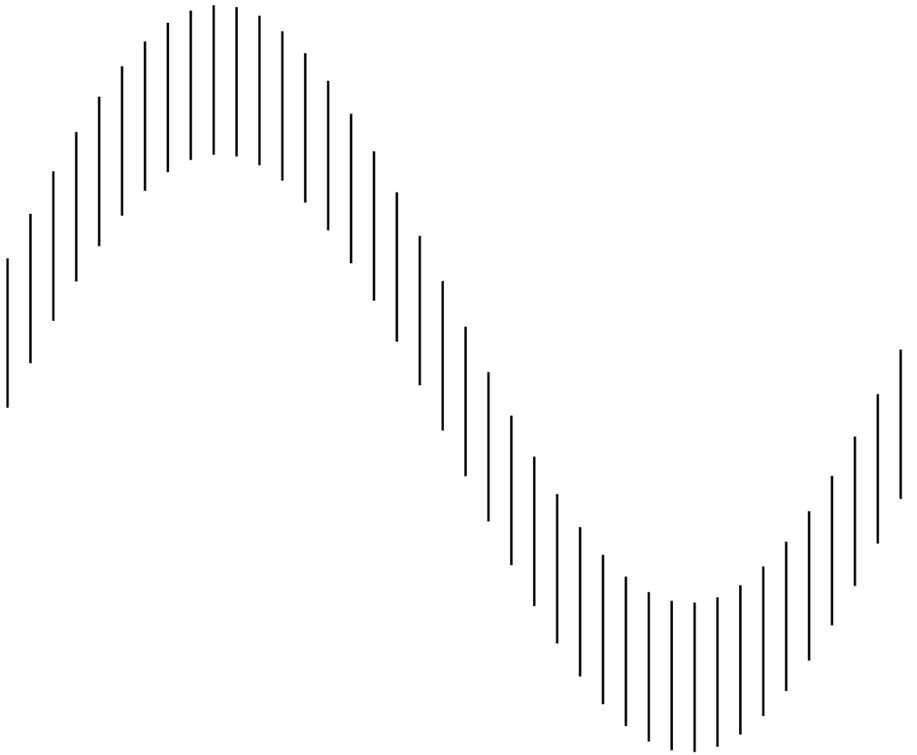
Purpose

How do we effectively communicate with graphics?

Papers

- Visual Illusions in Statistical Graphics
  - **Signs of the Sine Illusion:** Why We Need to Care
  - **The Curse of Three Dimensions:** Why Your Brain is Lying to You
- Fundamental Skills for Graphical Perception
  - **Spatial Reasoning and Data Displays**
- Quantifying the Effects of Plot Aesthetics
  - **Statistical Graphics and the Hierarchy of Visual Features**

