Rethinking your plotting habits

An introduction to the *Grammar of Graphics*

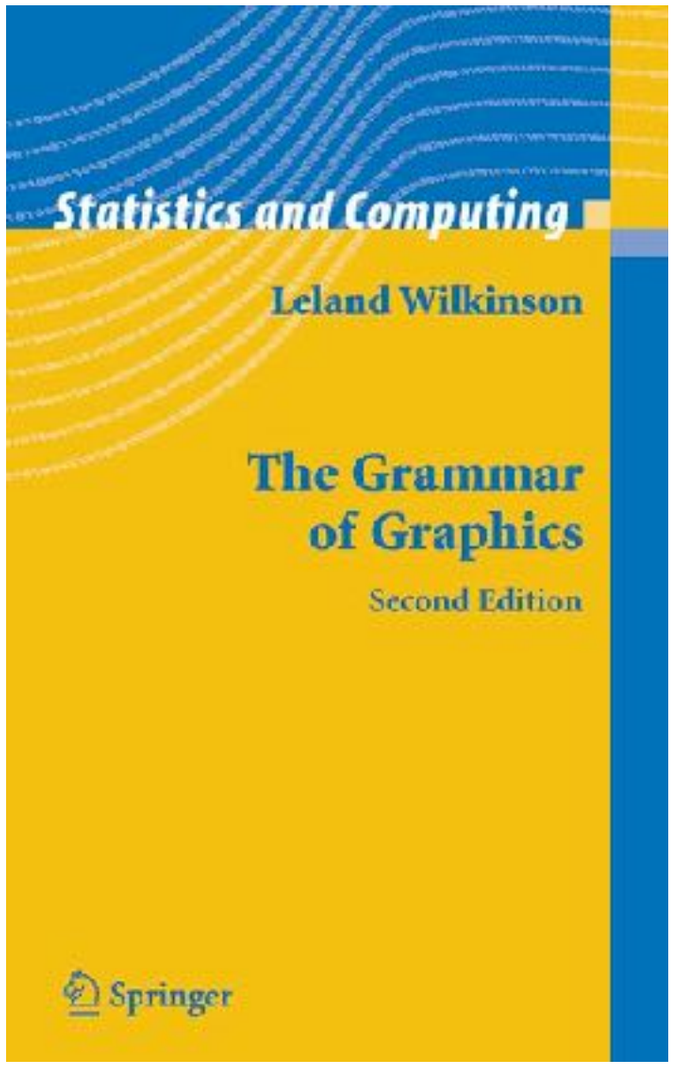
denis schluppeck
09-03-2017

Aim

Make plots / visualisations of **data:**

- reproducible
- more flexible for exploration
- publication-ready (no editing by hand)
- principles apply across different languages:
  MATLAB, PYTHON, R, JULIA, …
- and different kinds of data: fMRI, EEG, psychophys, …

The ideas



A Layered Grammar of Graphics

Hadley WICKHAM

A grammar of graphics is a tool that enables us to concisely describe the components of a graphic. Such a grammar allows us to move beyond named graphics (e.g., the "scatterplot") and gain insight into the deep structure that underlies statistical graphics. This article builds on Wilkinson, Anand, and Grossman (2005), describing extensions and refinements developed while building an open source implementation of the grammar of graphics for R, `ggplot2`.

The topics in this article include an introduction to the grammar by working through the process of creating a plot, and discussing the components that we need. The grammar is then presented formally and compared to Wilkinson's grammar, highlighting the hierarchy of defaults, and the implications of embedding a graphical grammar into a programming language. The power of the grammar is illustrated with a selection of examples that explore different components and their interactions, in more detail. The article concludes by discussing some perceptual issues, and thinking about how we can build on the grammar to learn how to create graphical "poems."

Supplemental materials are available online.

Key Words: Grammar of graphics; Statistical graphics.

1. INTRODUCTION

What is a graphic? How can we succinctly describe a graphic? And how can we create the graphic that we have described? These are important questions for the field of statistical graphics.

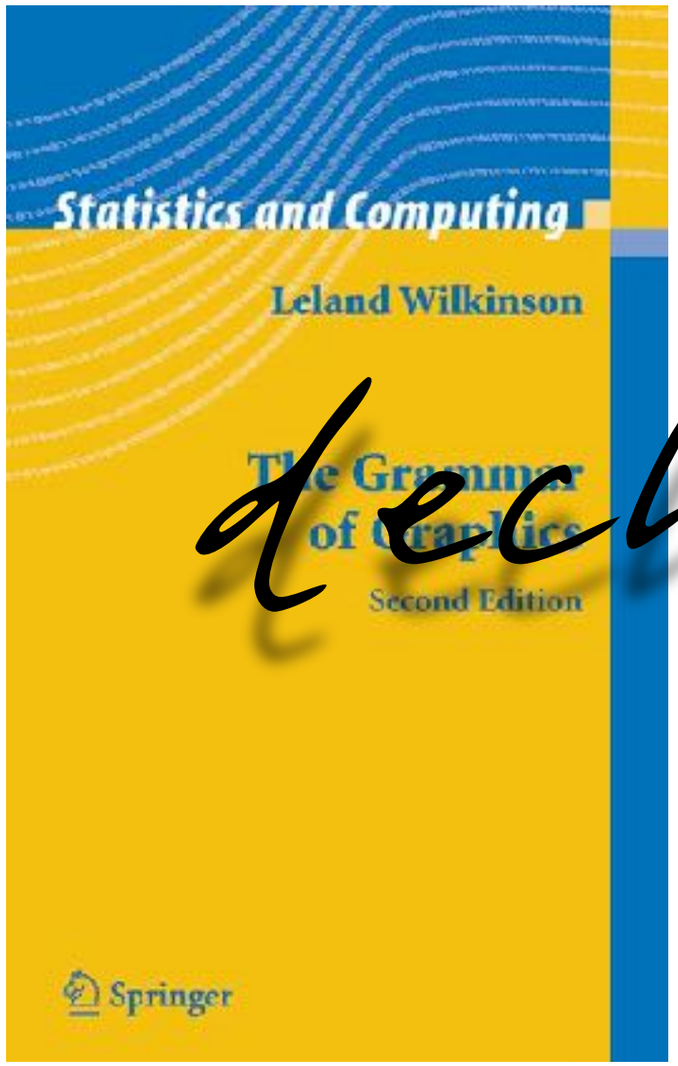
One way to answer these questions is to develop a grammar: "the fundamental principles or rules of an art or science" (OED Online 1989). A good grammar will allow us to gain insight into the composition of complicated graphics, and reveal unexpected connections between seemingly different graphics (Cox 1978). A grammar provides a strong foundation for understanding a diverse range of graphics. A grammar may also help guide us on what a well-formed or correct graphic looks like, but there will still be many grammatically correct but nonsensical graphics. This is easy to see by analogy to the English language: good grammar is just the first step in creating a good sentence.

Hadley Wickham is Assistant Professor of Statistics, Rice University, Houston, TX 77030 (E-mail: *h.wicham@gmail.com*).

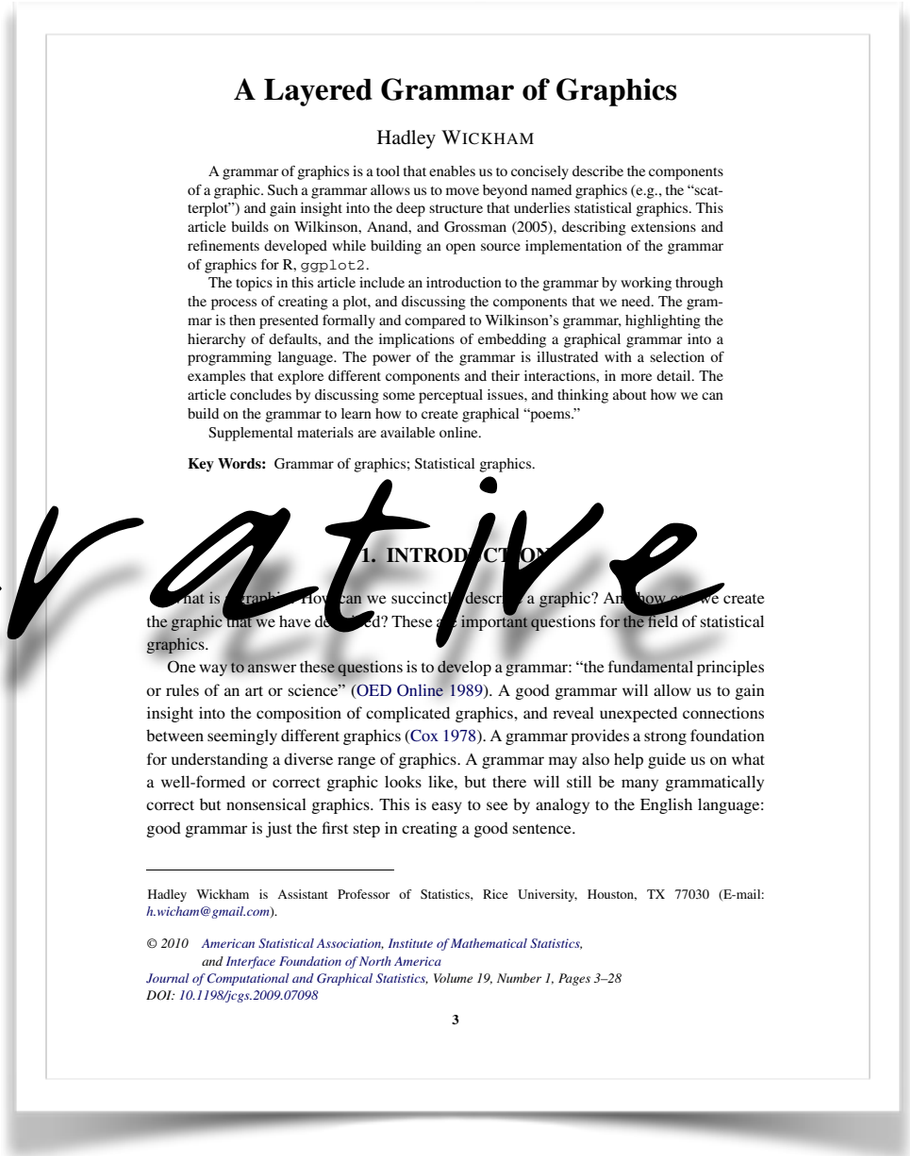
Journal of Computational and Graphical Statistics, Volume 19, Number 1, Pages 3–28
DOI: 10.1198/jcgs.2009.07098

Wickham (2010)

