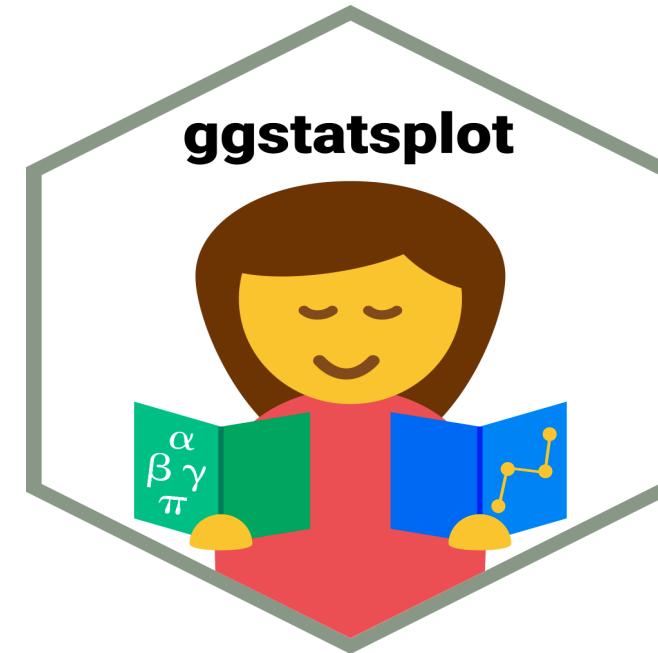


# Statistical Visualizations with `{ggstatsplot}`: A Biography

Indrajeet Patil



# **Genesis**

**Why a new software?**

(Or why did a social psychologist get into software development?)

# 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”<sup>1</sup>

- **Interpretation errors:**

“in 72% of cases, nonsignificant results were misinterpreted [to mean] that effect was absent”<sup>2</sup>

- **Replication crisis:**

“39% of effects were subjectively rated to have replicated the original result”<sup>3</sup>

and more...

## ⚠ Internal Response



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

# 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!

# 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

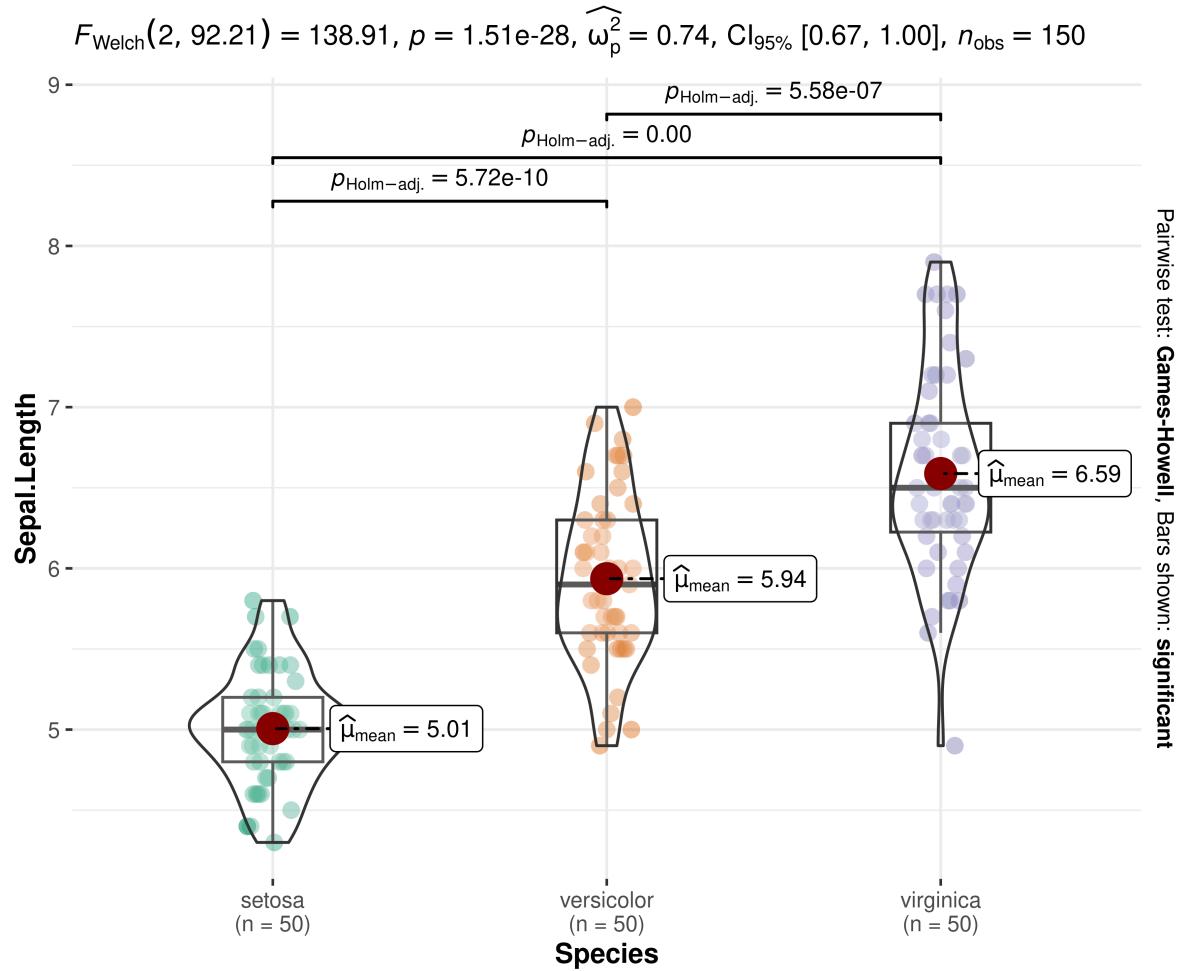
{ggstatsplot} was born!