Visual Illusions in Statistical Graphics



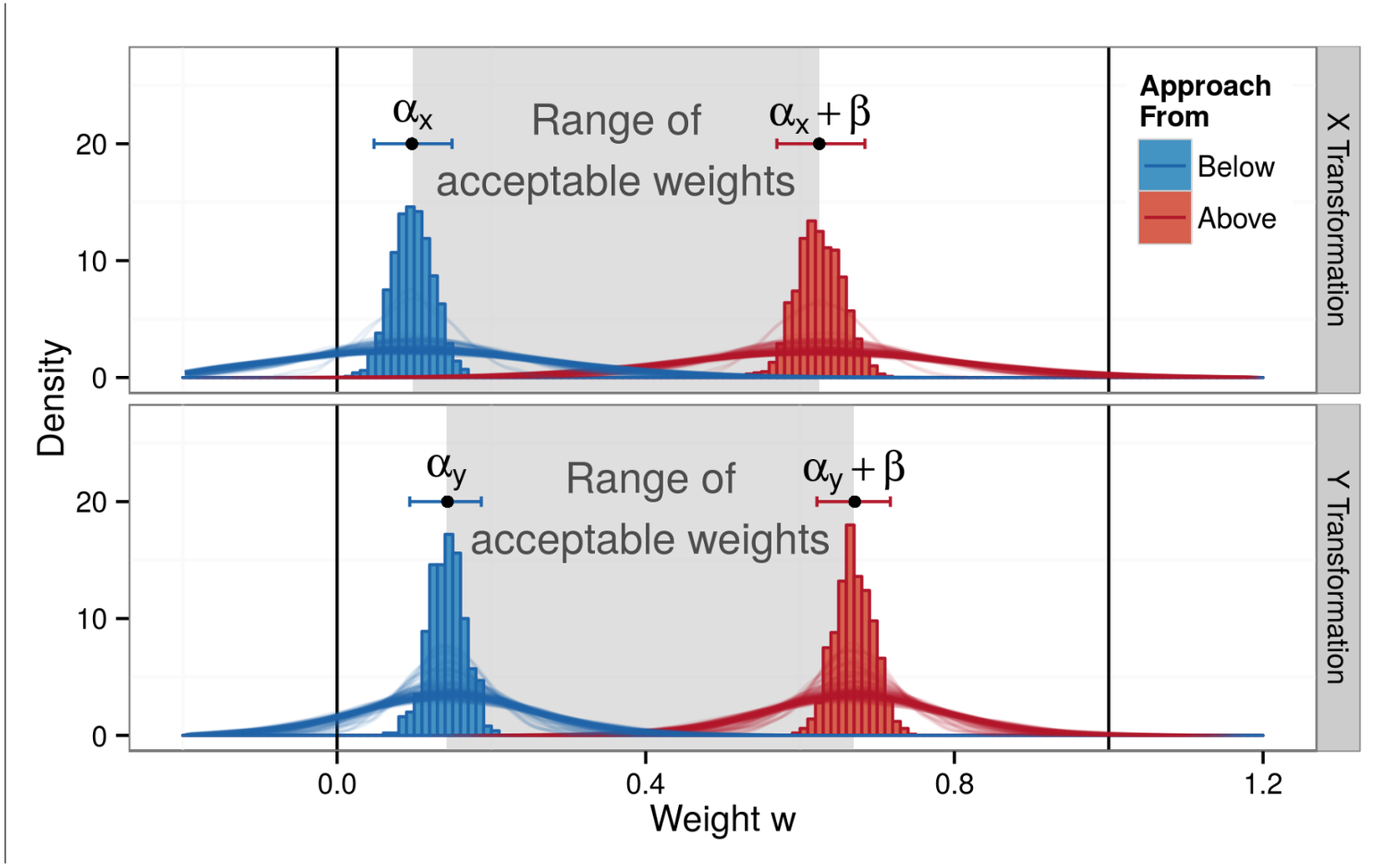
Signs of the Sine Illusion

Forthcoming in JCGS (Accepted July 2014)

- Sine illusion in statistical graphics
- Quantify the effect of the illusion
- Implement remedial transformations in x and y