The ideas



declarative



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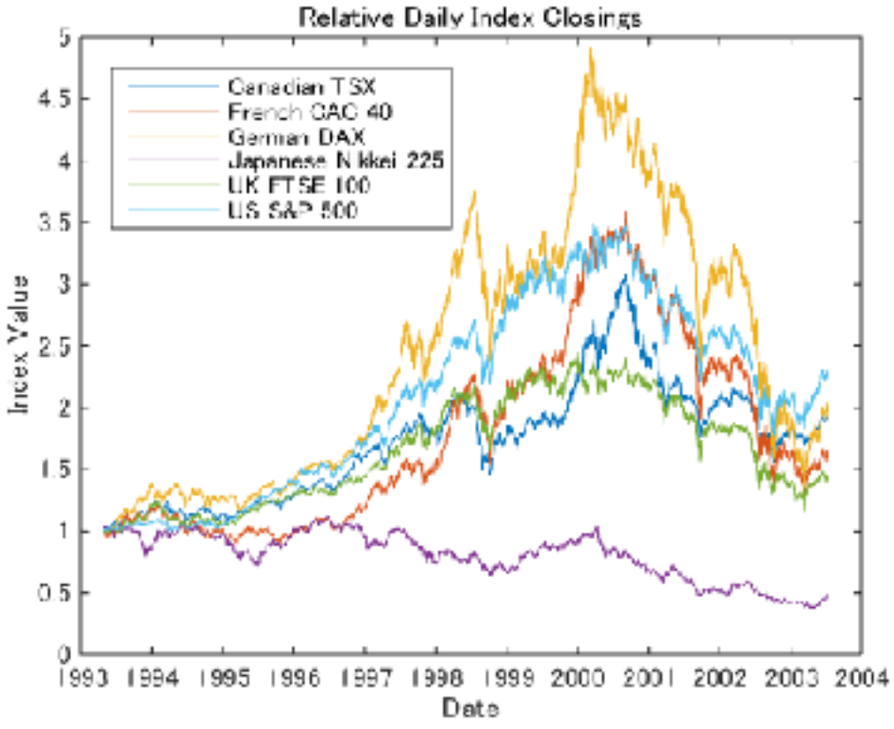
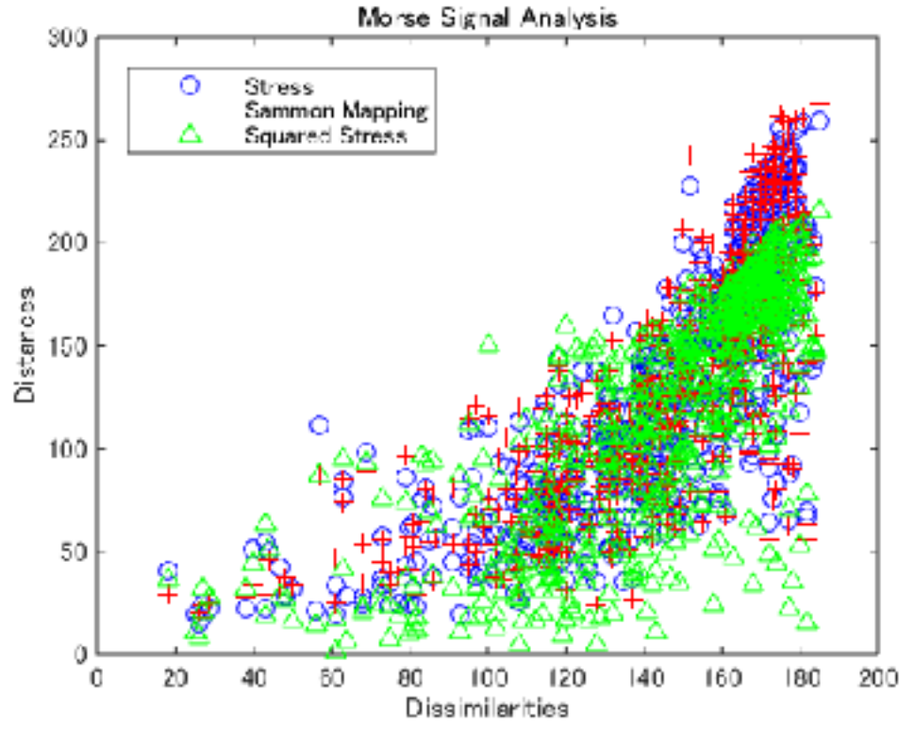
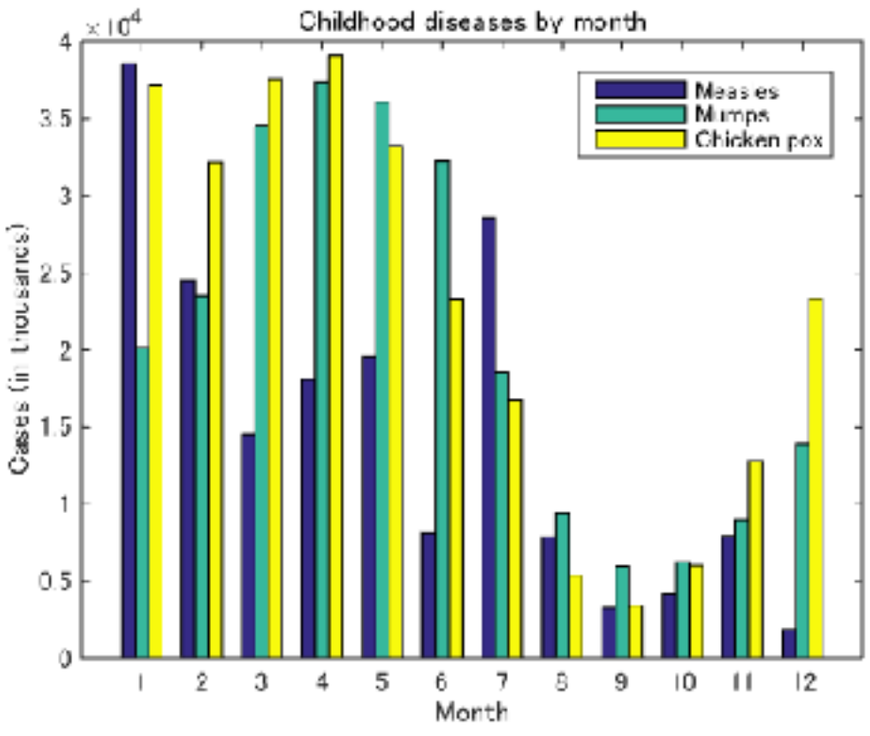
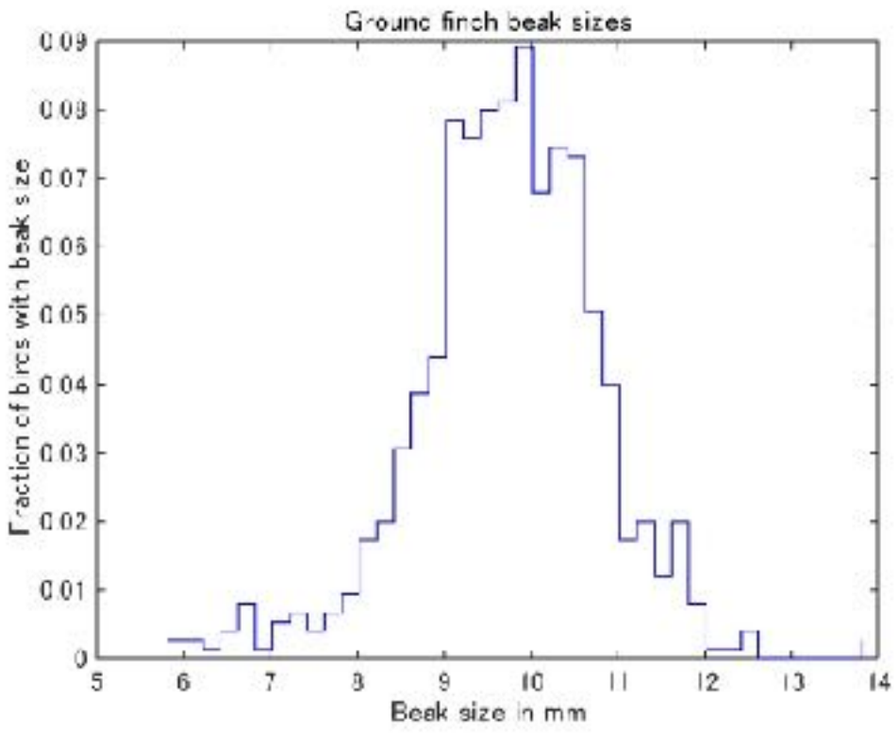
Wickham (2010)

imperative



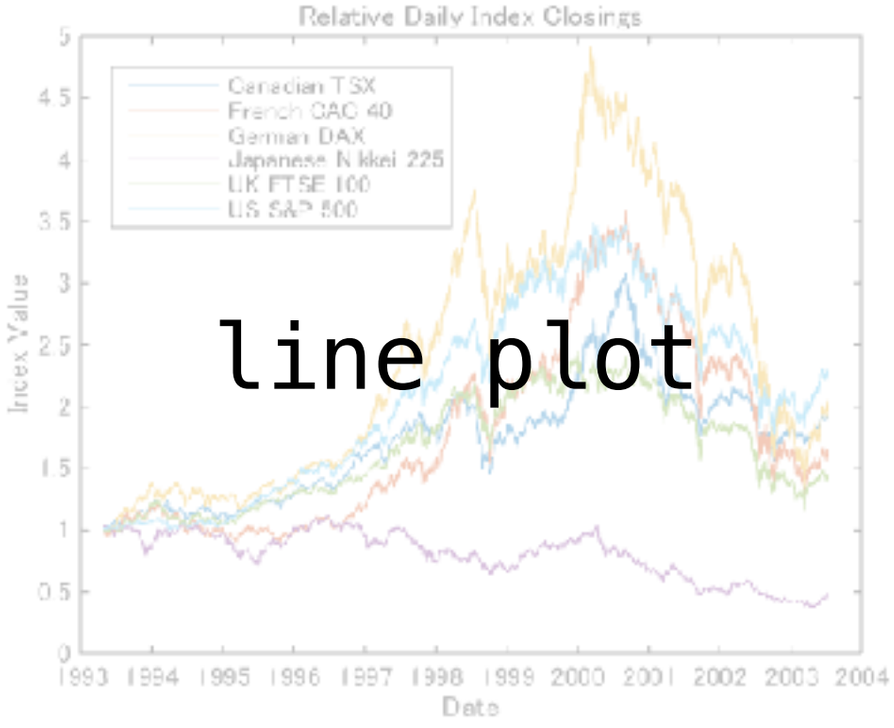


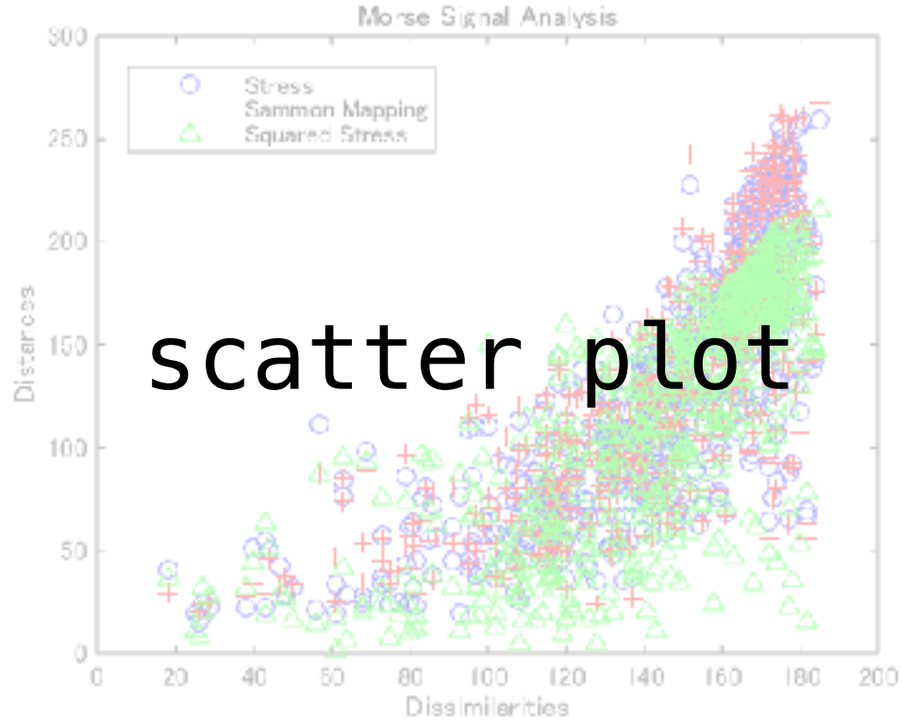


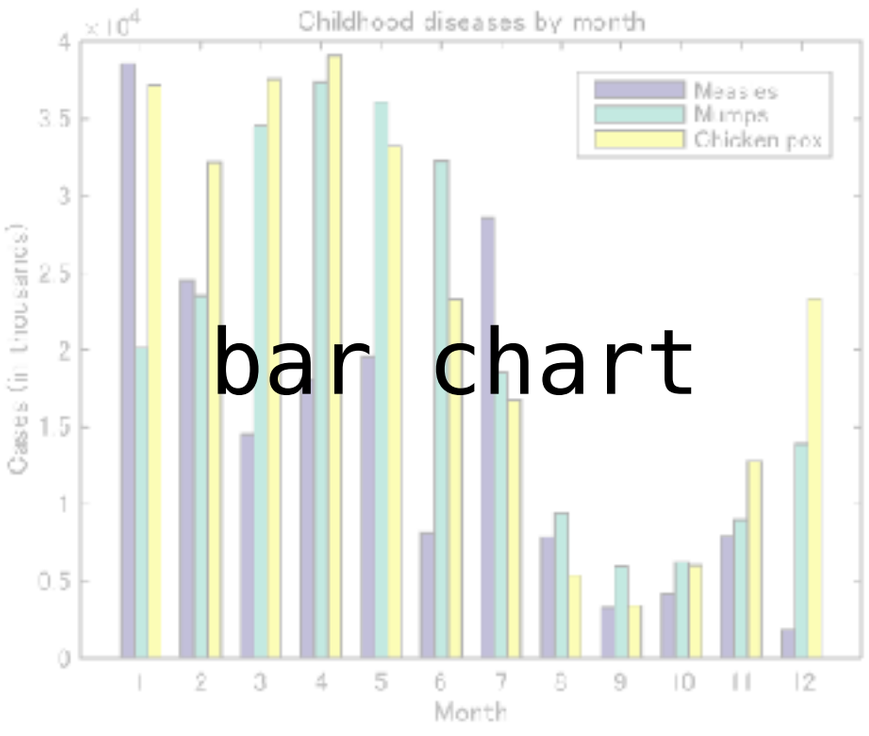


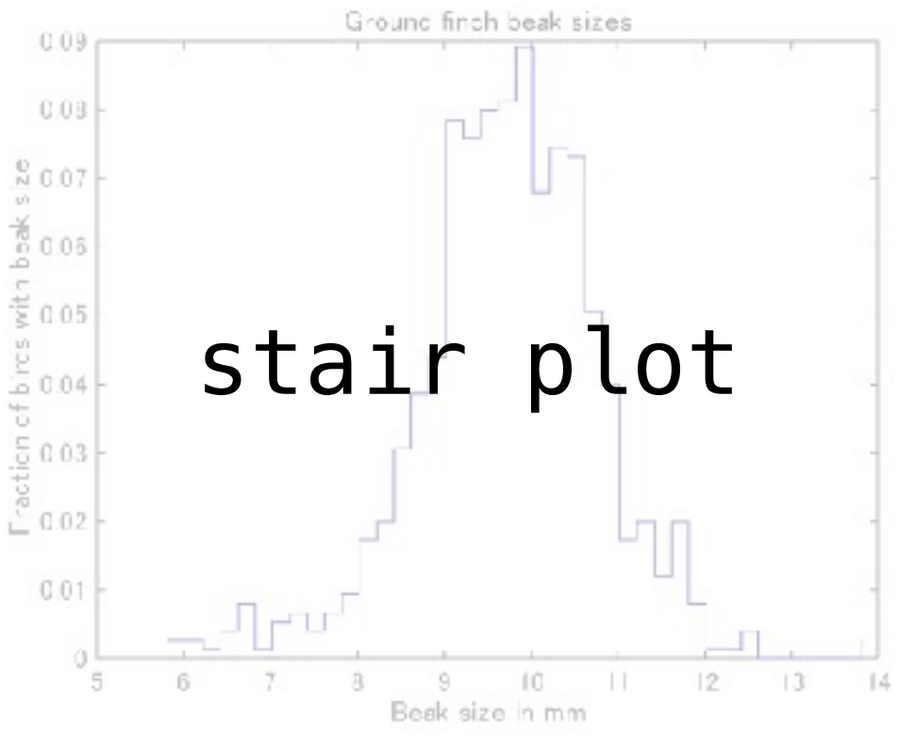
https://uk.mathworks.com/products/matlab/plot-gallery.html

