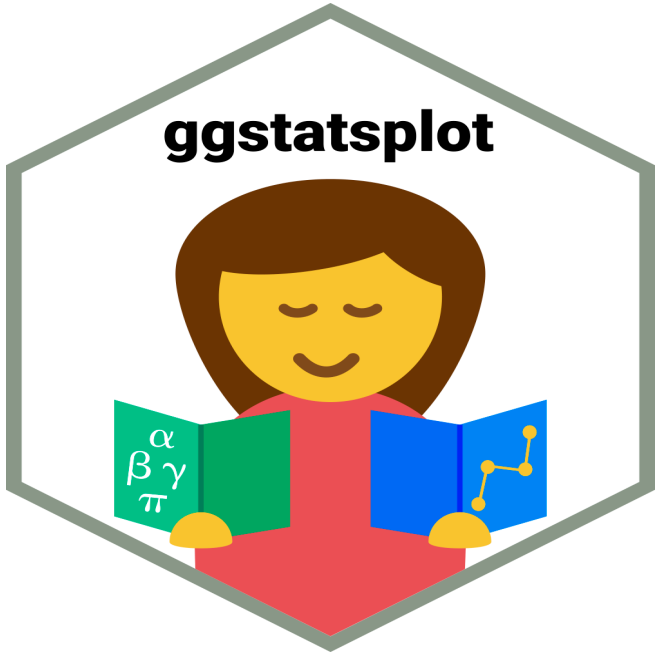
Statistical Visualizations with {ggstatsplot}: A Biography

Indrajeet Patil



Or How I Learned to Stop Worrying about Data Visualization and Statistical Reporting

Genesis

Why a new software?

Life in the trenches (c. 2017, Harvard)

External Stimulus

- **Reporting errors**:

> "half of all published psychology papers contained at least one *p*-value that was inconsistent"[1]

- **Interpretation errors**:

> "in 72% of cases, nonsignificant results were misinterpreted [to mean] that effect was absent"[2]

- **Replication crisis**:

> "39% of effects were subjectively rated to have replicated the original result"[3]

and more…

Internal Response

How to:

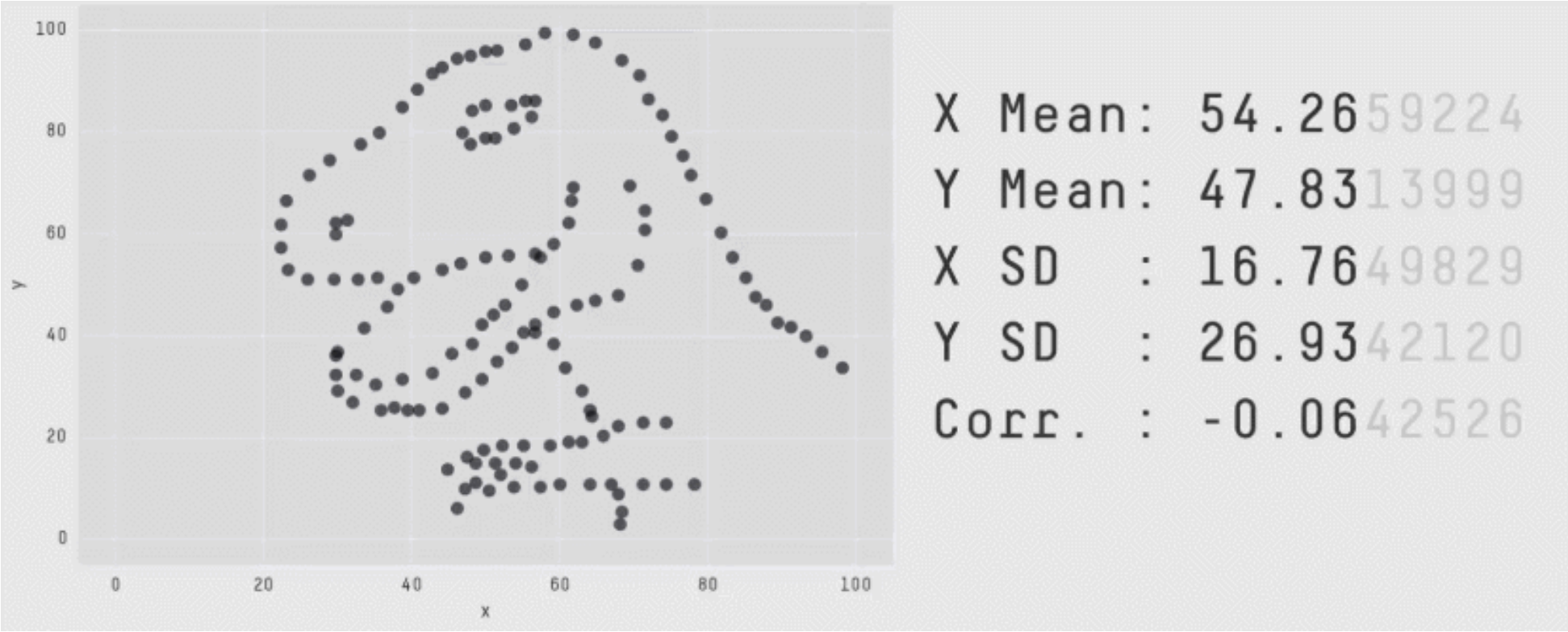
- avoid reporting errors?
- improve quality of statistical reporting?
- emphasize the importance of the effect?
- interpret null results?
- easily assess validity of model assumptions?
- increase replicability?