Signs of the Sine Illusion

Summary of Results



The Curse of Three Dimensions

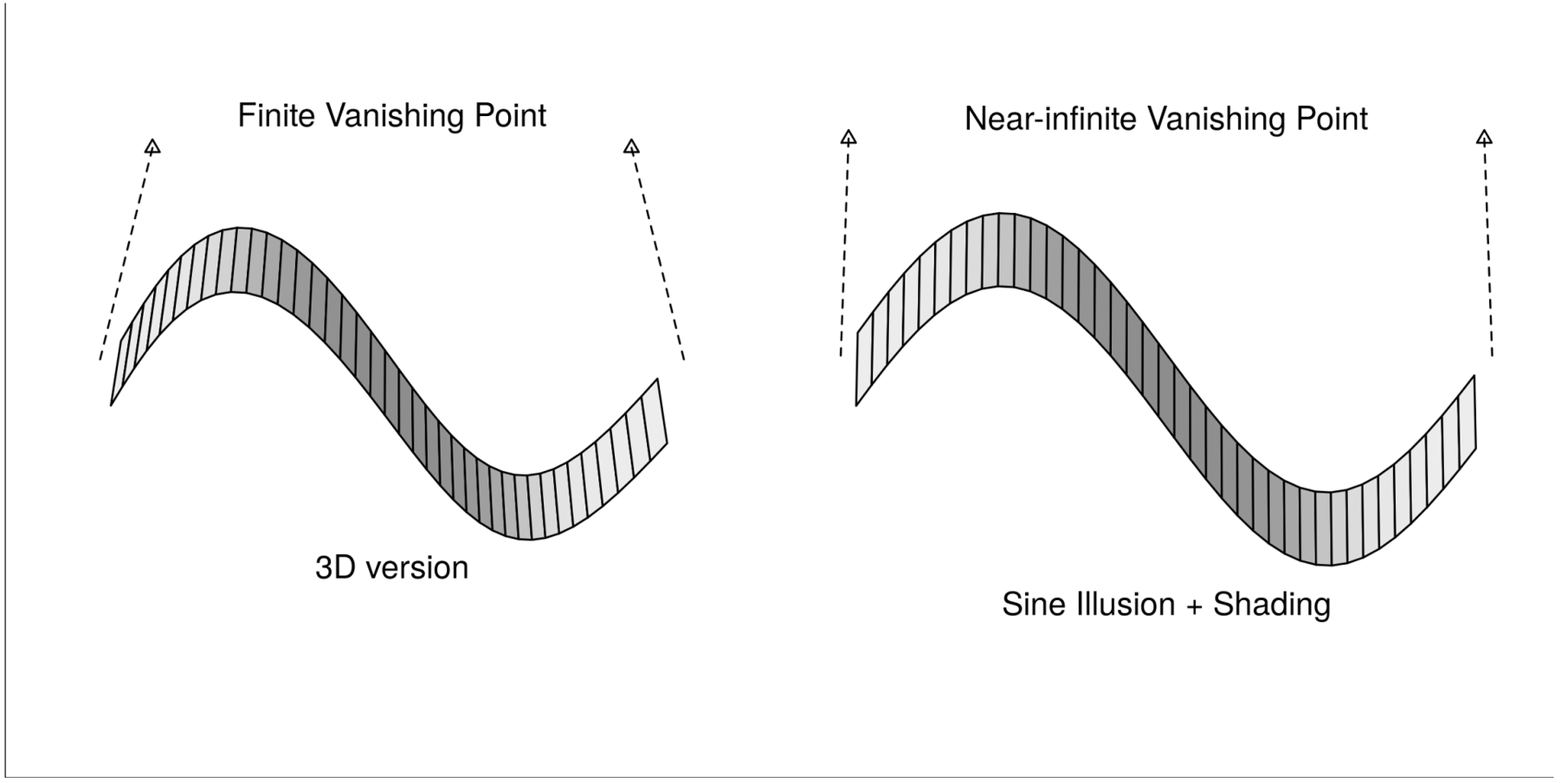
Student Paper Award (ASA Stat. Graphics, 2014)