imperative









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imperative

declarative

decide on plot type,
build plot step by step, …

–ve: leads to repetitive code / work

declarative

/dɪˈklarətɪv/

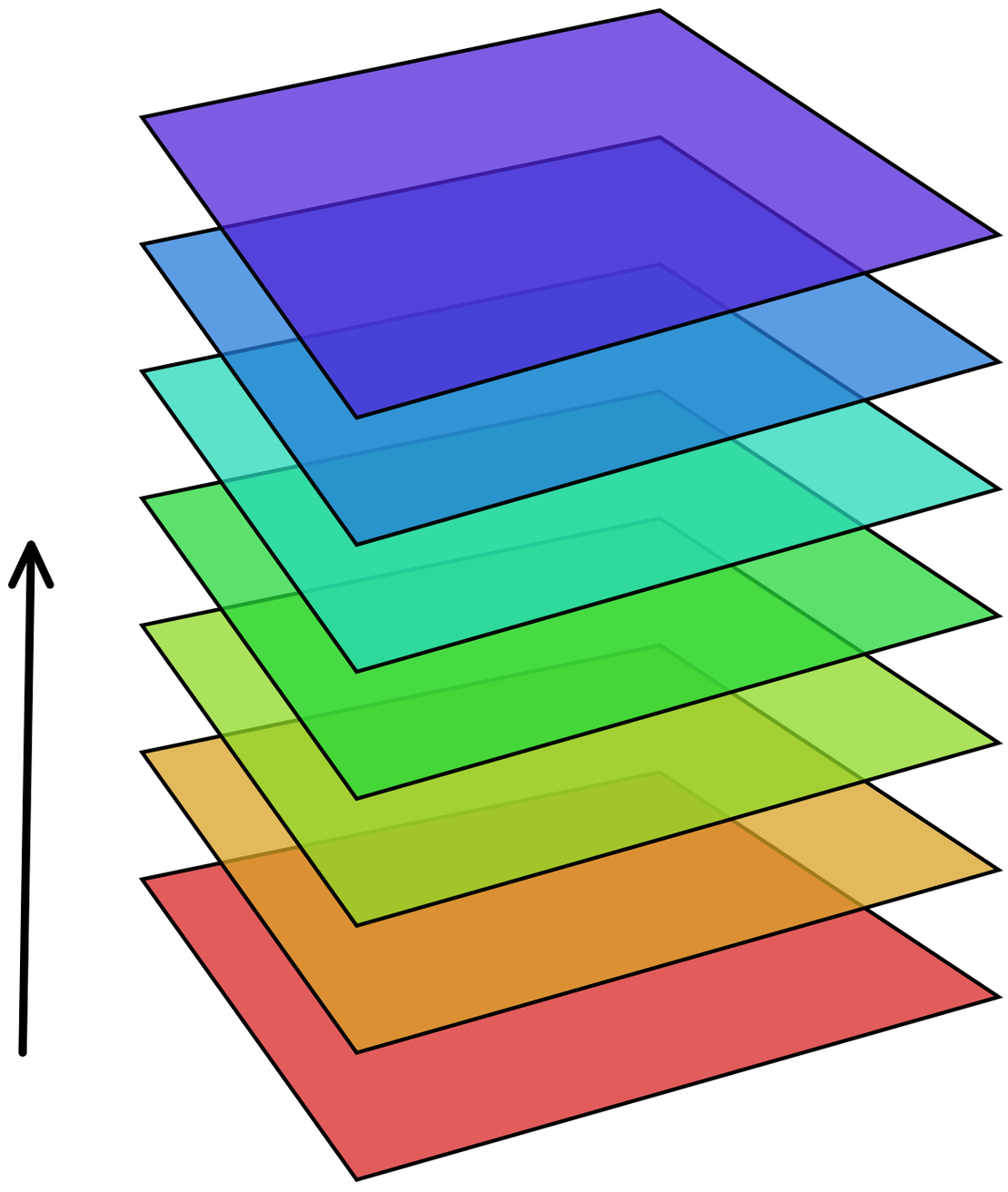
adjective

1. of the nature of or making a declaration.
   "declarative statements"
2. COMPUTING
   denoting high-level programming languages which can be used to solve problems without requiring the programmer to specify an exact procedure to be followed.

noun

1. a statement in the form of a declaration.