Proposal

Information-rich, ready-made statistical visualizations

(minimal effort and maximum transparency)

A visualization with statistical summary

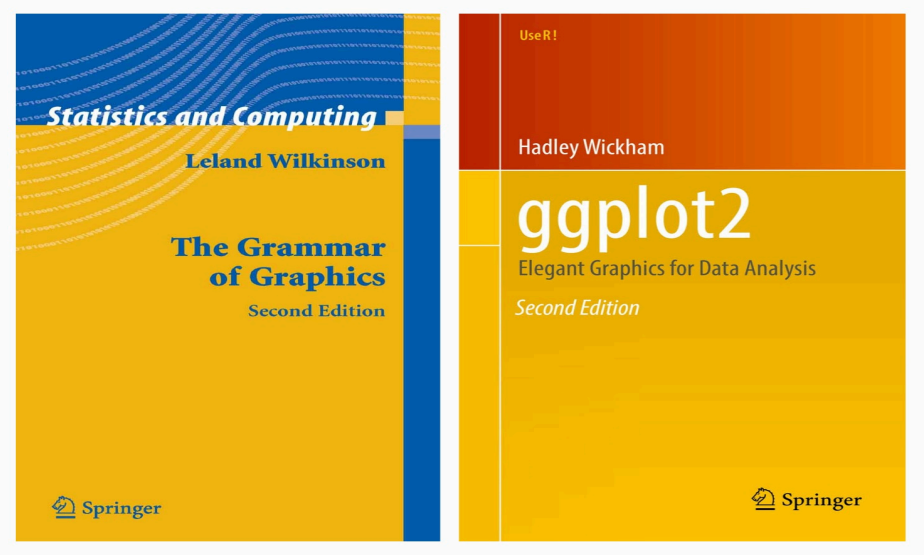


💡 **Visualizations** reveal problems not discernible from **model summaries**!

(Matejka & Fitzmaurice, *Autodesk Research*,2017)

Ready-made plots with one-line syntax

The **grammar of graphics** framework can prepare **any** visualization! But building plots from scratch can be time-consuming.



💡 Using **ready-made plots** lowers the effort needed for visualizing data!

Action Plan

`{ggstatsplot}` was born!

(open-sourced on GitHub in 2017; still actively developed)

Example function

E.g., for hypothesis about differences *between* groups

```
1  ggbetweenstats(iris, Species, Sepal.Length)
```

Important

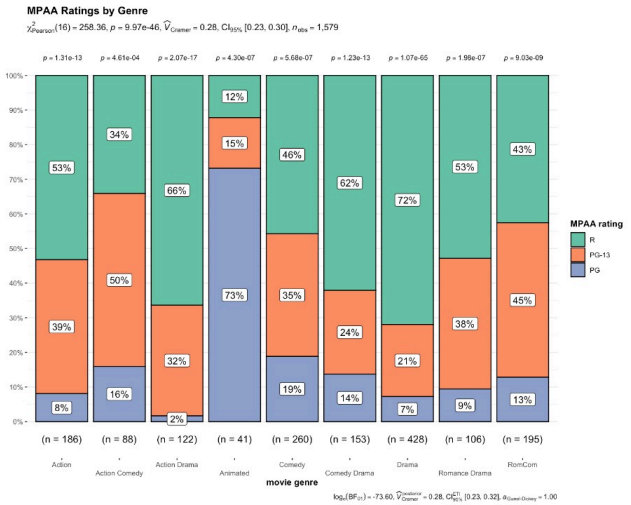
Information-rich defaults

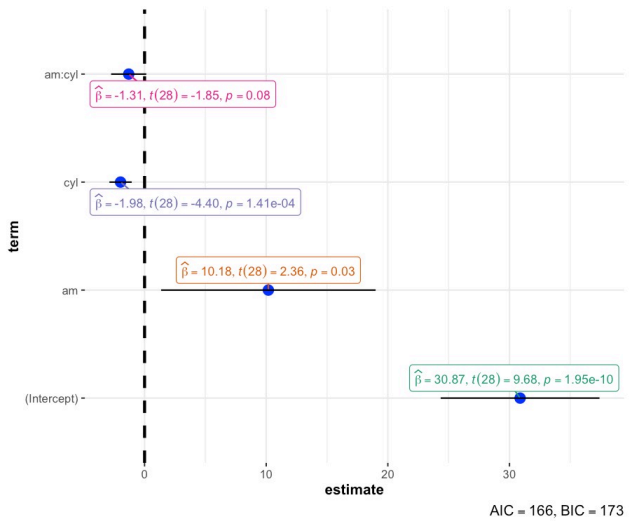
- raw data + distributions
- descriptive statistics
- inferential statistics
- effect size + uncertainty
- pairwise comparisons
- Bayesian hypothesis-testing
- Bayesian estimation

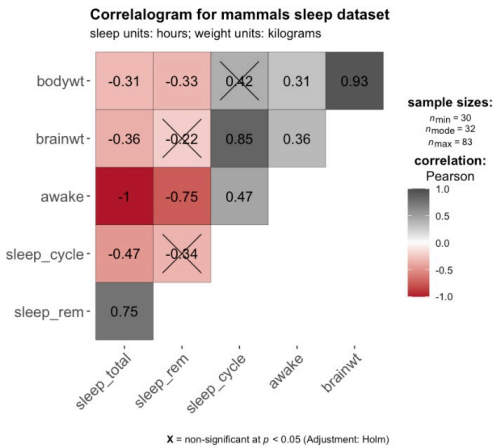
Statistical approaches available

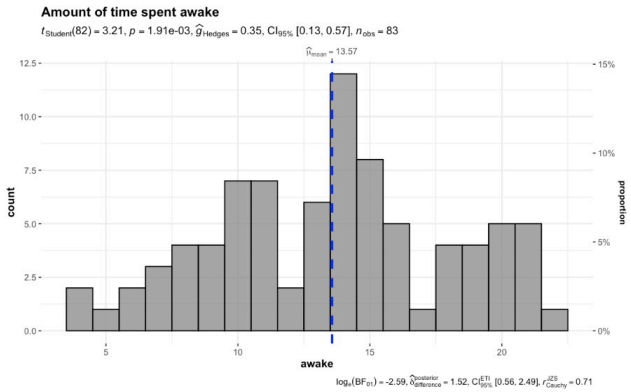
- parametric
- non-parametric
- robust
- Bayesian

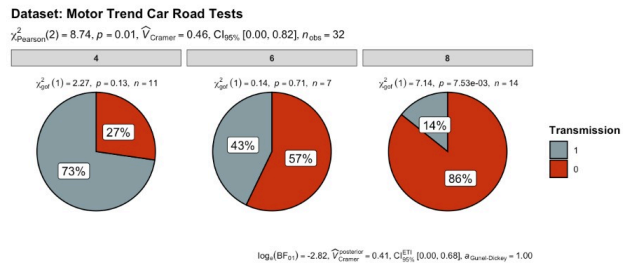
And there is more!