To be submitted to ACM Trans. on Applied Perception

- Identify perceptual basis of the sine illusion: depth perception
- Case Study

The Curse of Three Dimensions

Depth Perception



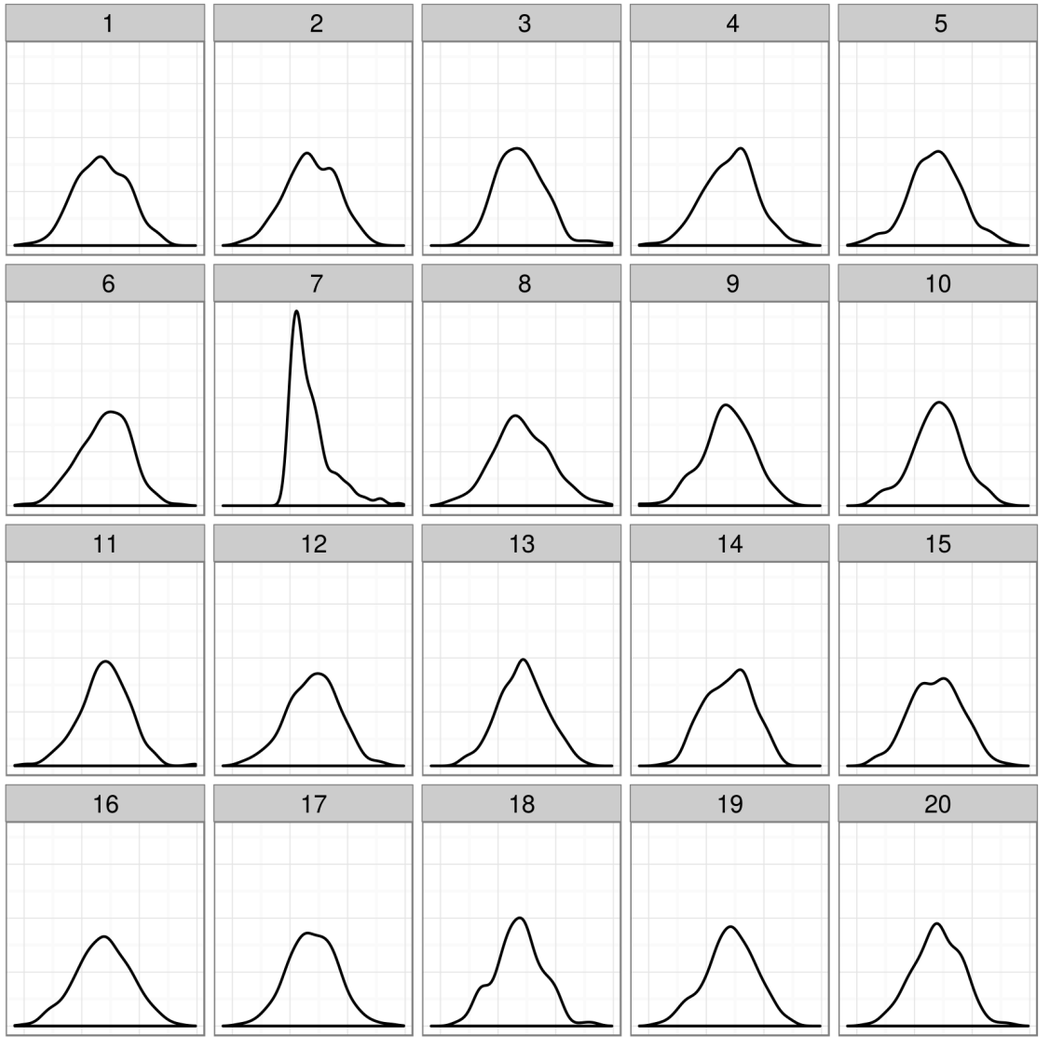
Signs of the Sine Illusion

Impact

- Increase awareness of the illusion
- Implement two useful corrections
- Quantify correction strength required
- Identify the cause of the illusion

Lineups - Methodology

Lineups - Methodology



- A data plot is inserted among decoys
- If the observer picks out the data plot, this is evidence that the data plot differs from the decoys

Lineups - Methodology

- Hypothesis Test: Decoys created under H_0
  If data is identifiable, we reject H_0 for the data
- Suppose for K participants, k identify the data plot.
  Visual p-value: $P(X \geq k | H_0)$
- For the previous lineup,
  - KS Test p-value: 0.0000
  - Lineup p-values for 5 participants, k who identify plot 7:

k	0	1	2	3	4	5
p-value	1.0000	0.2262	0.0226	0.0012	0.0000	0.0000

- Objective test of whether we see structure in the data display

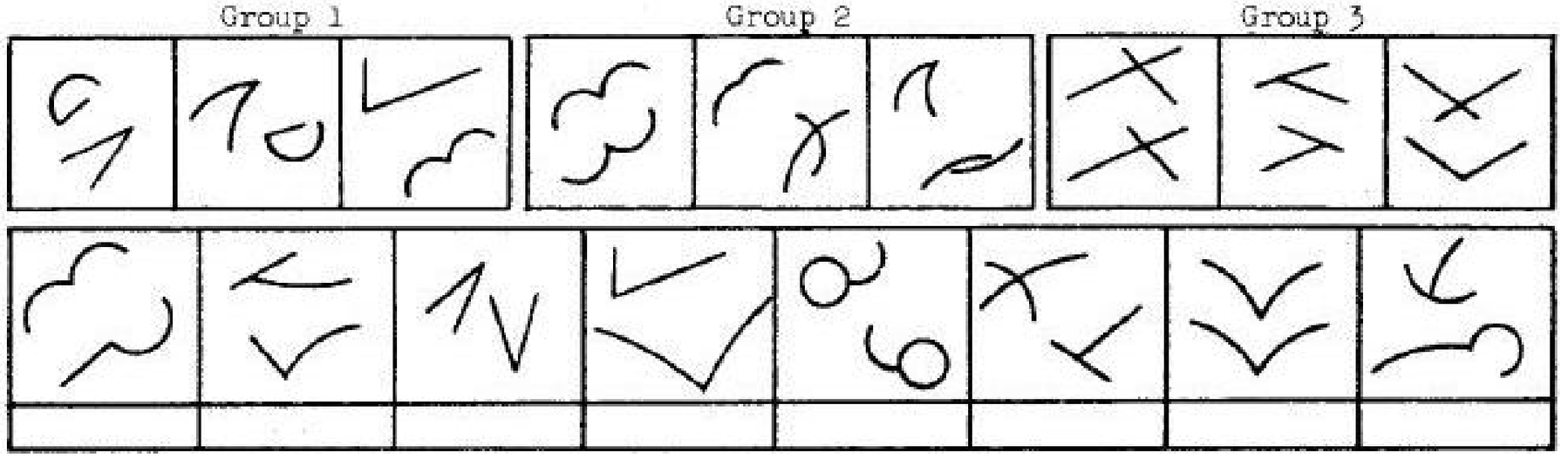
Fundamental Skills for Graphical Perception