instead: common framework

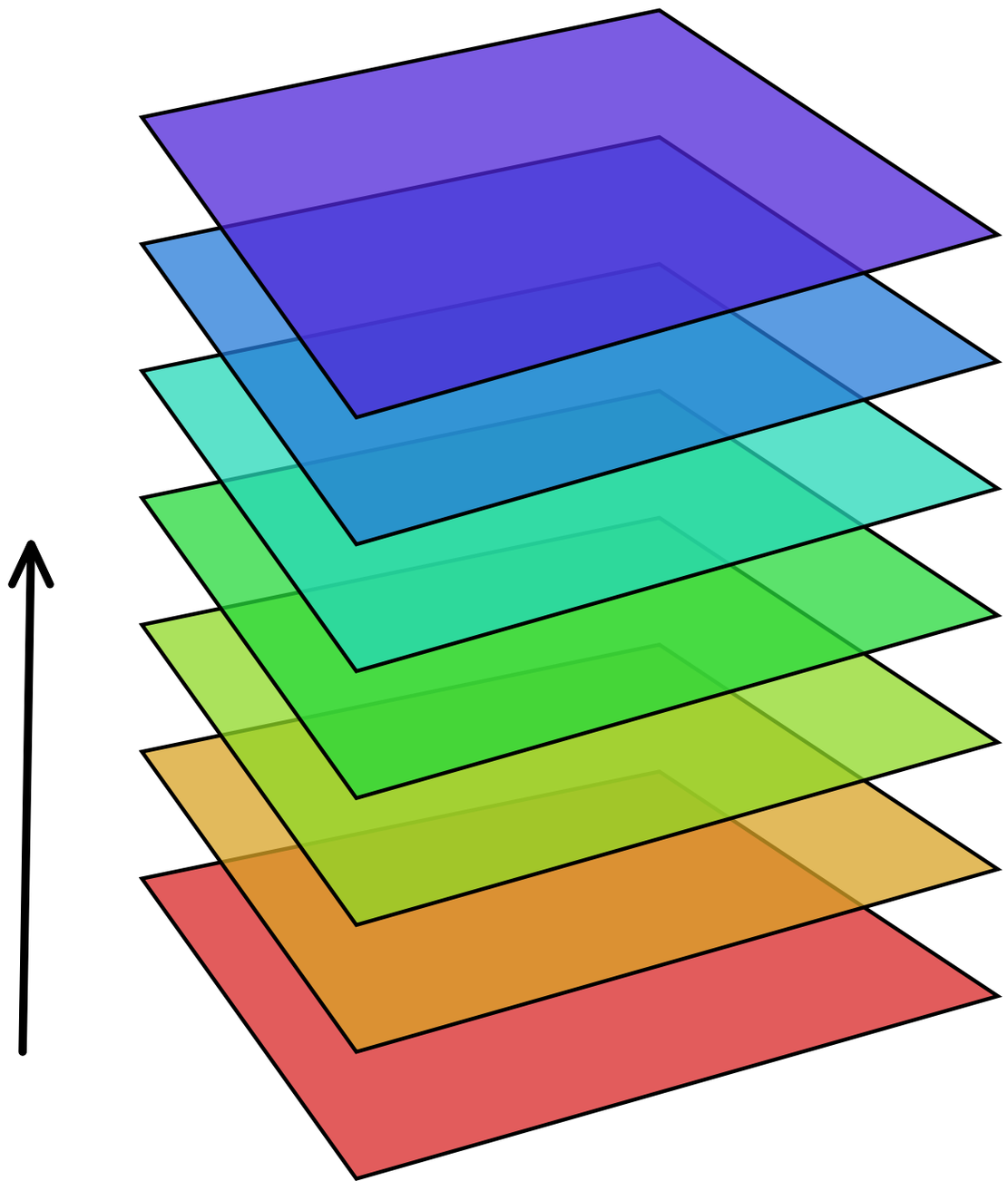


geometry

aesthetics

data

instead: common framework



coordinates

stats

facets

scales

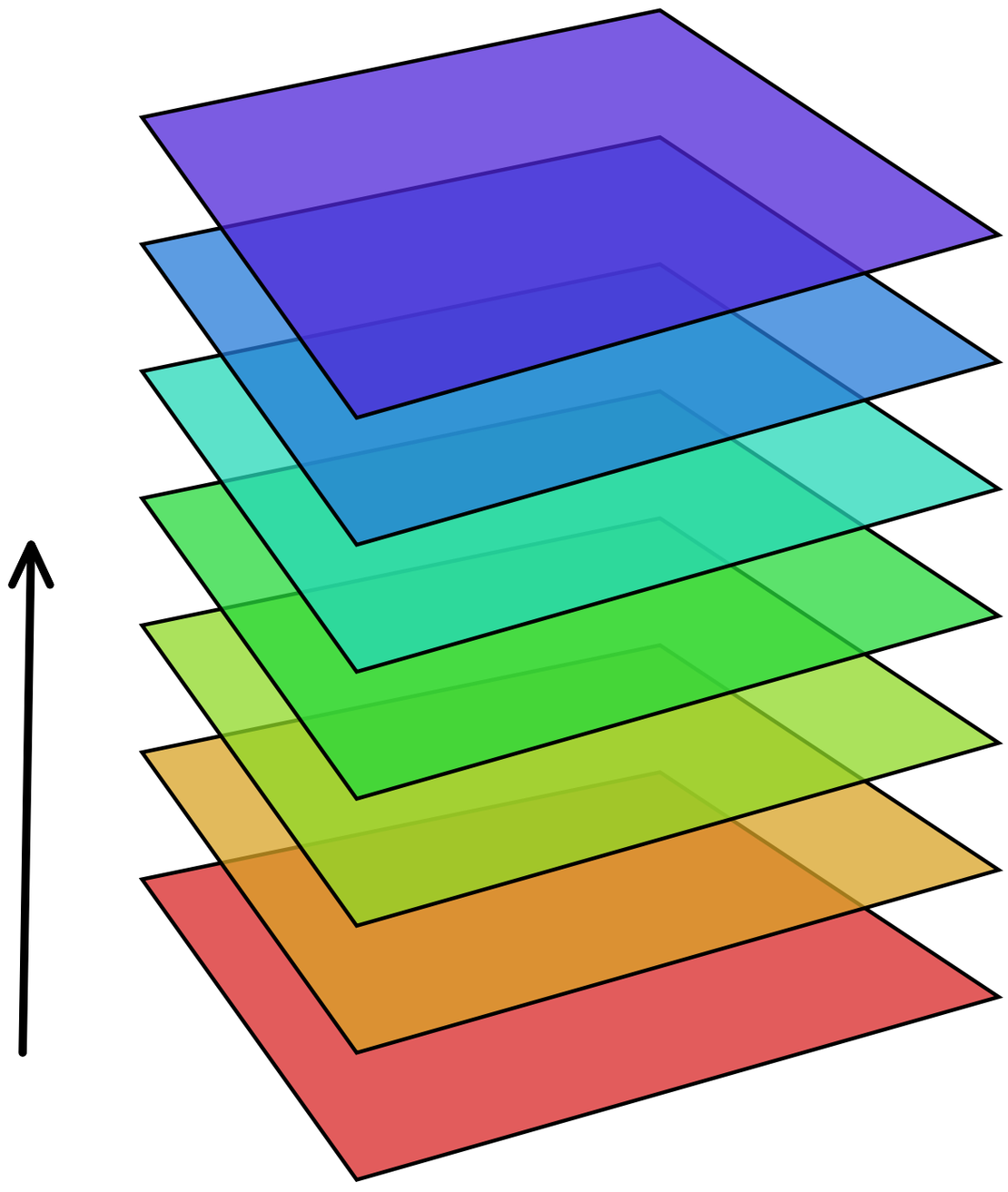
geometry

aesthetics

data

a grammar

instead: ~~common framework~~



coordinates

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an example

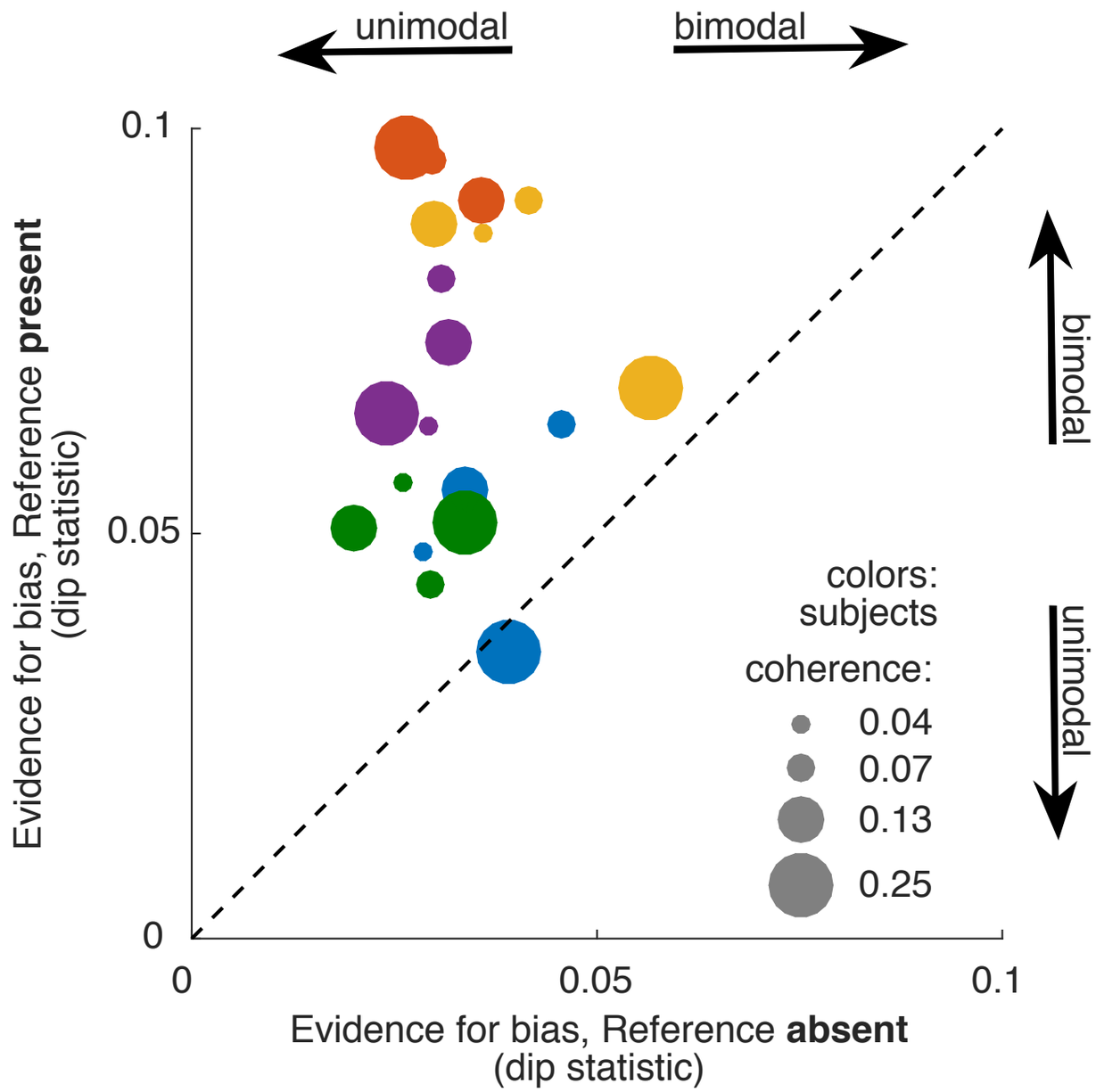

Figure 3b

Zamboni et al (2016) Proc Biol Sci.

recreating this graphic in R/ggplot2

code: https://gist.github.com/schluppeck/9a54b9b7a37793d8959779629b4cd2fc

data, d

```
head(d)
```

```
  X subject coherence   absent  present
1 1       1         4 0.035996 0.087079
2 2       2         7 0.026042 0.056272
3 3       3        13 0.028604 0.047791
4 4       4        25 0.029221 0.063149
5 5       5         4 0.025157 0.096832
6 6       1         7 0.041558 0.091160
```

4 variables that we want to **map** into a plot

aesthetics

- `x, y (position)`
- `alpha, color, fill`
- `size`
- `shape`
- `linetype`

http://docs.ggplot2.org/current/vignettes/ggplot2-specs.html

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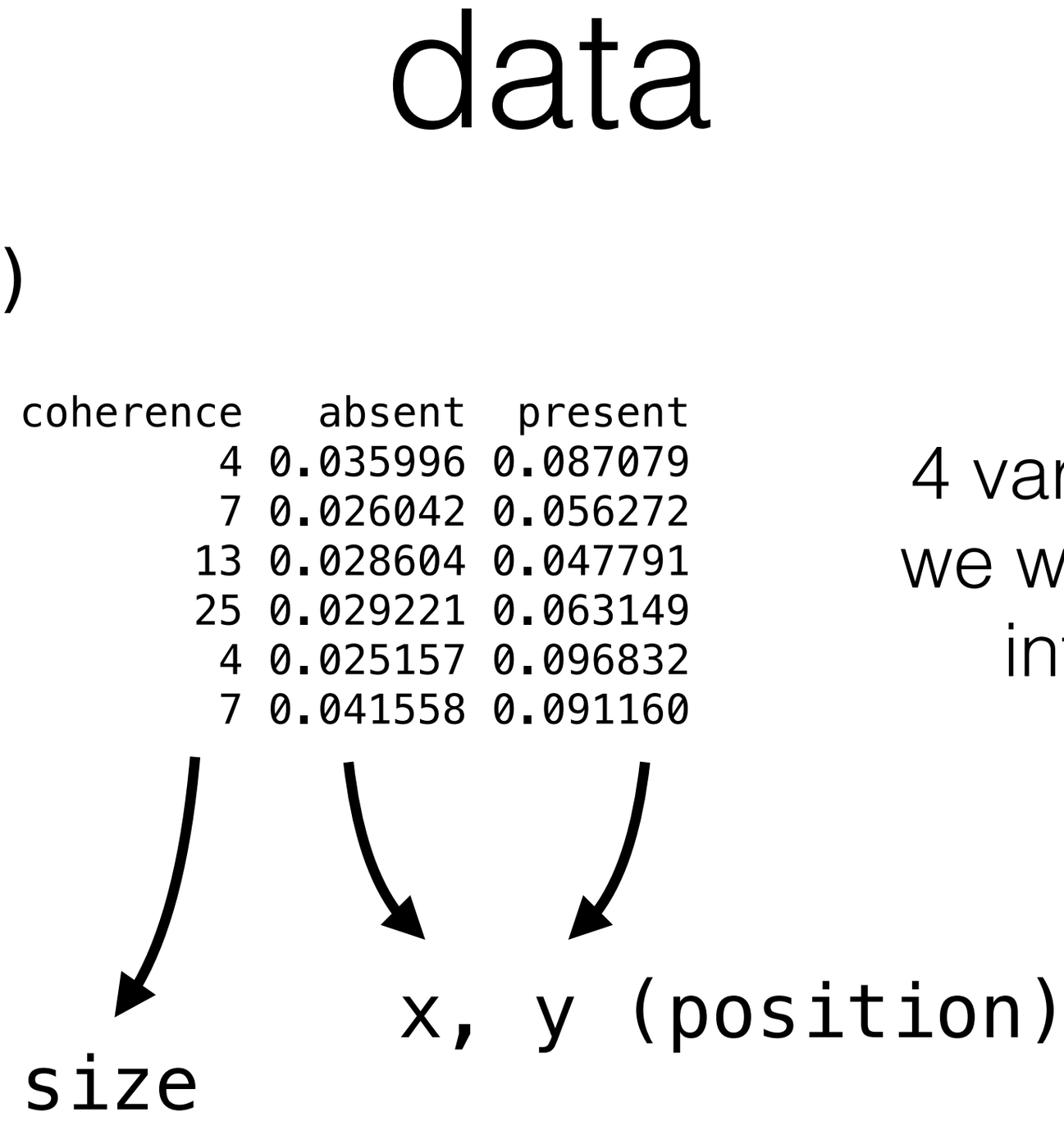

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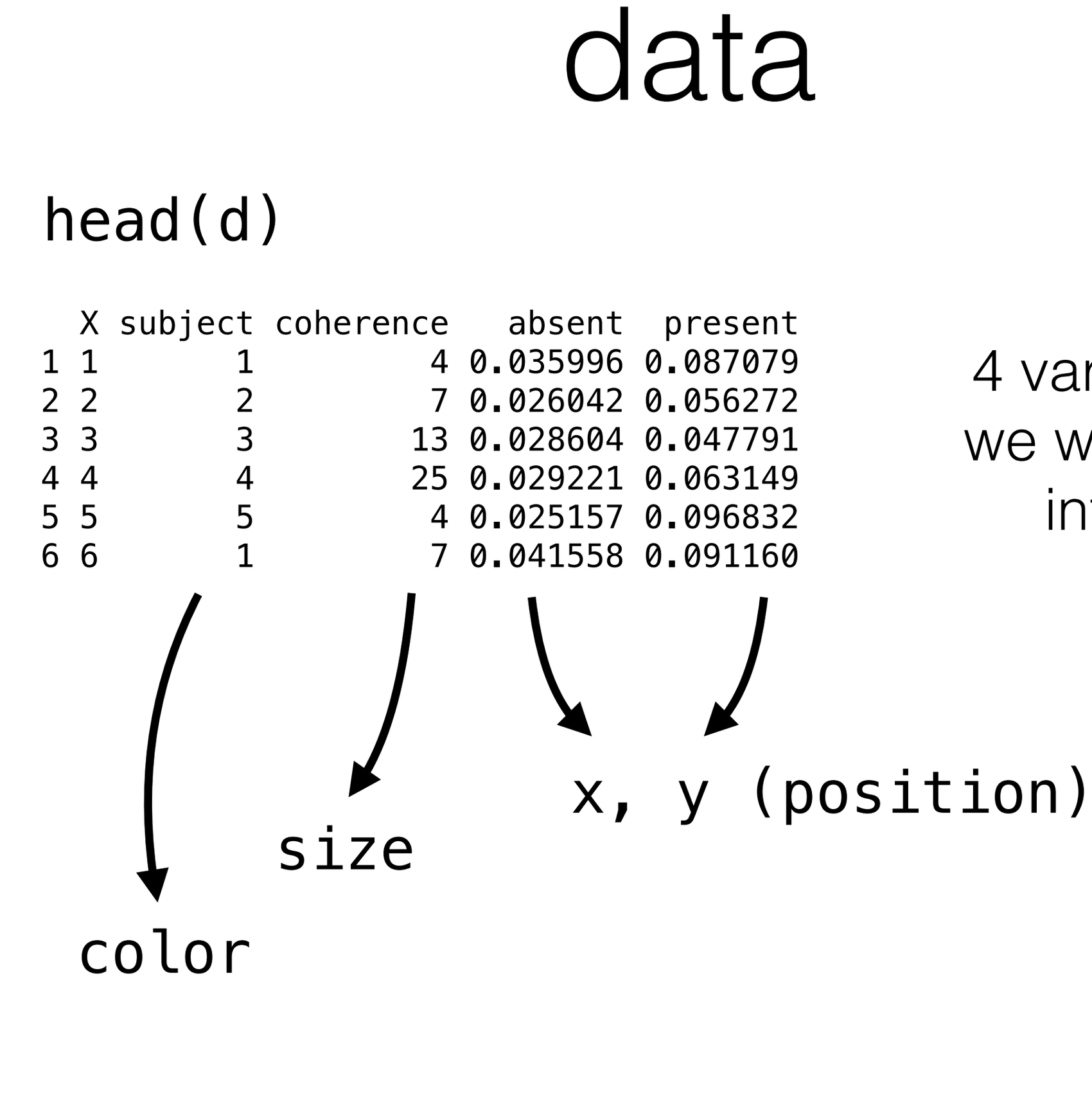