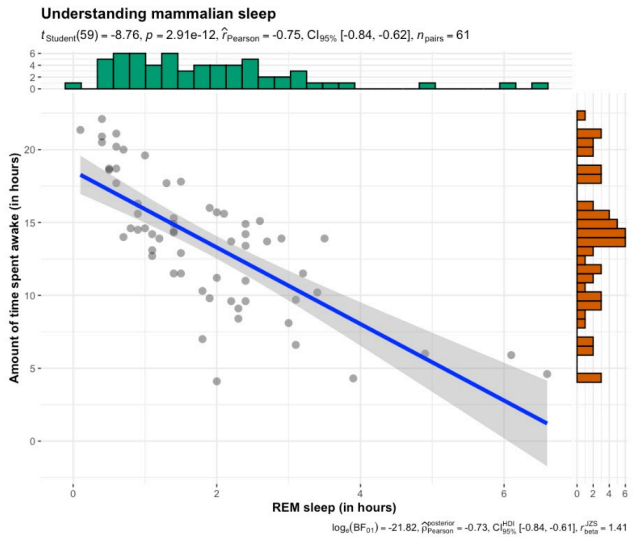












Appendix provides more details.

Promised Land

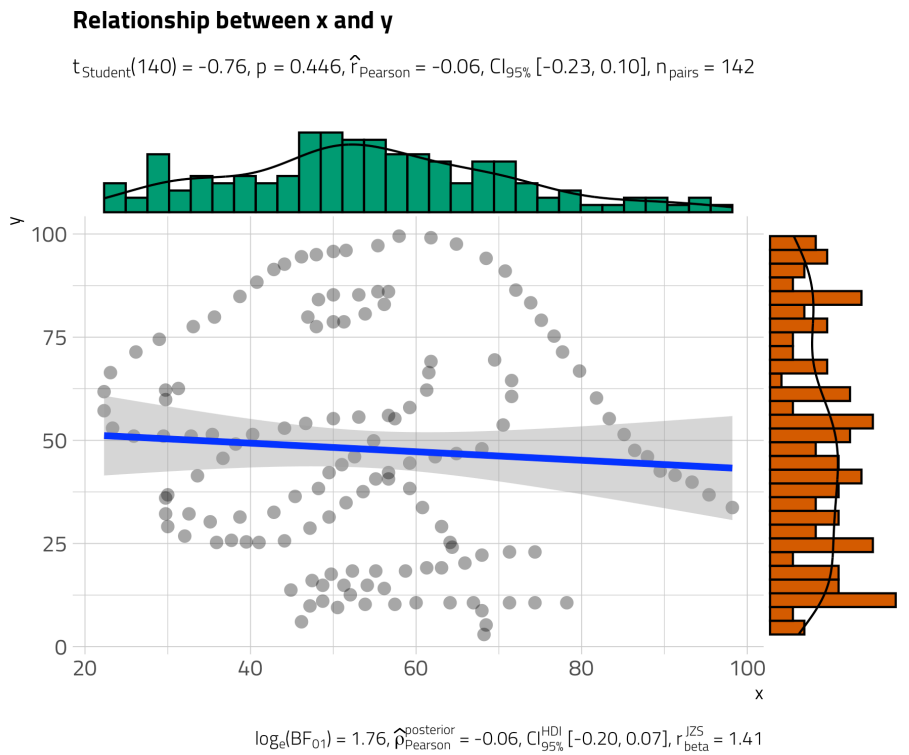
Does it deliver?

Show, don't tell

Without `{ggstatsplot}`

Pearson's correlation test revealed that, across 142 participants, variable `x` was negatively correlated with variable `y`: $t(140) = -0.76, p = 0.446$. The effect size $(r = -0.06, 95\%CI[-0.23, 0.10])$ was small, as per Cohen's (1988) conventions. The Bayes Factor for the same analysis revealed that the data were 5.81 times more probable under the null hypothesis as compared to the alternative hypothesis. This can be considered moderate evidence (Jeffreys, 1961) in favor of the null hypothesis (absence of any correlation between `x` and `y`).

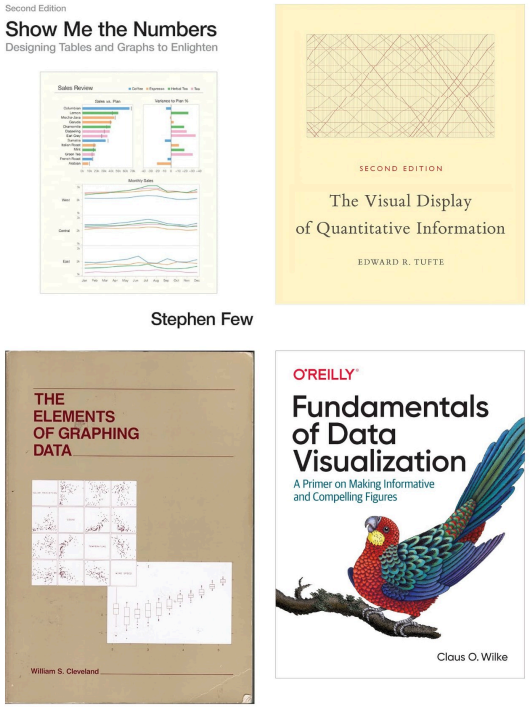
With `{ggstatsplot}`



✅ No need to worry about reporting or interpretation errors!