Submitted to Infovis 2015

What skills are necessary to evaluate lineups?

Fundamental Skills for Graphical Perception

Figure Classification



Measures ability to classify images according to inferred rules

French, J. W., R. B. Ekstrom and L. A. Price. Kit of reference tests for cognitive factors. Educational Testing Service. Princeton, NJ, 1963.

Fundamental Skills for Graphical Perception

Study Setup

- 3 blocks of 20 lineups

  Boxplots and alternatives, qq plot modifications

- 4 tests of Visuospatial ability

  Figure Classification, Card Rotation, Paper Folding, Visual Search Test

- Demographic Information

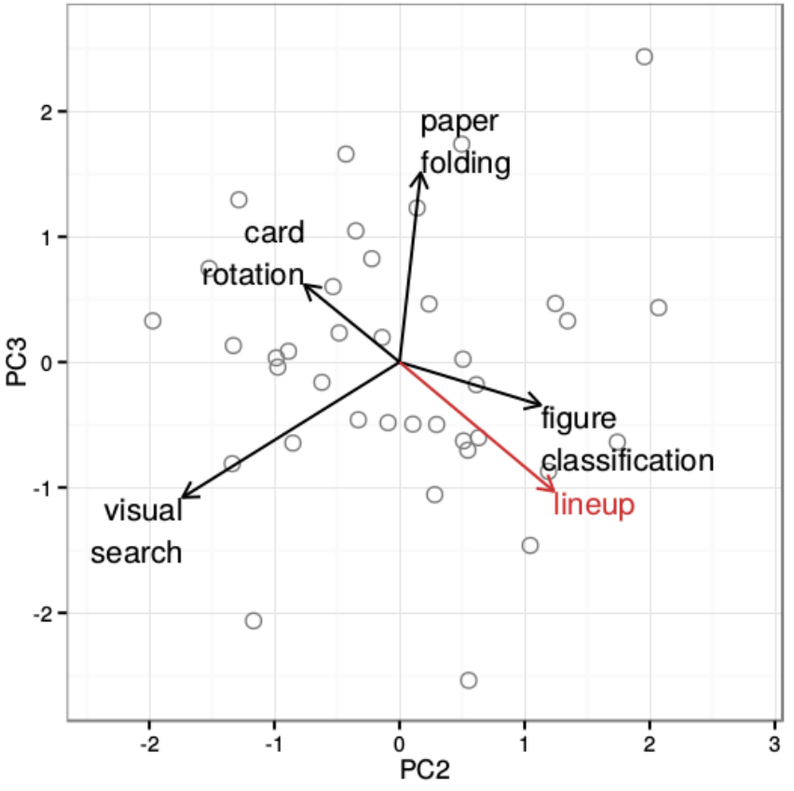
- Participants: 38 ISU Undergraduates