(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

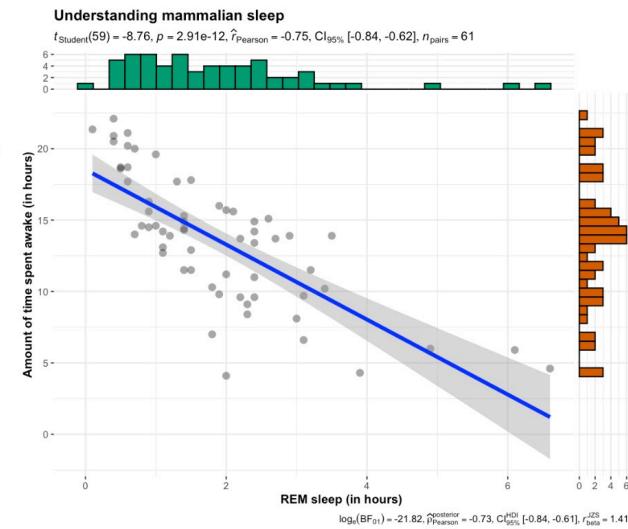
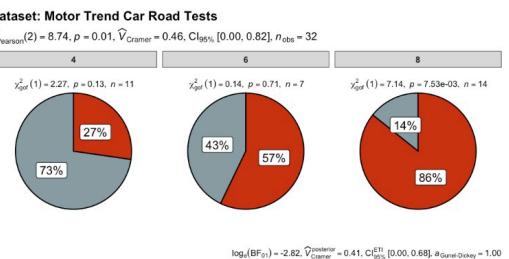
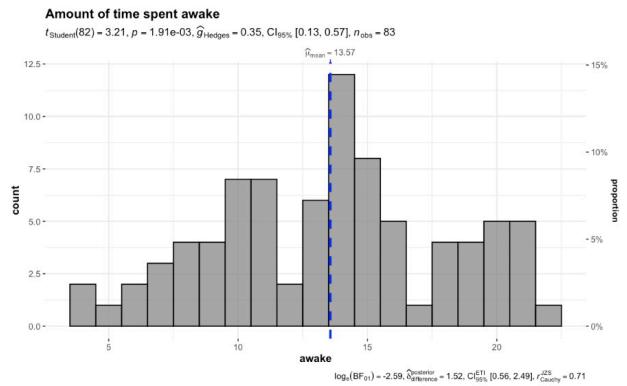
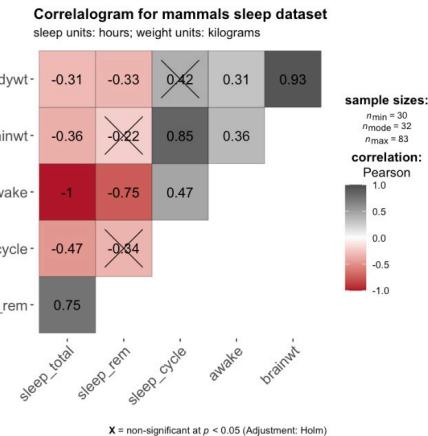
### Information-rich defaults