Thoughtful Defaults

Data Visualization



Statistical Reporting

Results from Welch's t-test with {statsExpressions}

Template for Frequentist analysis

test | parameter | statistic | significance | effect size type + estimate + confidence intervals | number of observations

$$t_{\text{Welch}}(281.95) = -10.75,\ p = 8.31\text{e-}23,\ \hat{g}_{\text{Hedges}} = -1.27,\ \text{CI}_{99\%}[-1.61, -0.94],\ n_{\text{obs}} = 284$$

Template for Bayesian analysis

evidence in favor of null over alternative hypothesis | natural logarithm of Bayes Factor | posterior type + estimate + credible intervals | prior type and value

$$\log_e(\text{BF}_{01}) = -6.20,\ \delta^{\text{posterior}}_{\text{difference}} = -5.06,\ \text{CI}^{\text{HDI}}_{95\%}\ [-6.75, -3.53],\ r^{\text{JZS}}_{\text{cauchy}} = 0.71$$

<https://indrajeetpatil.github.io/statsExpressions/>

src: @patilindrajeets

(Doorn et al., 2020; APA Manual)

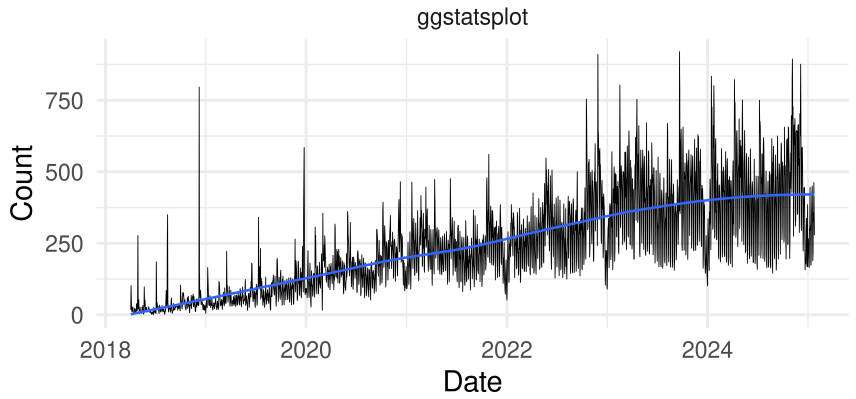
✅ Follows best practices in data visualization and statistical reporting!

Impact

I can haz users?!

User Love

Total downloads > 500K (97 percentile)



Second most starred `{ggplot2}`-extension!

ggstatsplot Public

Enhancing {ggplot2} plots with statistical analysis

R ☆ 2k 190

Total citations > 1000

From publications across a wide range of fields: biology, medicine, psychology, economics, etc.

JOSS
The Journal of Open Source Software

Visualizations with statistical details: The 'ggstatsplot' approach

Indrajeet Patil[1]

1 Center for Humans and Machines, Max Planck Institute for Human Development, Berlin, Germany

DOI: 10.21105/joss.03167

Software
- Review
- Repository
- Archive

Editor: Charlotte Soneson
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- @njtierney
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Summary

Graphical displays can reveal problems in a statistical model that might not be apparent from purely numerical summaries. Such visualizations can also be helpful for the reader to evaluate the validity of a model if it is reported in a scholarly publication or report. But, given the onerous costs involved, researchers often avoid preparing information-rich graphics and exploring several statistical approaches or tests available. The `ggstatsplot` package in the R programming language (R Core Team, 2021) provides a one-line syntax to enrich `ggplot2`-based visualizations with the results from statistical analysis embedded in the visualization itself. In doing so, the package helps researchers adopt a rigorous, reliable, and robust data exploratory and reporting workflow.

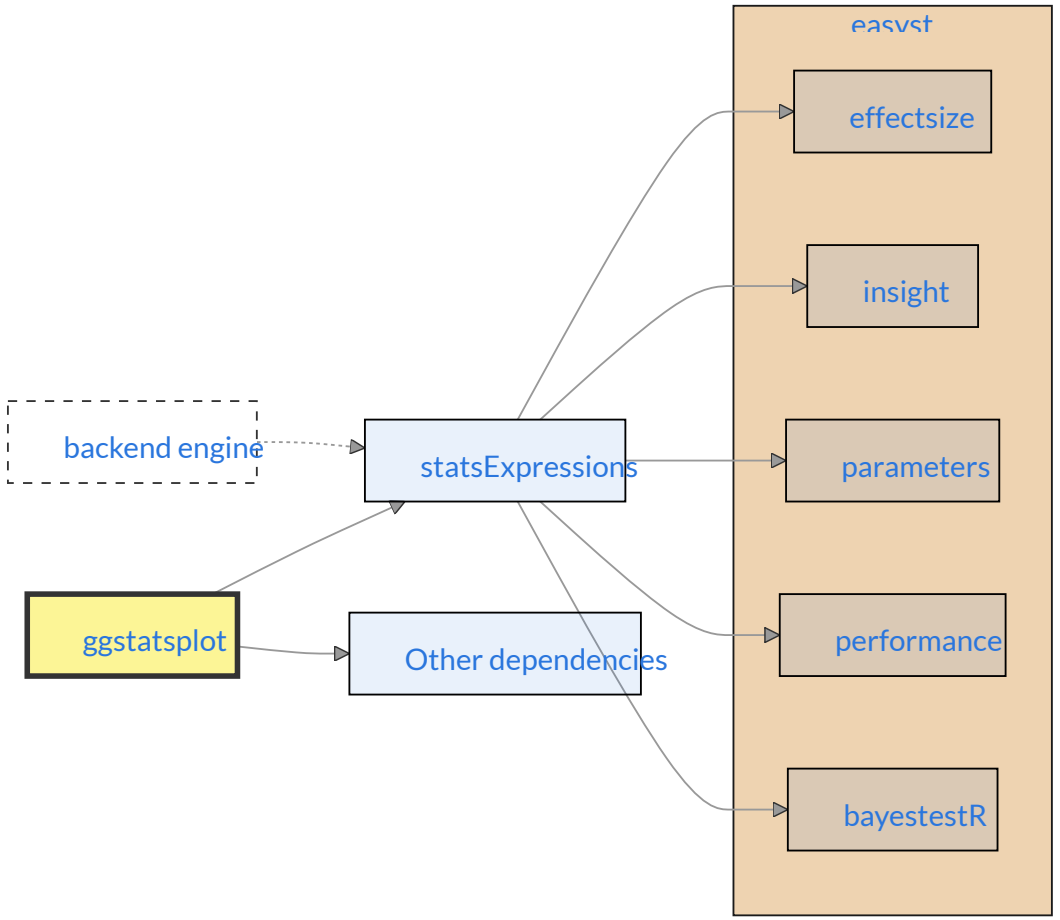
Improving Psychological Science Award (2020)