- Scores on validated cognitive tests were similar to other populations

Fundamental Skills for Graphical Perception

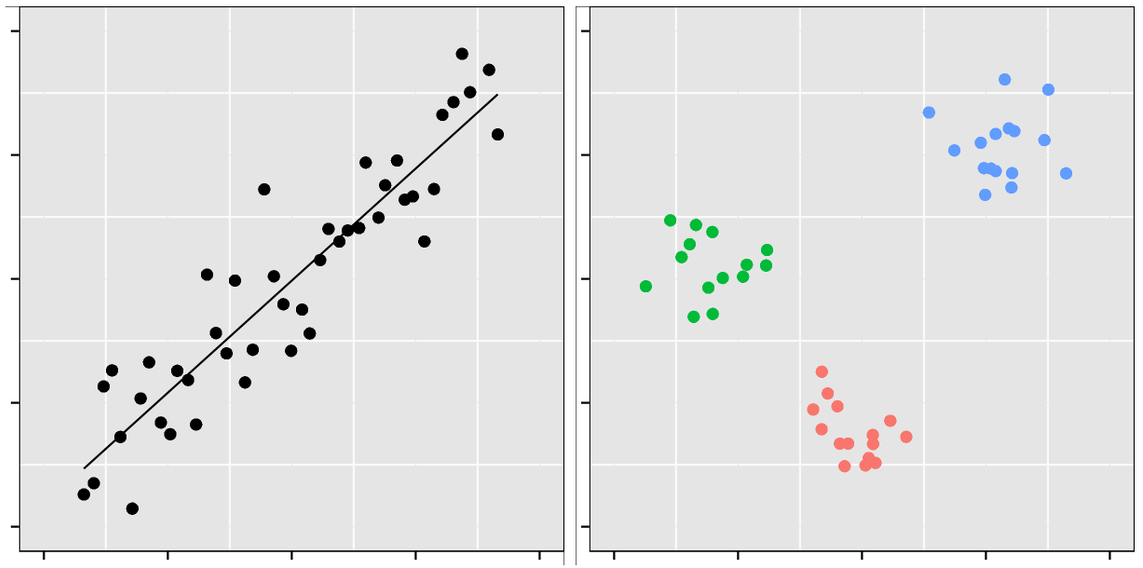
Results

- Lineups: a classification task in a visual domain
- Specific visuospatial skills (outside of overall aptitude) are not required
- Demographic factors such as completion of Calculus I and STEM training are also important



PC1 shows general aptitude

Quantifying the Effect of Plot Aesthetics



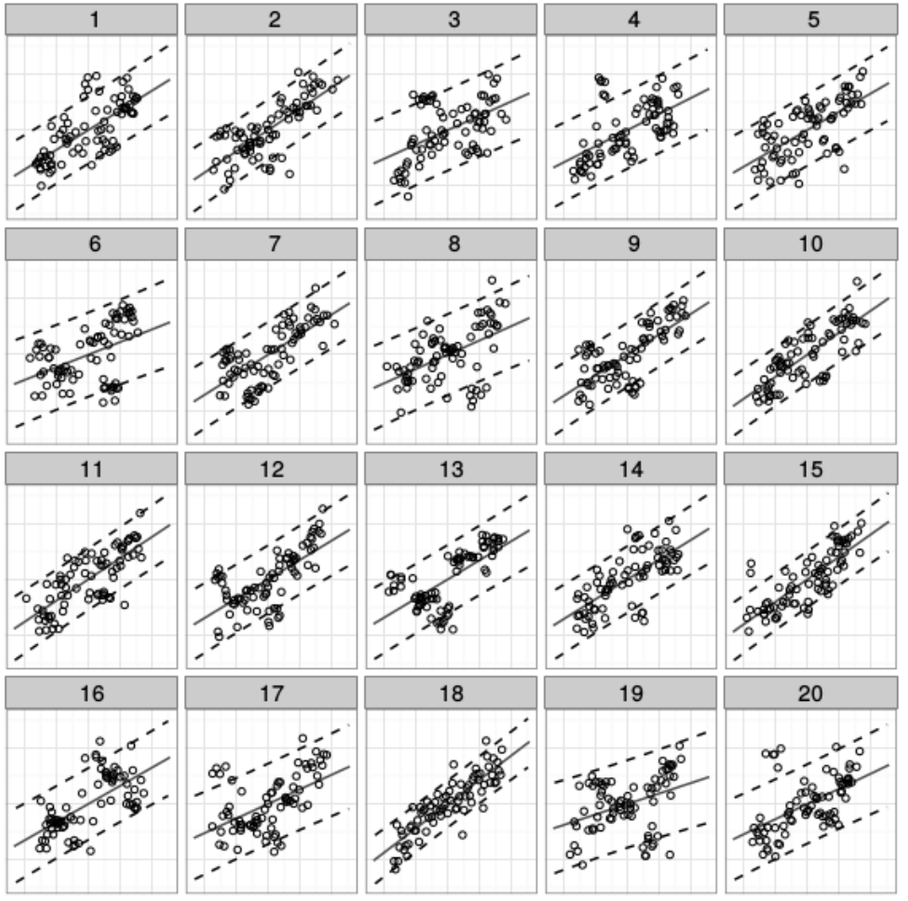
Intended for submission to JCGS

Quantifying the Effect of Plot Aesthetics

Summary

- 2 models: M_T (trend) and M_C (cluster)
- M_0, a mixture model
- Test 10 combinations of plot aesthetics

Lineups: "Which plot is the most different?"