geometry

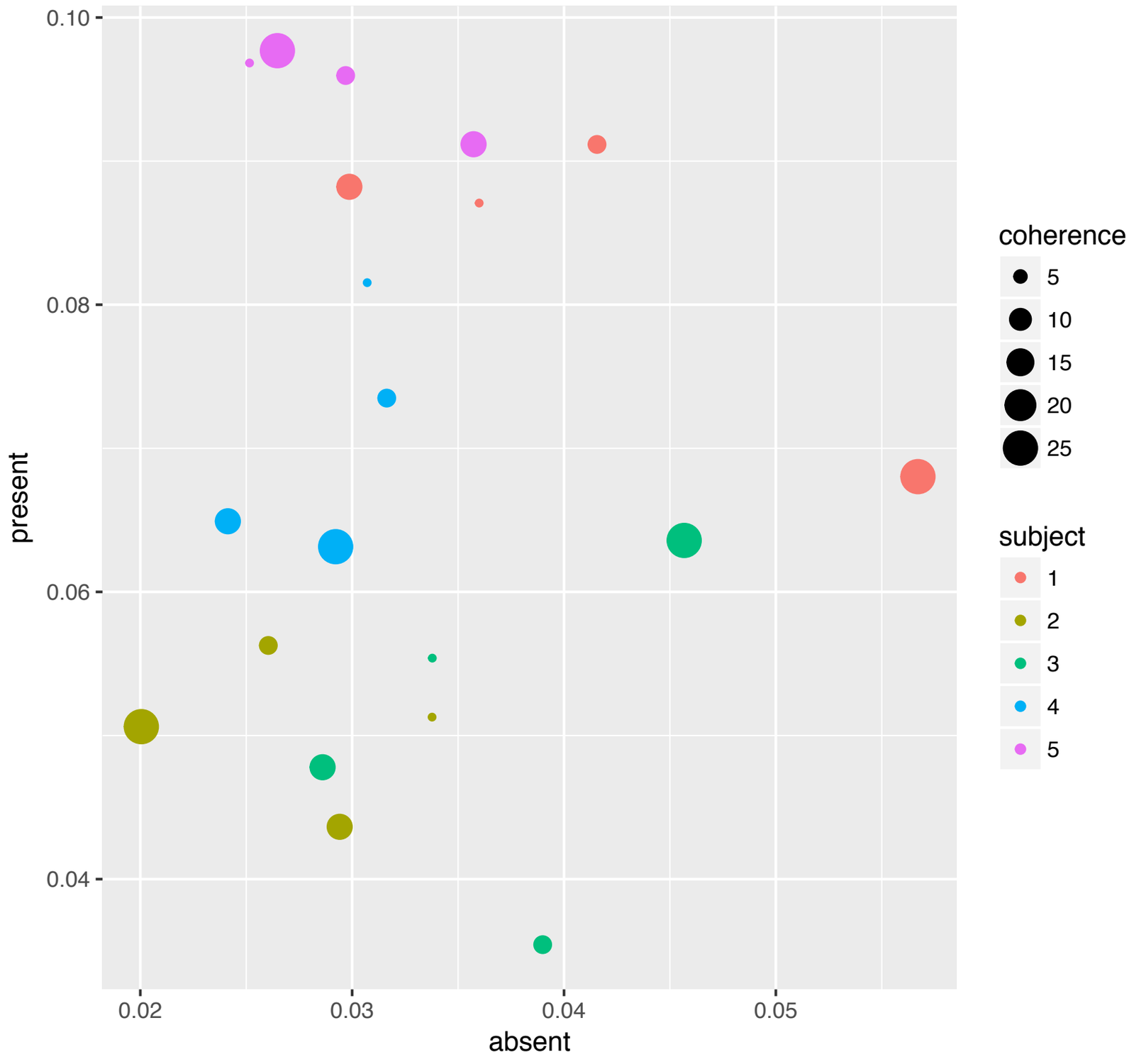
- 0d: points, text
- 1d: lines, paths
- 2d: polygons, intervals

Wickham (2010)

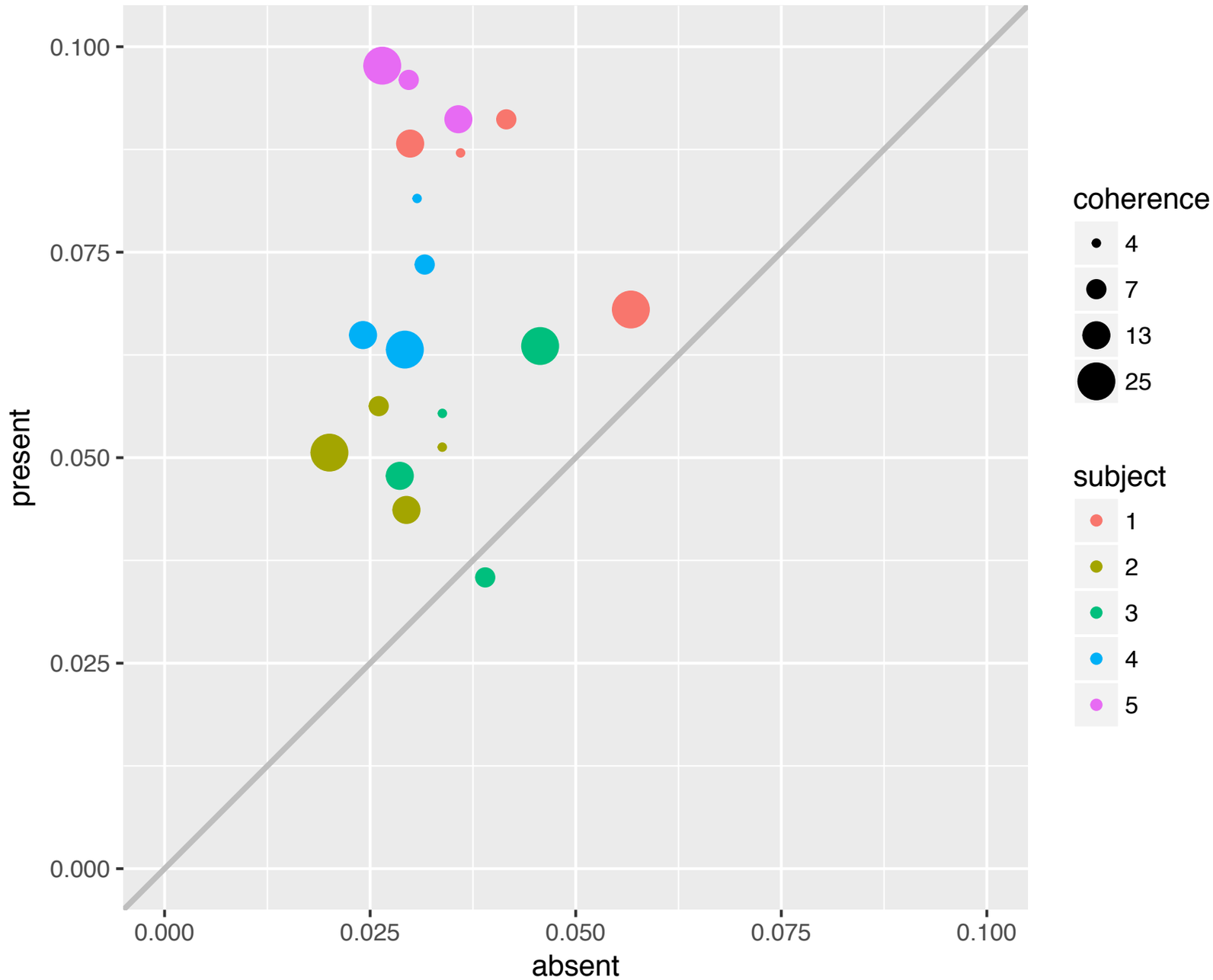
geometry

- 0d: points, text 
- 1d: lines, paths
- 2d: polygons, intervals

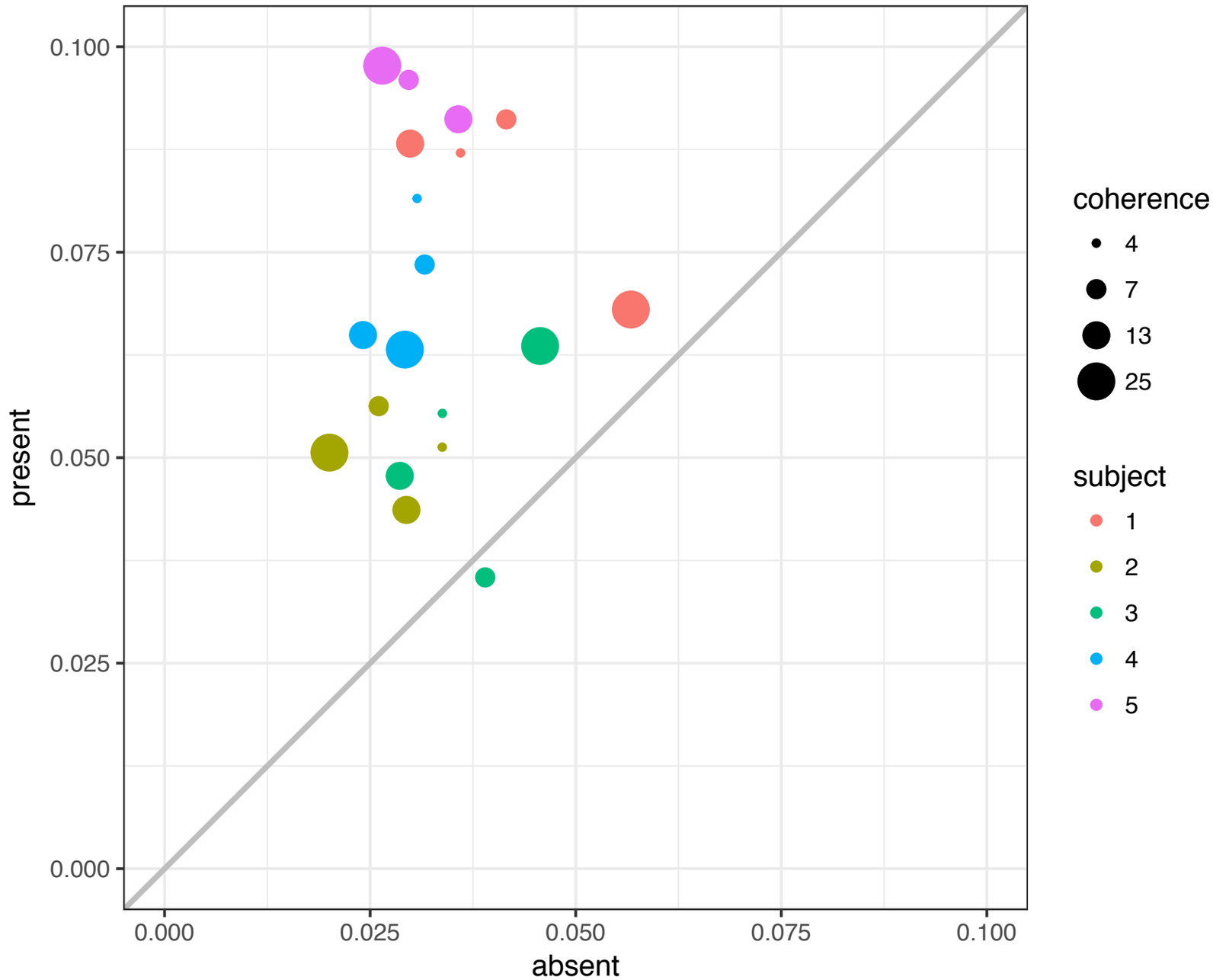
Wickham (2010)