Pleasant Side Effects

Maybe the real treasure was the skills we acquired along the way!

Software Architecture

Breaking down the monolith: $20K_{(2017)} \rightarrow 1K_{(2024)}$ lines of code



Collaborative Solutions

While re-architecting `{ggstatsplot}`, I started contributing upstream.

As part of `{easystats}` core team

- leadership skills to steer the project
- long-term vision for the project
- API design
- CI infrastructure
- code review
- documentation
- scouting for new talent
- developer advocacy
- community engagement

Making it a habit

- co-maintainer of `{ggsignif}`
- contributor to `{WRS2}`, `{ggcorrplot}`
- co-author of `{lintr}` (linter for R)
- co-author of `{styler}` (code formatter)

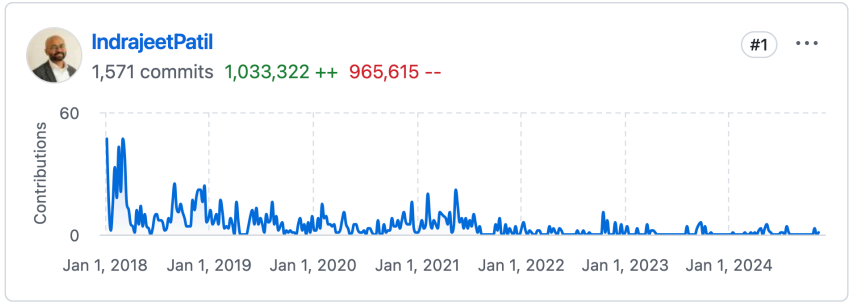
Quality Assurance

> *"The only way to go fast, is to go well."*
> - Robert C. Martin

CI Checks (GitHub Actions)

- Unit tests (random-order)
- Code coverage (100%)
- Linting (0 lints)
- Formatting (0 issues)
- Documentation (website, no link rot, plenty examples)
- Pre-commit hooks (0 issues)
- Zero user-facing warnings
- Portability (Linux, macOS, Windows)
- Robustness (dependencies, language versions)
- CRAN checks (0 notes, 0 warnings, 0 errors)

Healthy and active code base



Communication

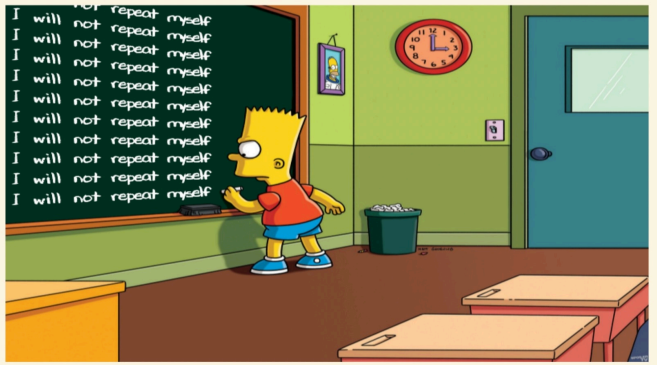
Training material on best practices in software/package development to support community contributions keeping in mind the diverse backgrounds of contributors.