- 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!

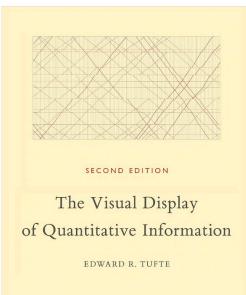
# Thoughtful Defaults

## >Data Visualization

Second Edition  
Show Me the Numbers  
Designing Tables and Graphs to Enlighten



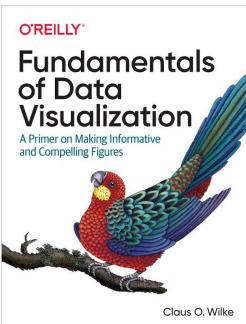
Stephen Few



SECOND EDITION  
The Visual Display  
of Quantitative Information  
EDWARD R. TUFTÉ



THE  
ELEMENTS  
OF GRAPHING  
DATA



O'REILLY®  
Fundamentals  
of Data  
Visualization  
A Primer on Making Informative  
and Compelling Figures

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

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

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

src: @patilindrajeets

(Doorn et al., 2020; APA Manual)



Follows best practices in data visualization and statistical reporting!

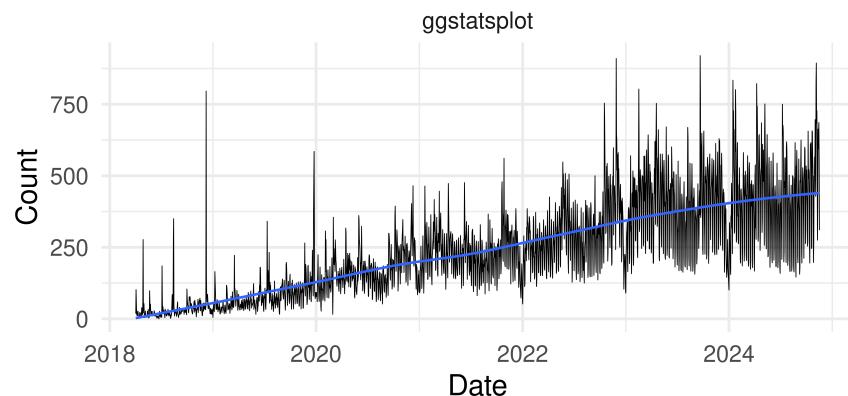
# Impact

*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.



The Journal of Open Source Software

Visualizations with statistical details: The 'ggstatsplot' approach

Indrajeet Patil<sup>1</sup>

<sup>1</sup> Center for Humans and Machines, Max Planck Institute for Human Development, Berlin, Germany

DOI: [10.21105/joss.03167](https://doi.org/10.21105/joss.03167)

Software

- Review ↗
- Repository ↗
- Archive ↗

Editor: Charlotte Soneson ↗

Reviewers:

- @njtierney
- @kevinrue

Submitted: 30 March 2021

Published: 25 May 2021

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.