with default settings



+ scale, coord (aspect ratio), unity line



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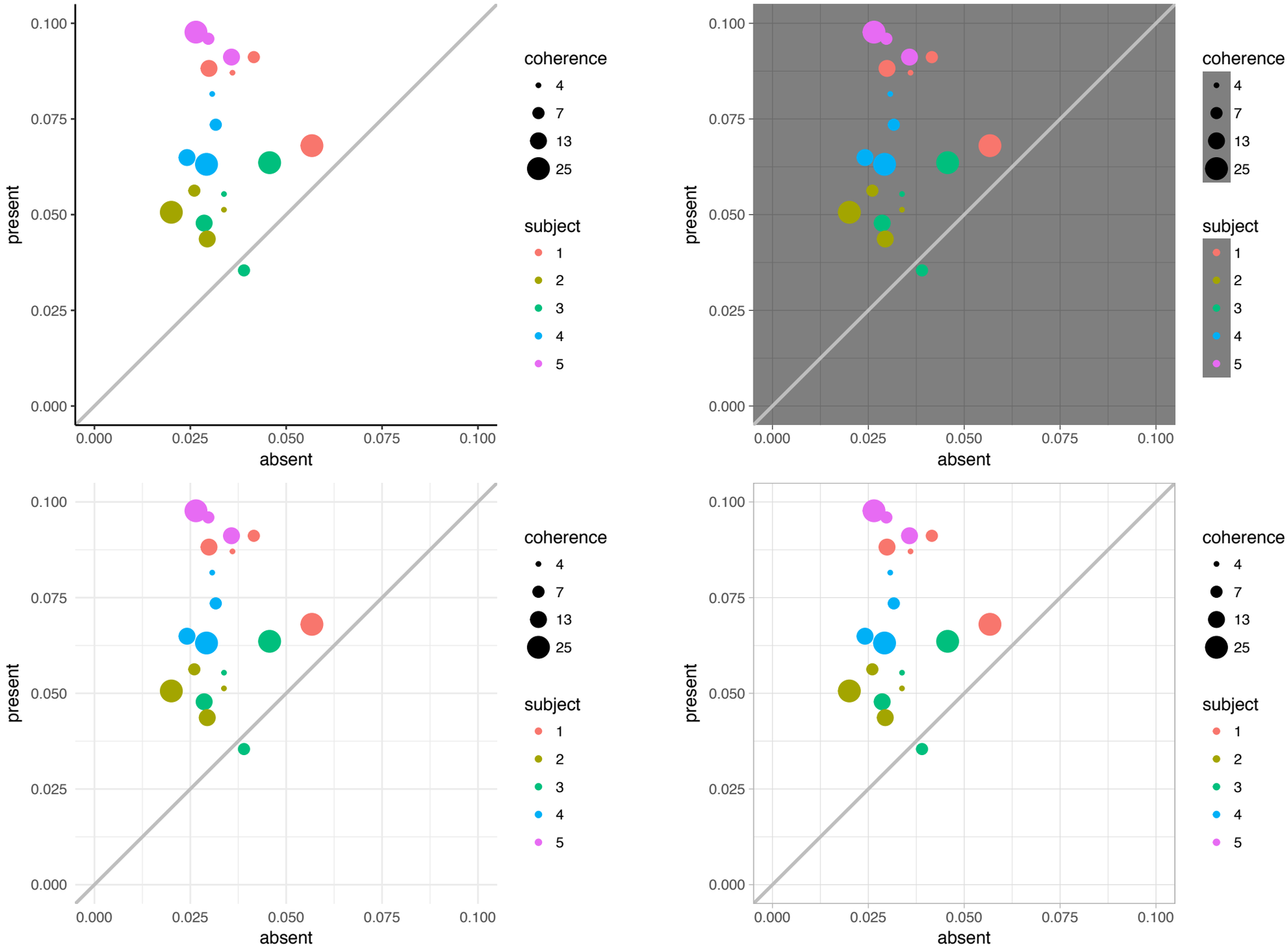
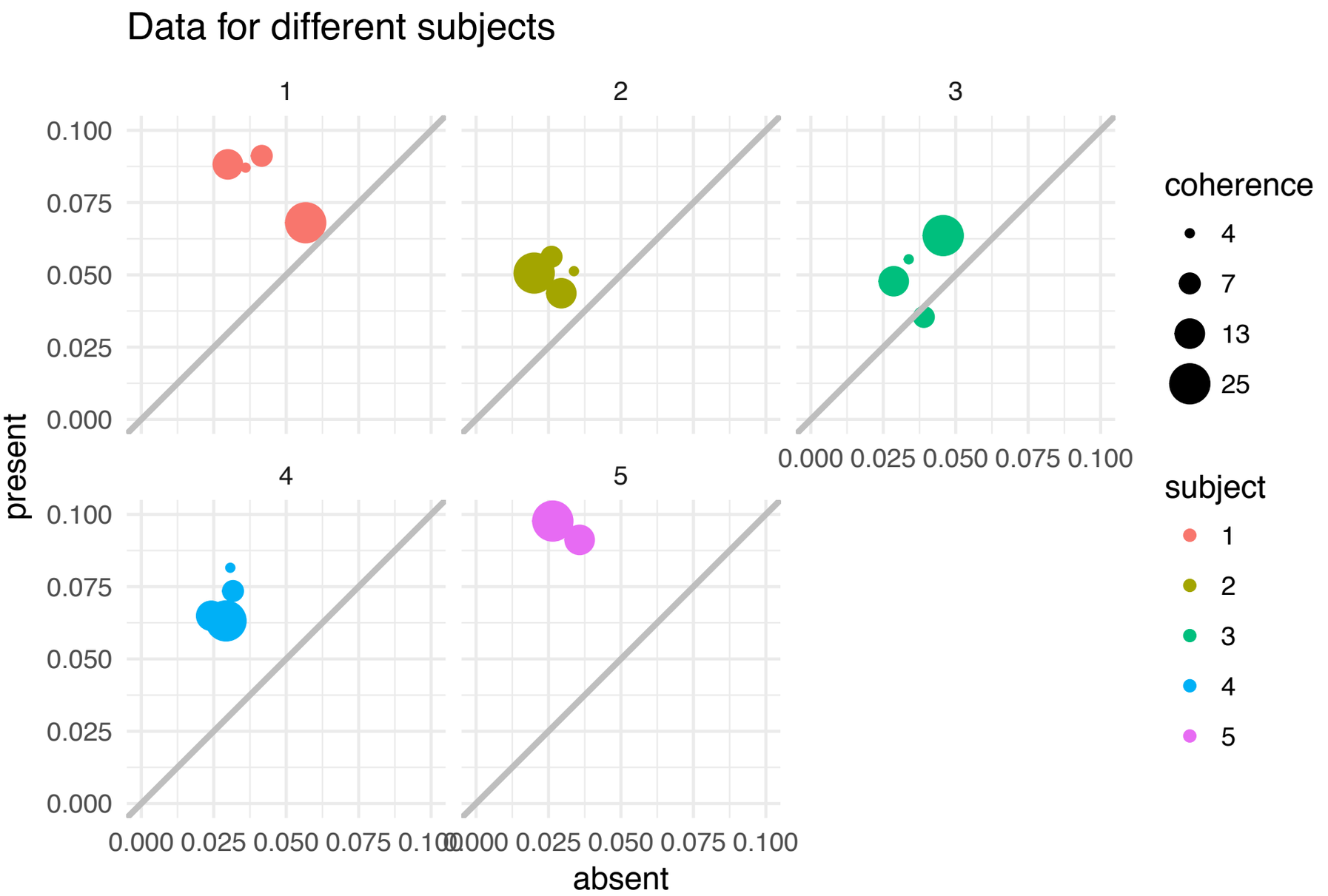
themes / look of plot



worth the hassle?

- I think yes: already for basic plotting
- for data exploration we often slice across different dimensions:
  - subjects, regions of interest, …
  - measures: RT, % correct, fMRI response amplitude, …

facet (lattice)



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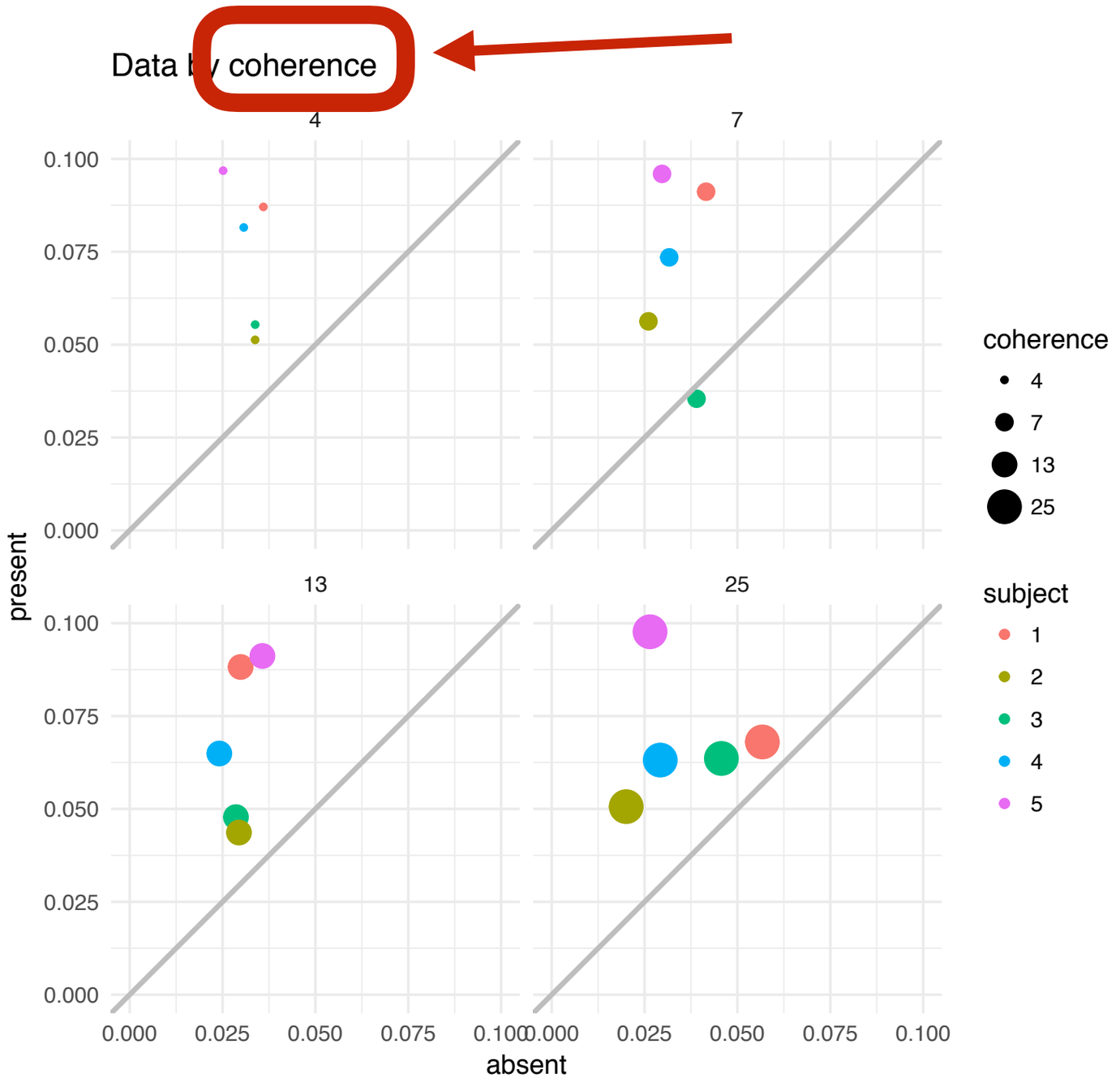
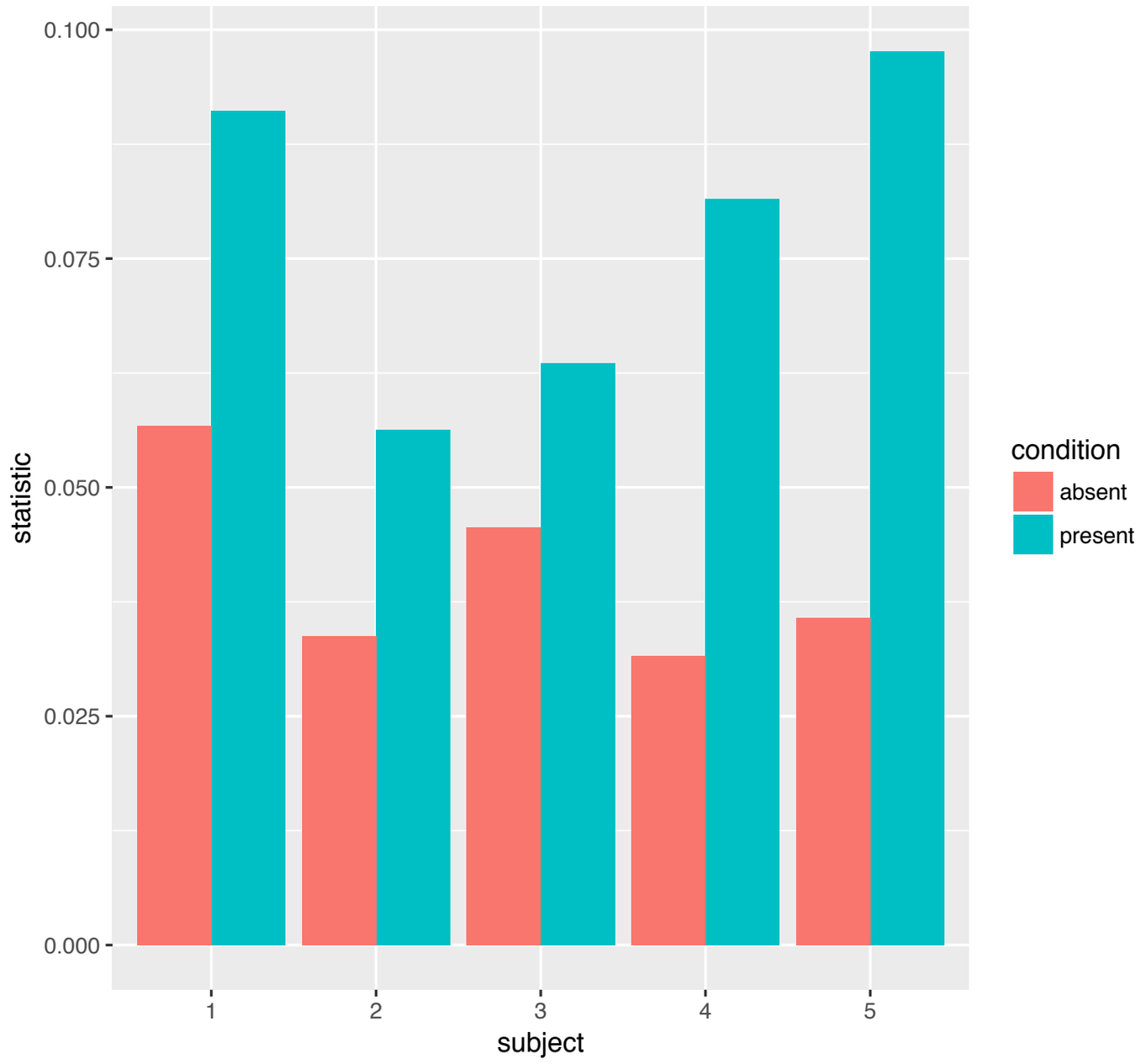


rearrange


0.100
0.075
0.050
0.025
0.000
statistic
1
2
3
4
5
subject
condition
absent
present