Preventive Care for R Packages

Indrajeet Patil

DRY PACKAGE DEVELOPMENT IN R

Indrajeet Patil



Dealing with the Second Hardest Thing in Computer Science

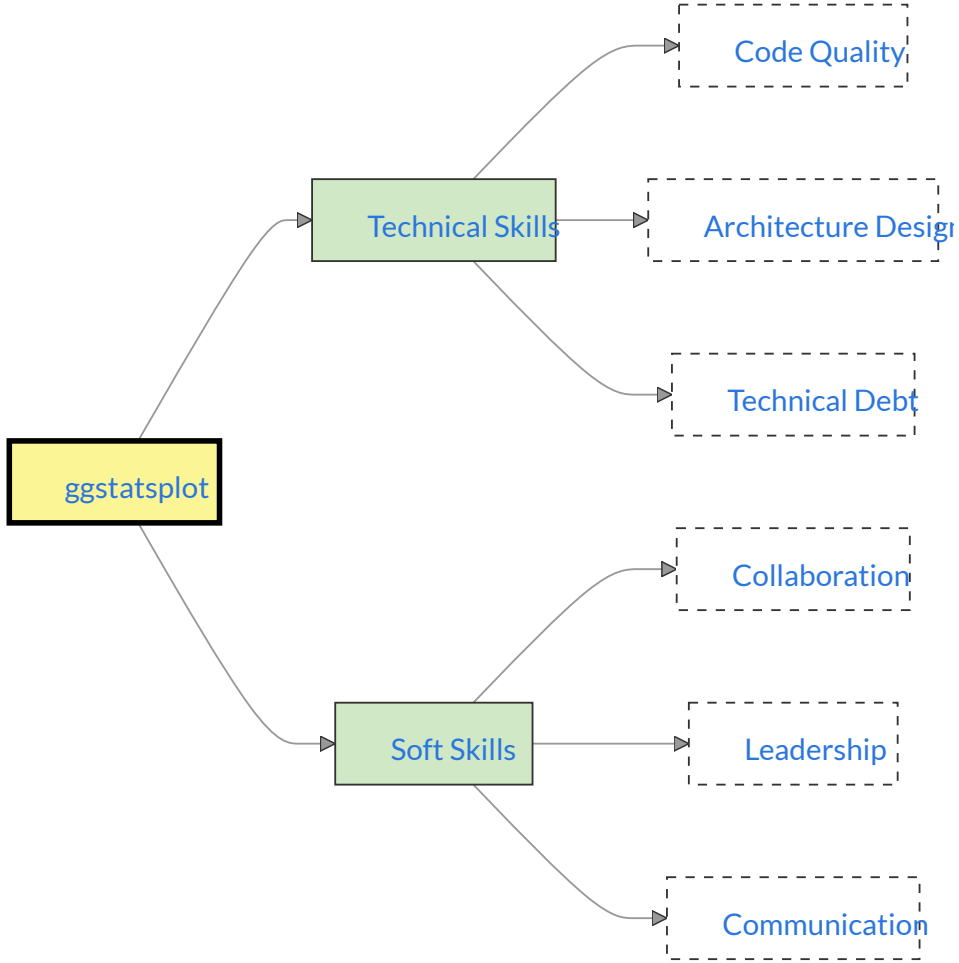
Indrajeet Patil

Introduction to Snapshot Testing in R

Indrajeet Patil

Biography (2017-)

(Or how developing `{ggstatsplot}` continues to help me grow as a software developer)



Conclusion

`{ggstatsplot}` offers an intuitive interface for creating detailed statistical visualizations, enabling users to adopt rigorous, reliable, and robust workflows for data exploration and reporting across various academic and industrial disciplines. It is a well-maintained tool with high-quality infrastructure and widespread adoption.

Thank You 

Source code for these slides can be found on GitHub.

For more

If you are interested in good programming and software development practices, check out my other slide decks.

Find me at...

 Twitter

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 GitHub

 Website

 E-mail

Session information

```
sessioninfo::session_info(include_base = TRUE)
```

Appendix

Examples of other functions

`ggwithinstats()`

Hypothesis about group differences: repeated measures design

```
ggwithinstats(
  data = WRS2::WineTasting,
  x = Wine,
  y = Taste
)
```

Important

✏️ **Defaults**

- raw data + distributions
- descriptive statistics
- inferential statistics
- effect size + uncertainty
- pairwise comparisons
- Bayesian hypothesis-testing
- Bayesian estimation

Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

`gghistostats()`

Distribution of a numeric variable

```
gghistostats(
  data = movies_long,
  x = budget,
  test.value = 30
)
```

Important

✏️ **Defaults**

- counts + proportion for bins
- descriptive statistics
- inferential statistics
- effect size + uncertainty
- pairwise comparisons
- Bayesian hypothesis-testing
- Bayesian estimation

Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

`ggdotplotstats()`

Labeled numeric variable

```
ggdotplotstats(
  data = movies_long,
  x = budget,
  y = genre,
  test.value = 30
)
```

Important

✏️ **Defaults**

- descriptive statistics
- inferential statistics
- effect size + uncertainty
- pairwise comparisons
- Bayesian hypothesis-testing
- Bayesian estimation

Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

`ggscatterstats()`

Hypothesis about correlation: Two numeric variables

```
ggscatterstats(
  data = movies_long,
  x = budget,
  y = rating
)
```

Important

✏️ **Defaults**

- joint distribution
- marginal distribution
- effect size + uncertainty
- pairwise comparisons
- Bayesian hypothesis-testing
- Bayesian estimation

Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

`ggcorrmat()`

Hypothesis about correlation: Multiple numeric variables

```
1  ggcorrmat(dplyr::starwars)
```

Important

✏️ **Defaults**

- inferential statistics
- effect size + uncertainty
- careful handling of `NA`s
- partial correlations

Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

`ggpiestats()`

Hypothesis about composition of categorical variables

```
ggpiestats(
  data = mtcars,
  x = am,
  y = cyl
)
```

Important

Defaults

- descriptive statistics
- inferential statistics
- effect size + uncertainty
- goodness-of-fit tests
- Bayesian hypothesis-testing
- Bayesian estimation

`ggbarstats()`

Hypothesis about composition of categorical variables

```
ggbarstats(
  data = mtcars,
  x = am,
  y = cyl
)
```

Important

✏️ **Defaults**

- descriptive statistics
- inferential statistics
- effect size + uncertainty
- goodness-of-fit tests
- Bayesian hypothesis-testing
- Bayesian estimation

`ggcoefstats()`

Hypothesis about regression coefficients

```
mod <- lm(
  formula = rating ~ mpaa,
  data = movies_long
)

ggcoefstats(mod)
```

Important

✏️ **Defaults**

- estimate + uncertainty
- inferential statistics (t, z, F, χ^2)
- model fit indices (AIC + BIC)

Supports all regression models supported in `{easystats}` ecosystem.

Meta-analysis is also supported!