Participant Responses

Plot 18: 68.2% (Trend target)

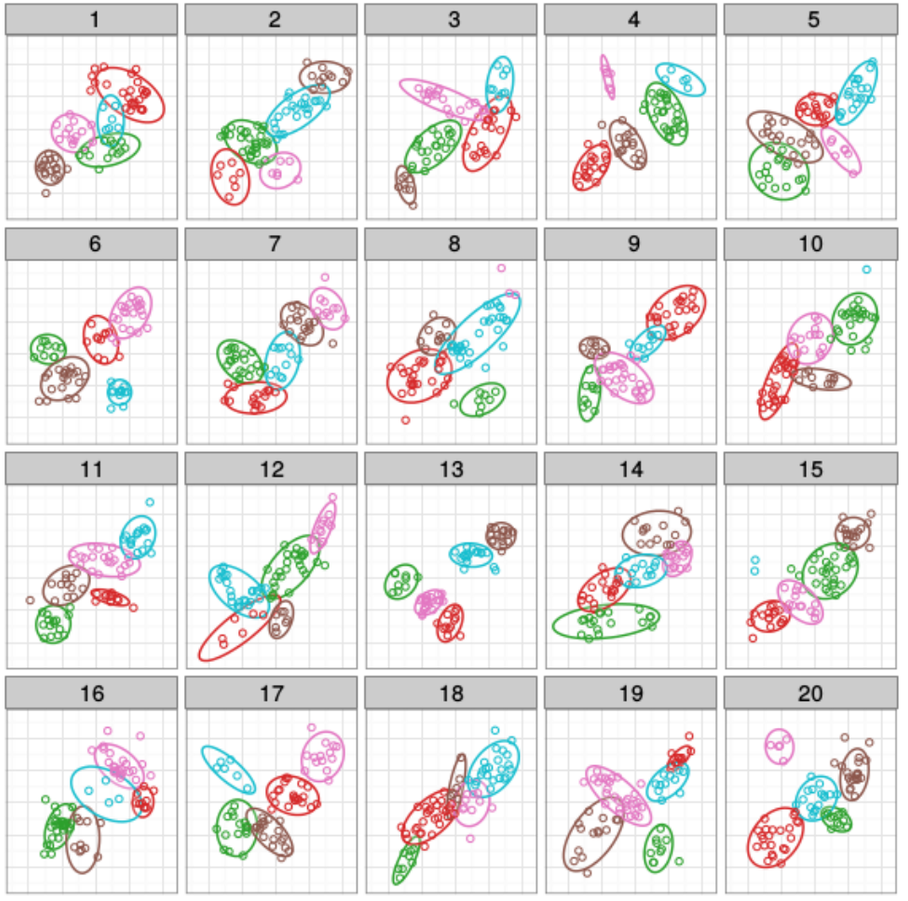
Plot 13: 9.1% (Cluster target)

Other: 22.5%

Sample size: 22

Trend: 18, Cluster: 13

Lineups: "Which plot is the most different?"



Trend: 18, Cluster: 13

Participant Responses

Plot 18: 0.0% (Trend target)

68.2%

Plot 13: 78.6% (Cluster target)

9.1%

Other: 21.3%

Sample size: 14

Previous plot's responses are shown in grey

Quantifying the Effect of Plot Aesthetics

Results: Selection of Trend Target

Good for Trends:		**Not as good:**	
1	2	3	4
Trend line + Pred. Int.	Trend line	Shape	Color + Ellipse
	Plain	Color + Shape	Color + Shape + Ellipse
		Color	

Quantifying the Effect of Plot Aesthetics

Results - Trend vs. Cluster

Color and Shape are not sig. different

Color + Shape is not a significant improvement over either aesthetic alone.