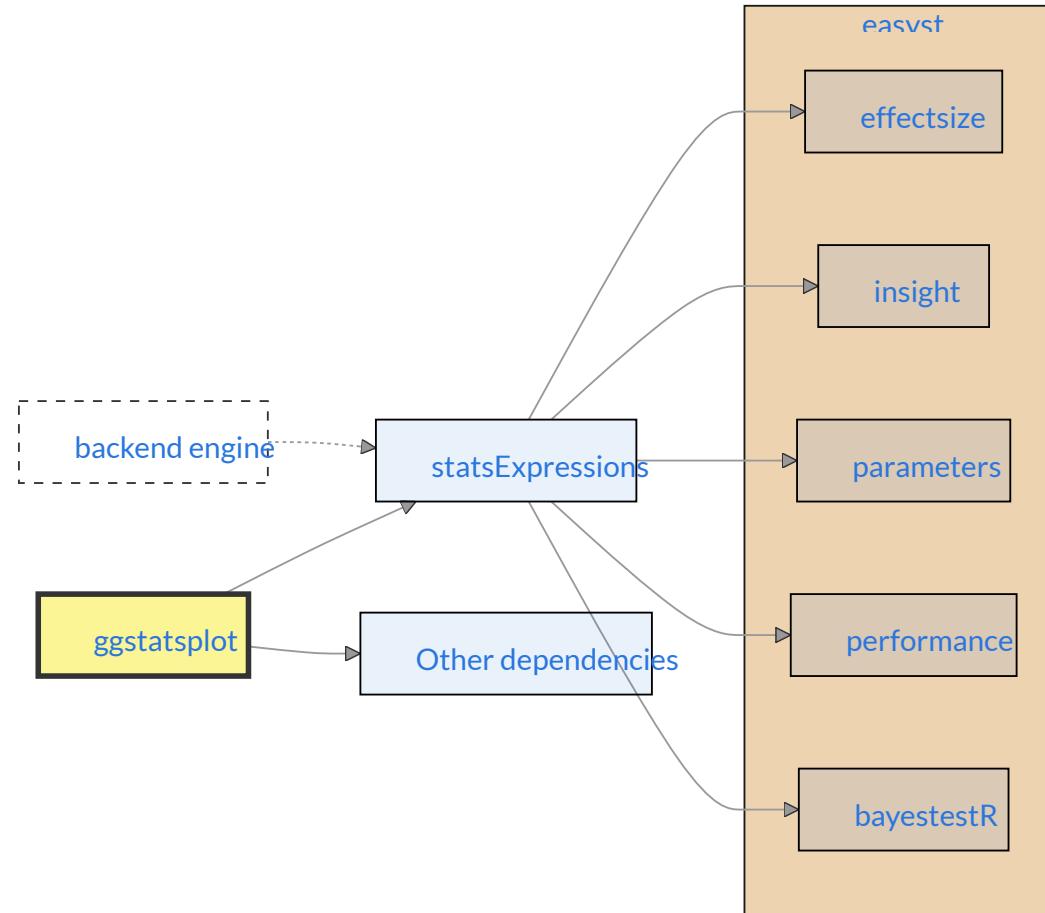
Improving Psychological Science Award (2020)

# 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



# Open-source involvement

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

## *i* 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}` and `{ggcorrplot}`
- co-author of `{lintr}` (linter for R)
- co-author of `{styler}` (tidyverse style)