*grouped_* variants

Iterating over a grouping variable

*grouped_* functions

```
grouped_ggpiestats(
  data = mtcars,
  x = cyl,
  grouping.var = am
)
```

Available `grouped_` variants:

- `grouped_ggbetweenstats()`
- `grouped_ggwithinstats()`
- `grouped_gghistostats()`
- `grouped_ggdotplotstats()`
- `grouped_ggscatterstats()`
- `grouped_ggcorrmat()`
- `grouped_ggpiestats()`
- `grouped_ggbarstats()`

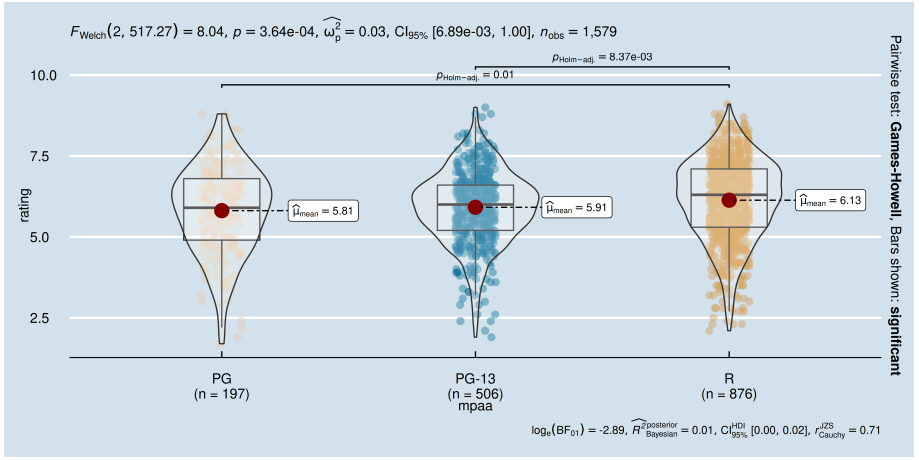
Customizability

“What if I don’t like the default plots?” 🤔

Modify the look 🎨

By changing **theme** and **palette**

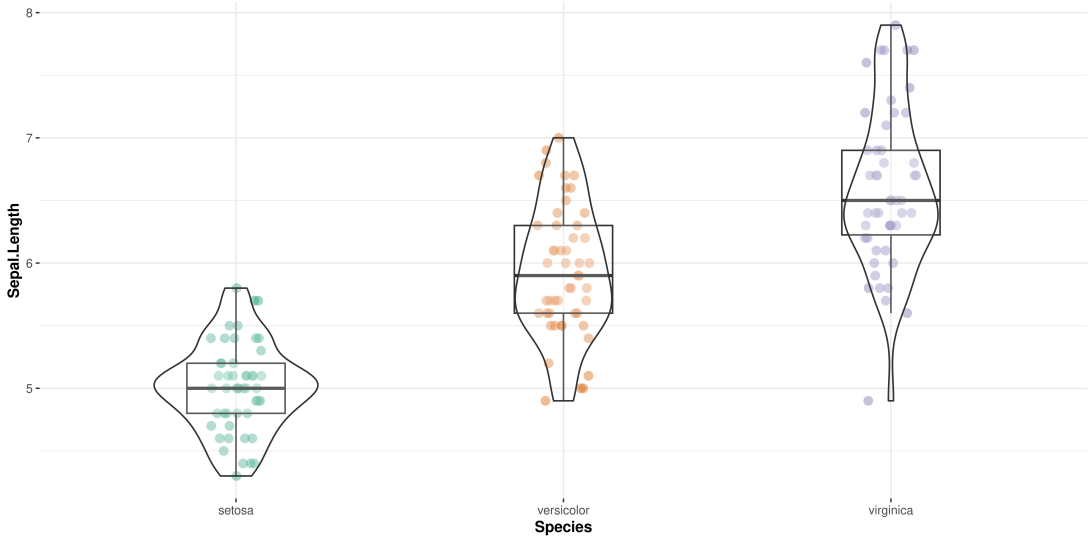
```
ggbetweenstats(
  data = movies_long,
  x = mpaa,
  y = rating,
  ggtheme = ggthemes::theme_economist(),
  palette = "Darjeeling2",
  package = "wesanderson"
)
```



Too much information 🙈

Get **only plots**:

```
ggbetweenstats(
  data = iris,
  x = Species,
  y = Sepal.Length,
  # turn off statistical analysis
  centrality.plotting = FALSE,
  results.subtitle = FALSE,
  bf.message = FALSE,
  # turn off pairwise comparisons
  pairwise.display = "none"
)
```



`{ggstatsplot}`: Details about statistical reporting

Supports different statistical approaches

Note

Functions	Description	Parametric	Non-parametric	Robust	Bayesian
`ggbetweenstats()`	Between group comparisons	✅	✅	✅	✅
`ggwithinstats()`	Within group comparisons	✅	✅	✅	✅
`gghistostats()`, `ggdotplotstats()`	Distribution of a numeric variable	✅	✅	✅	✅
`ggcorrmat()`	Correlation matrix	✅	✅	✅	✅
`ggscatterstats()`	Correlation between two variables	✅	✅	✅	✅
`ggpiestats()`, `ggbarstats()`	Association between categorical variables	✅	NA	NA	✅
`ggpiestats()`, `ggbarstats()`	Equal proportions for categorical variable levels	✅	NA	NA	✅
`ggcoefstats()`	Regression modeling	✅	✅	✅	✅
`ggcoefstats()`	Random-effects meta-analysis	✅	NA	✅	✅

Toggling statistical approaches 🔀

Parametric

```r
# anova
ggbetweenstats(
  data = mtcars,
  x = cyl,
  y = wt,
  type = "p"
)

# correlation analysis
ggscatterstats(
  data = mtcars,
  x = wt,
  y = mpg,
  type = "p"
)

# t-test
gghistostats(
  data = mtcars,
  x = wt,
  test.value = 2,
  type = "p"
)
```