Plot types are significantly different if they do not share a letter

Quantifying the Effect of Plot Aesthetics

Impact

- Aesthetics matter for plot design
- To emphasize linear relationships, use intervals as well as a trend line
- To emphasize clustering, use similarity (color or shape) and/or bounding ellipses

Conclusions

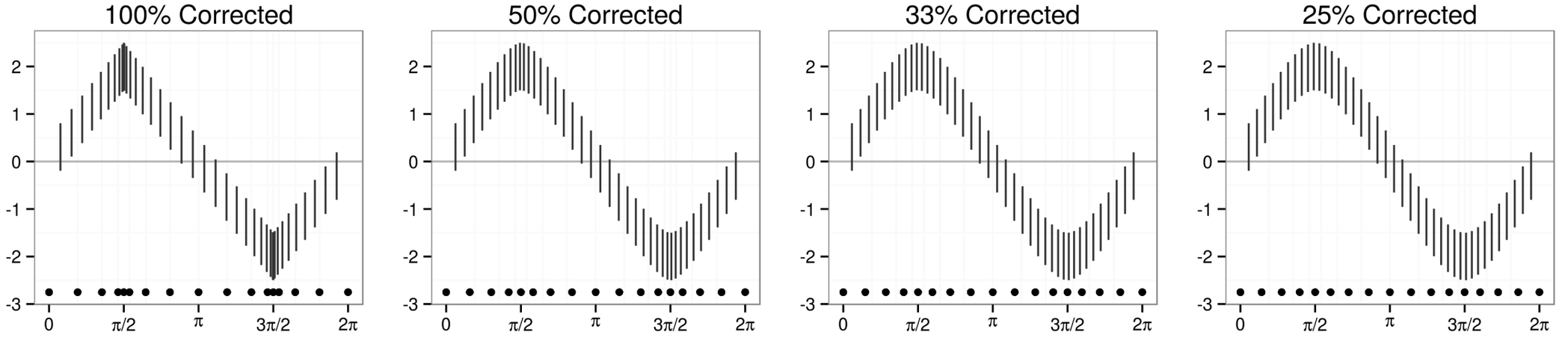
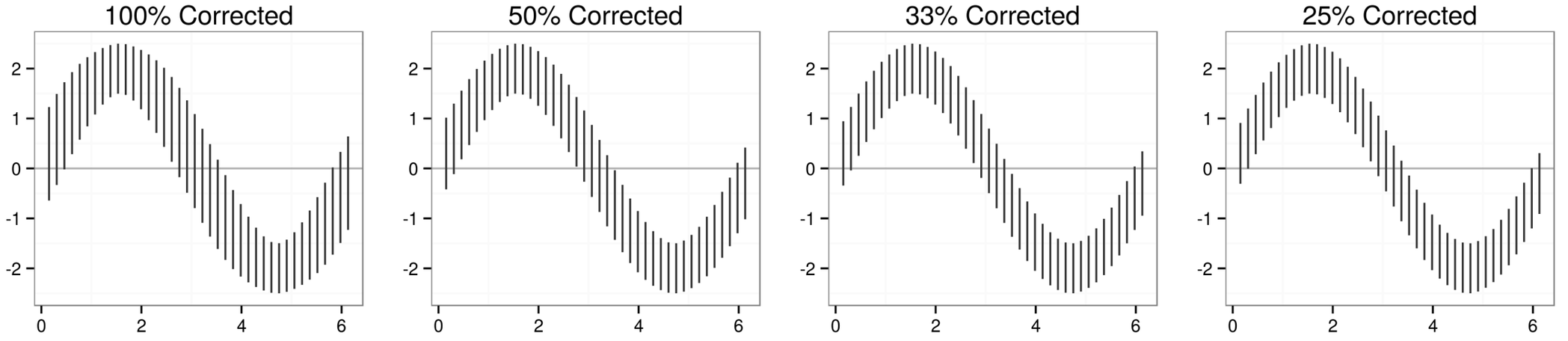
- It's important to consider the visual system when designing statistical plots
- Optical illusions can impact our conclusions from graphics
- Our ability to read statistical plots and identify visually significant results depends on mathematical training and reasoning ability
- Plot aesthetics can be effectively used to highlight important information in data displays

Future Work

- Relate gestalt heuristics to plot aesthetics experimentally
- Explore whether certain plot types require extra spatial skills
- Extend the hypothesis testing framework to cover competing-target lineups

Extra Information

X Transformation



Y Transformation