But I do use *Matlab*

```
# bash
cd ~/matlab
git clone https://github.com/piermorel/gramm
```

[or download + extract zip file]

```
% in matlab
addpath(genpath('~/matlab/gramm'))
```

[or put this in your startup.m file]

using the same approach

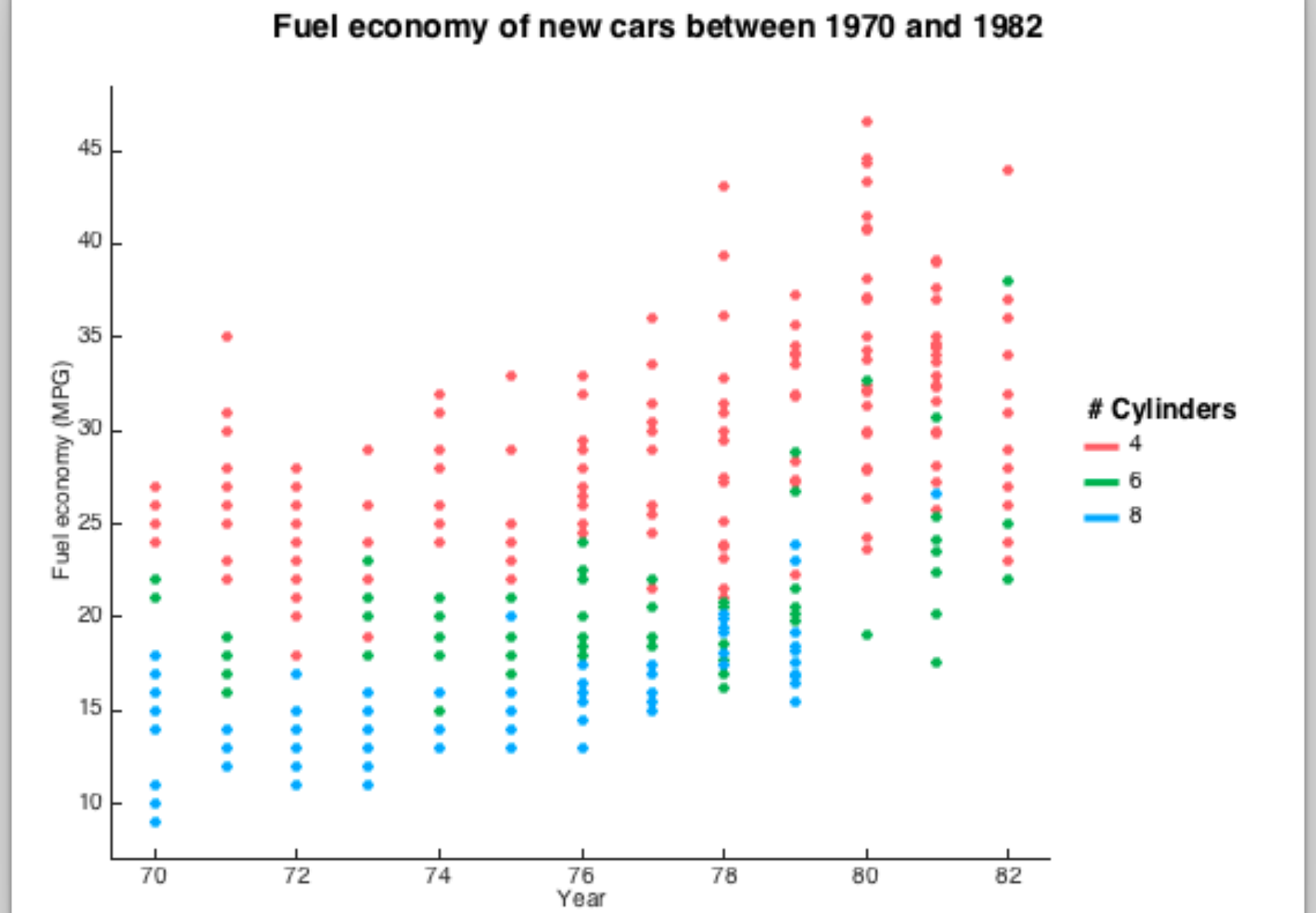
in `matlab/GRAMM`

`code:` https://gist.github.com/schluppeck/9a54b9b7a37793d8959779629b4cd2fc

```
% Load example dataset
load carbig.mat

% CREATE a gramm object with data -> AES
g=gramm('x', Model_Year,'y', . . .)

% Plot raw data as points
g.geom_point()

% Do the actual drawing
g.draw()
```

Figure 1

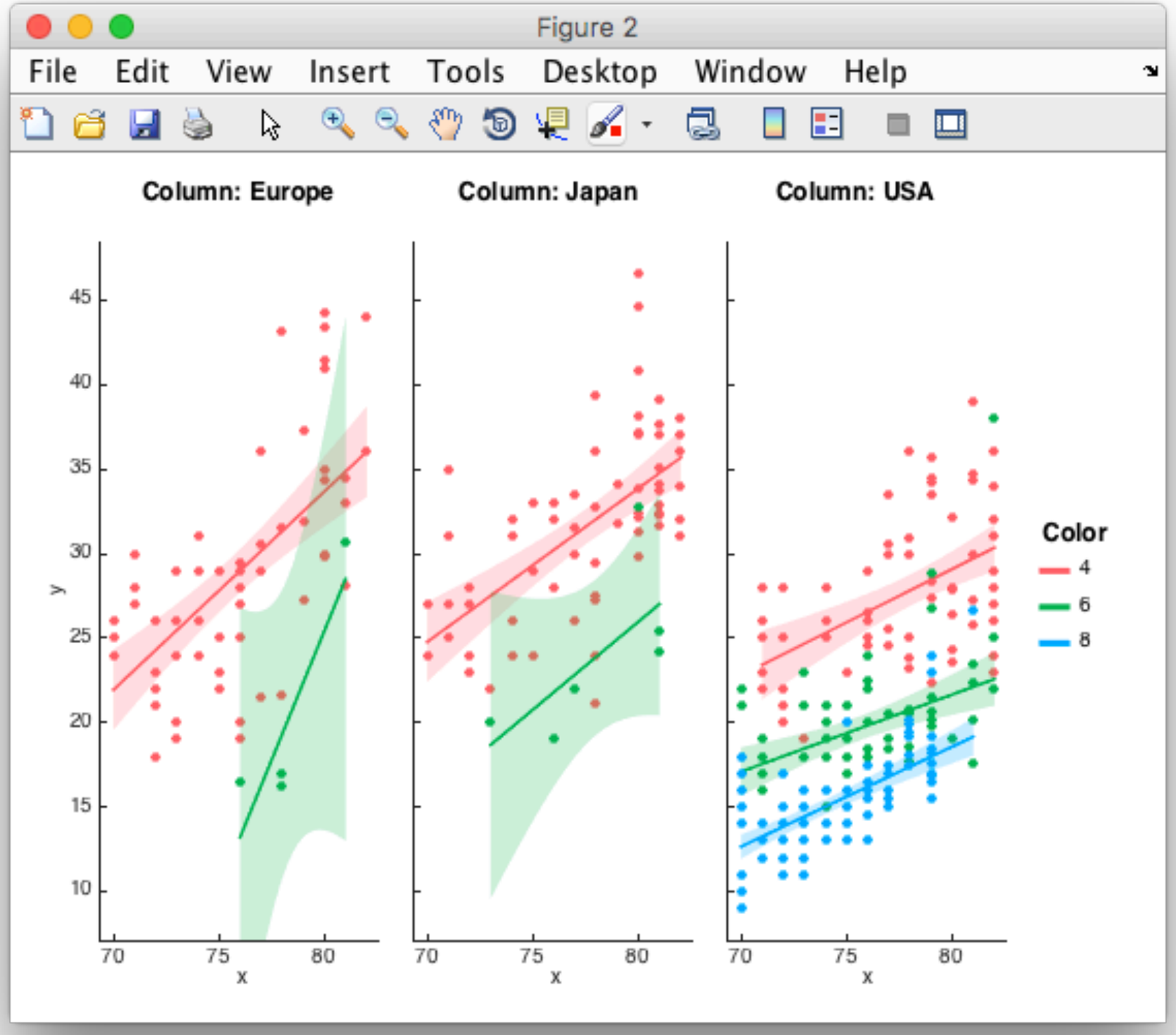
File Edit View Insert Tools Desktop Window Help



```
figure
h=gramm(‘x’,Model_Year,'y',. . .)

h.geom_point()
% Plot linear fits of the data
% with associated confidence intervals
h.stat_glm()
```

```
% Subdivide the data in subplots
% horizontally by region of origin
h.facet_grid([],origin_region)

% and draw this one
h.draw()
```

https://github.com/piermorel/gramm



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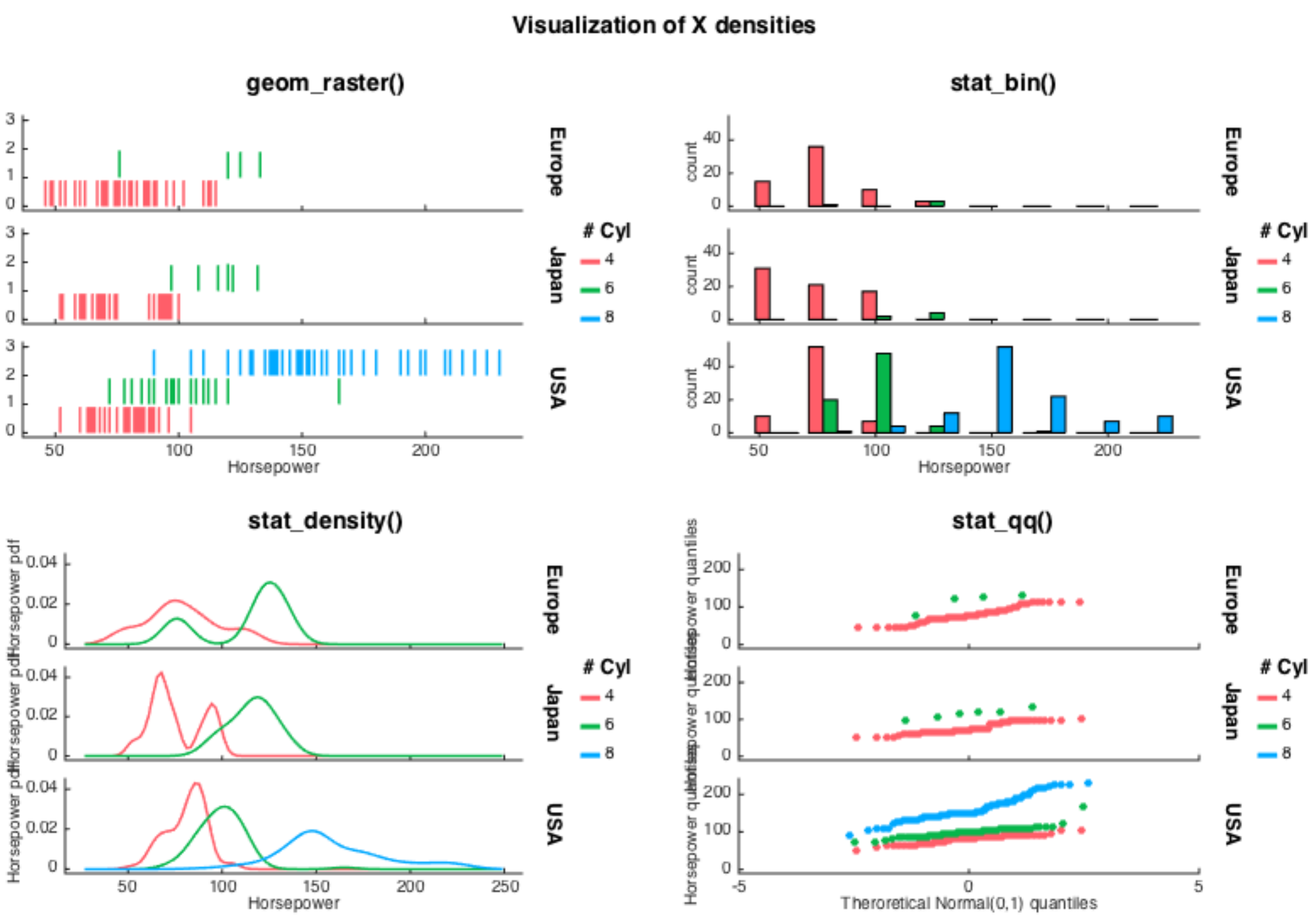