Non-parametric

```r
# anova
ggbetweenstats(
  data = mtcars,
  x = cyl,
  y = wt,
  type = "np"
)

# correlation analysis
ggscatterstats(
  data = mtcars,
  x = wt,
  y = mpg,
  type = "np"
)

# t-test
gghistostats(
  data = mtcars,
  x = wt,
  test.value = 2,
  type = "np"
)
```

Alternative: Pure Pain

🚧 Hunting for packages

- 📦 for inferential statistics (`{stats}`)
- 📦 computing effect size + CIs (`{effectsize}`)
- 📦 for descriptive statistics (`{skimr}`)
- 📦 pairwise comparisons (`{multcomp}`)
- 📦 Bayesian hypothesis testing (`{BayesFactor}`)
- 📦 Bayesian estimation (`{bayestestR}`)
- 📦 …

🚧 Inconsistent APIs

- 🤔 accepts data frame, vector, matrix?
- 🤔 long/wide format data?
- 🤔 works with `NA`s?
- 🤔 returns data frame, vector, matrix?
- 🤔 works with tibbles?
- 🤔 has all necessary details?
- 🤔 …

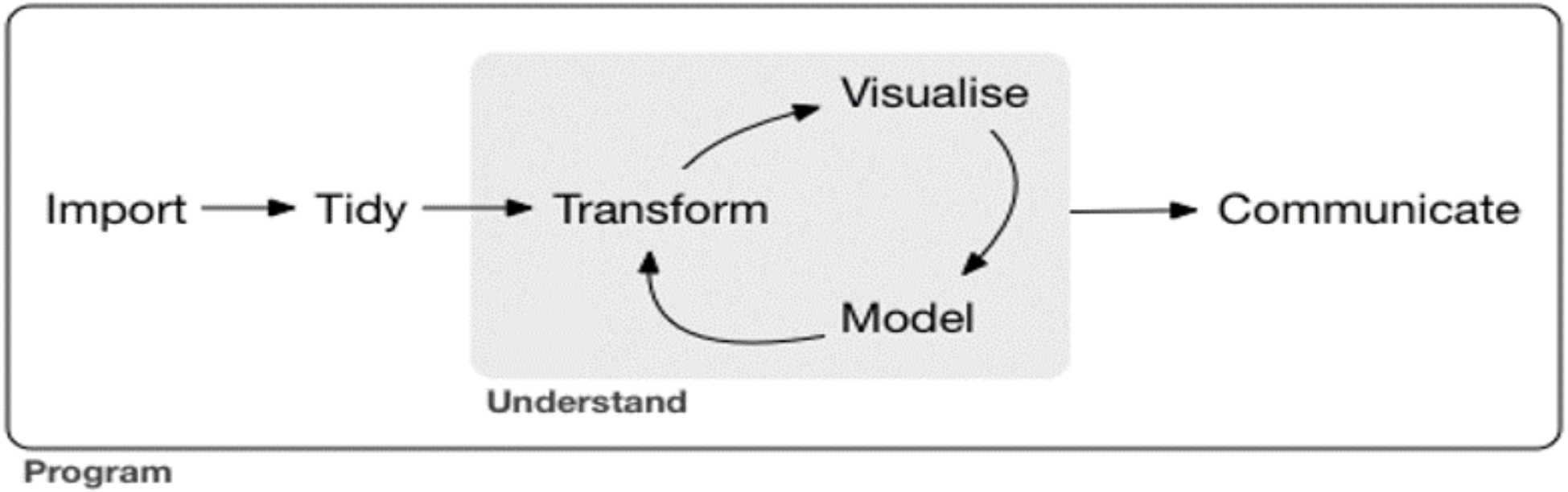
Benefits in details

`{ggstatsplot}` combines data visualization and statistical analysis in a single step.

It...

- provides ready-made plots with information-rich defaults
- minimizes the chances of making errors in statistical reporting
- follows best practices in data visualization and statistical reporting
- helps evaluate statistical analysis in the context of the underlying data
- highlights the importance of the effect by providing effect size measures
- provides an easy way to evaluate *absence* of an effect using Bayesian framework
- extremely beginner-friendly

Simplified data analysis workflow



✅ Quick insight into data by combining visualization and modeling!

(Grolemund & Wickham, *R for Data Science*, 2017)

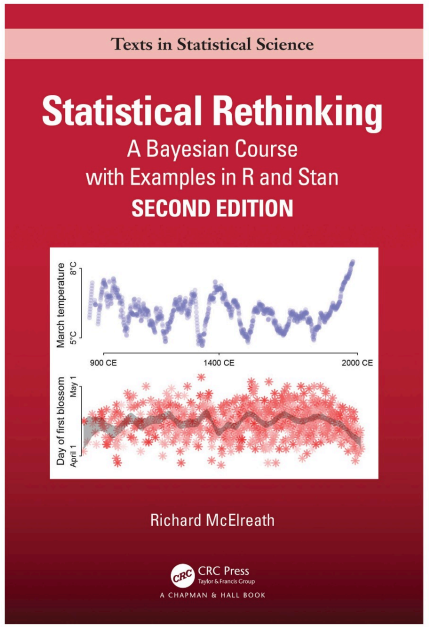
Community Involvement

- 11 contributors
- 3 reverse dependencies
- Widely covered in YouTube videos and social media posts
- Almost 100% resolution rate on StackOverflow (> 150 questions)
- Over 100 daily visitors on GitHub repo
- Usage in a wide range of fields: psychology, biology, medicine, economics, etc.
- Usage in data science training programs

A grain of salt

The "Golem of Prague" problem

❌ Promotes mindless application of statistical tests.



No stable release yet.

Footnotes

1. (Nuijten et al., *Behavior Research Methods*, 2016)

2. (Aczel et al., *AMPPS*, 2018)

3. Open Science Collaboration, *Science*, 2015