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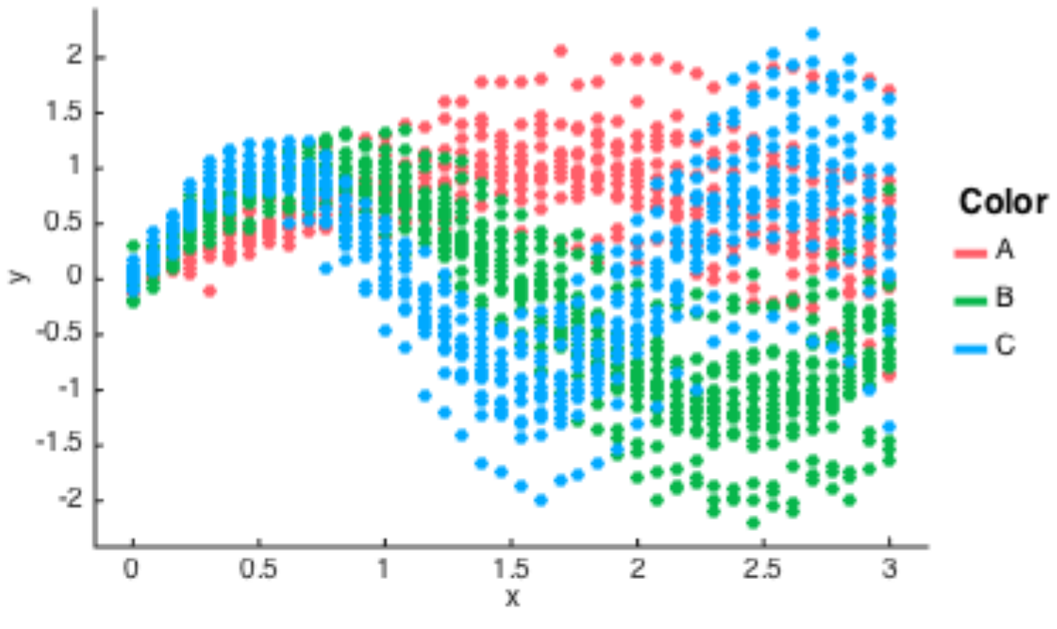
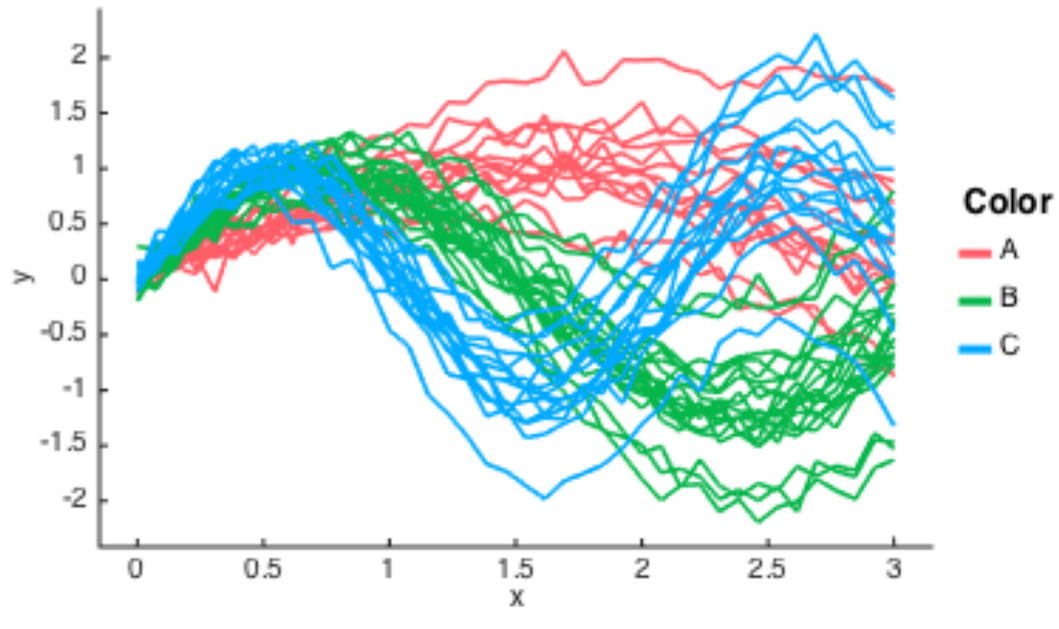
Visualization of repeated trajectories

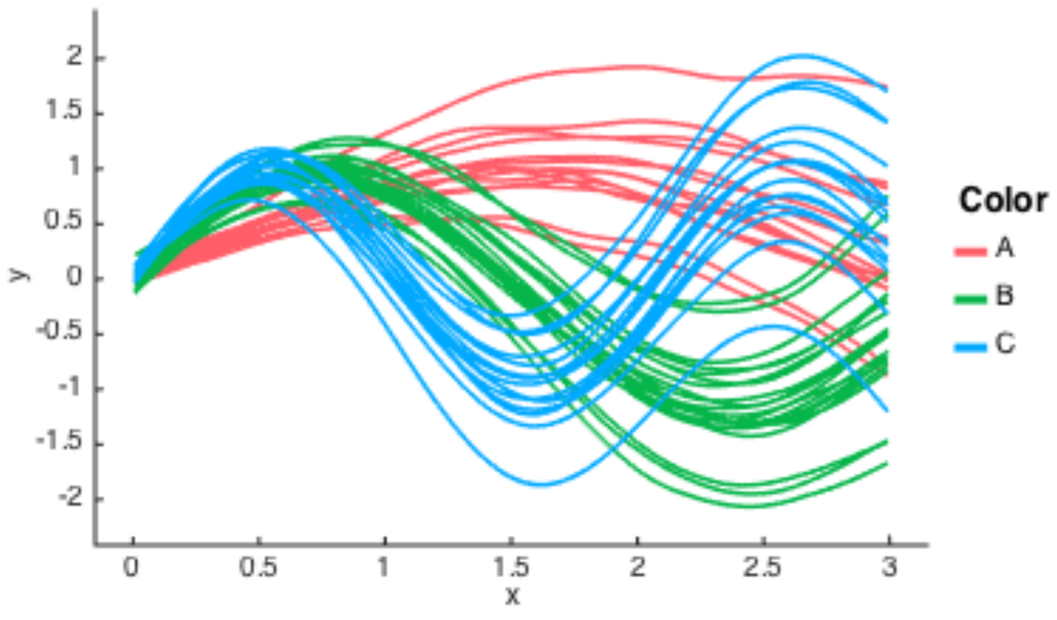
geom_point()



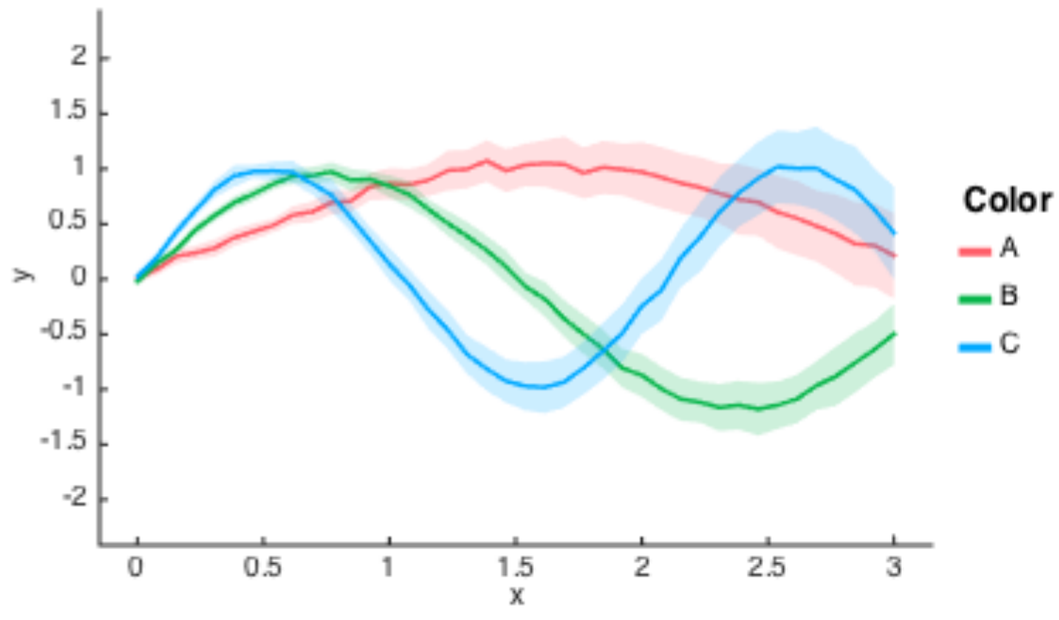
geom_line()



stat_smooth()



stat_summary()



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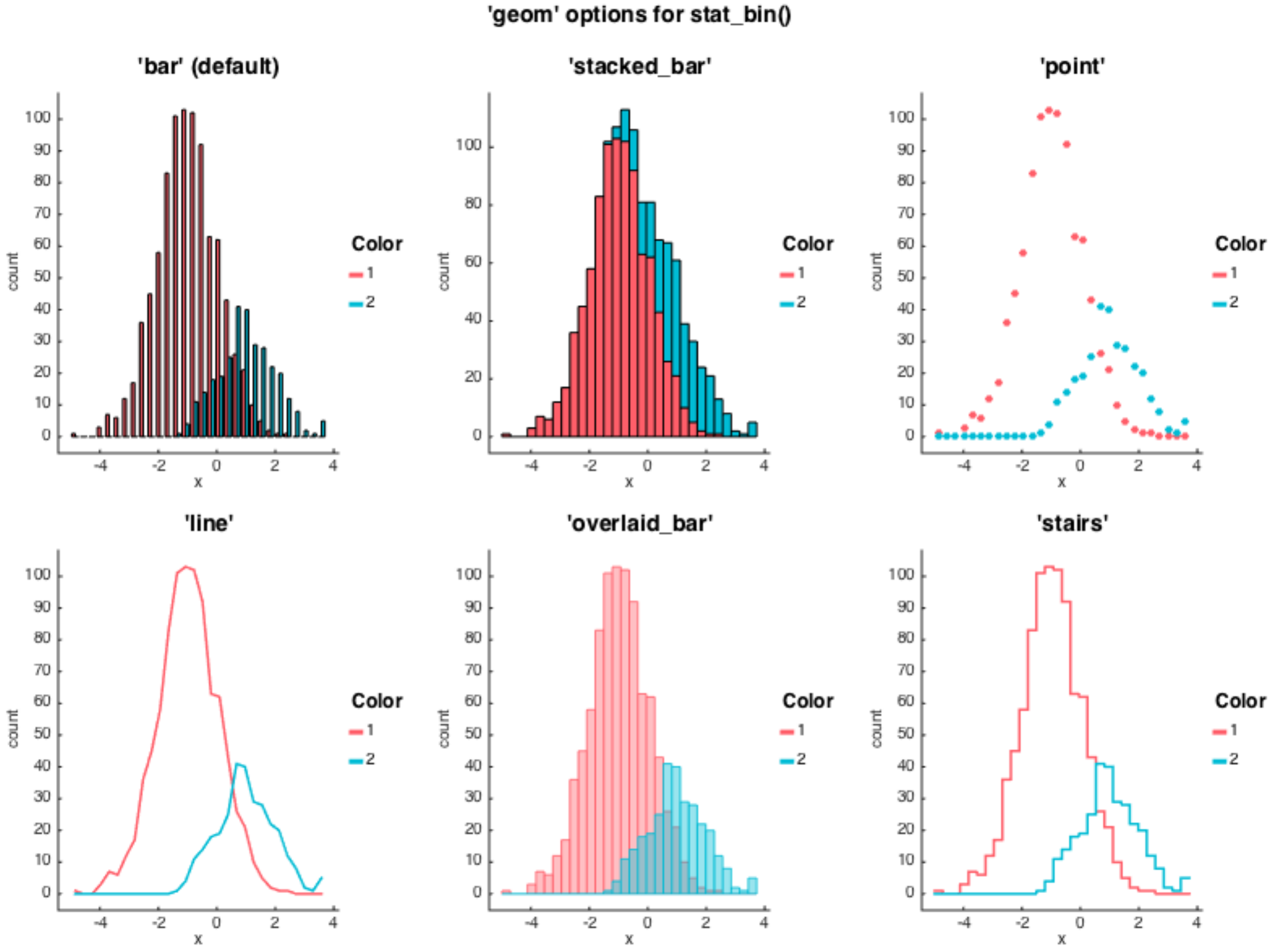

https://github.com/piermorel/gramm

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(tidy) data

```
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```

```
  X subject coherence condition statistic
1 1       1         4    absent  0.035996
2 2       2         7    absent  0.026042
3 3       3        13    absent  0.028604
4 4       4        25    absent  0.029221
5 5       5         4    absent  0.025157
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```

4 variables

side note: to fully make use of ggplot, it's best if the data are *tidy* (for details see http://vita.had.co.nz/papers/tidy-data.pdf)