# 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



All checks have passed

24 successful checks

Show all checks

# Communication

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

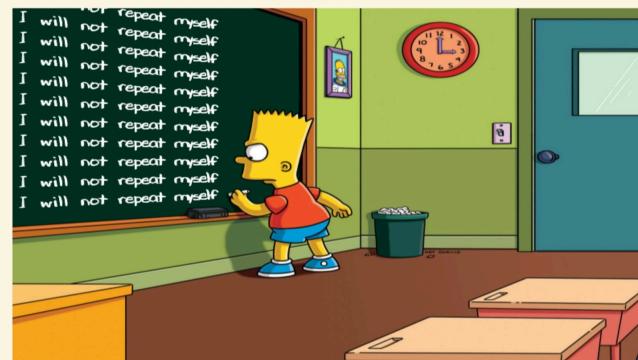
## Preventive Care for R Packages

Indrajeet Patil



## DRY PACKAGE DEVELOPMENT IN R

Indrajeet Patil



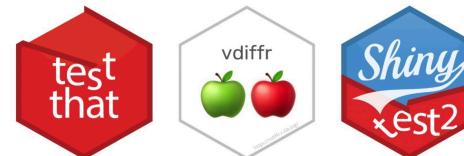
## Dealing with the Second Hardest Thing in Computer Science

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

 LinkedIn

 GitHub

 Website

 E-mail

# Session information

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

-- Session info --
setting  value
version  R version 4.4.2 (2024-10-31)
os        Ubuntu 22.04.5 LTS
system   x86_64, linux-gnu
hostname fv-az1501-188
ui        X11
language (EN)
collate  C.UTF-8
ctype    C.UTF-8
tz       UTC
date     2024-11-17
pandoc   3.5 @ /opt/hostedtoolcache/pandoc/3.5/x64/ (via rmarkdown)
quarto   1.6.36 @ /usr/local/bin/quarto

-- Packages --
package      * version    date (UTC) lib source
base          * 4.4.2      2024-10-31 [3] local
BayesFactor    0.9.12-4.7 2024-01-24 [1] RSPM
bayestestR     0.15.0     2024-10-17 [1] RSPM
[1] . . . . .
```

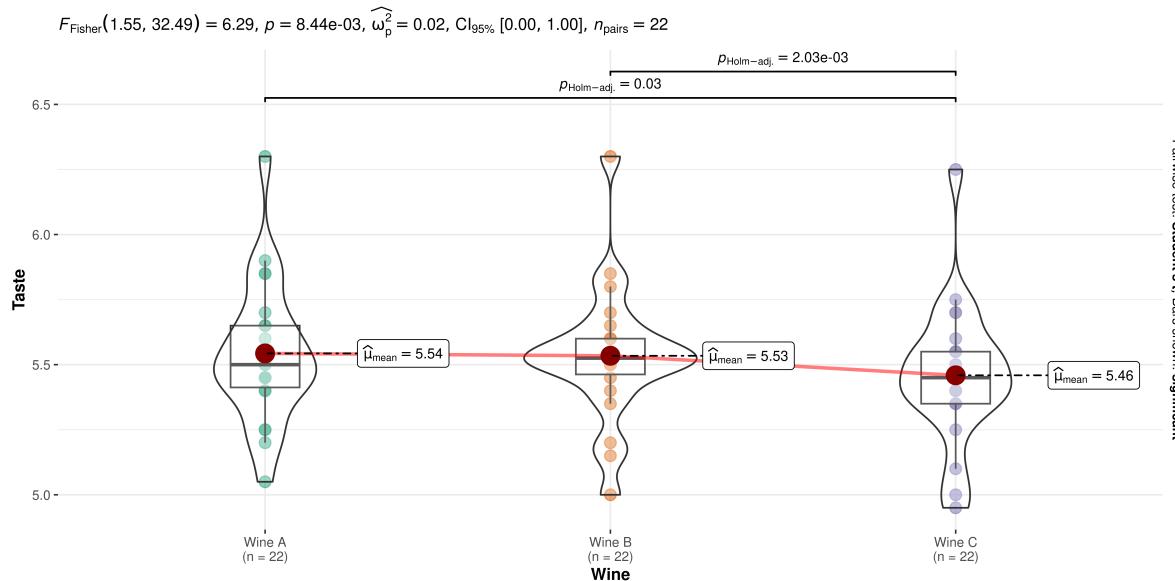
# Appendix

# Examples of other functions

# ggwithinstats()

Hypothesis about group differences: repeated measures design

```
1 ggwithinstats(  
2   data = WRS2::WineTasting,  
3   x = Wine,  
4   y = Taste  
5 )
```



## ! Important

## Defaults

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

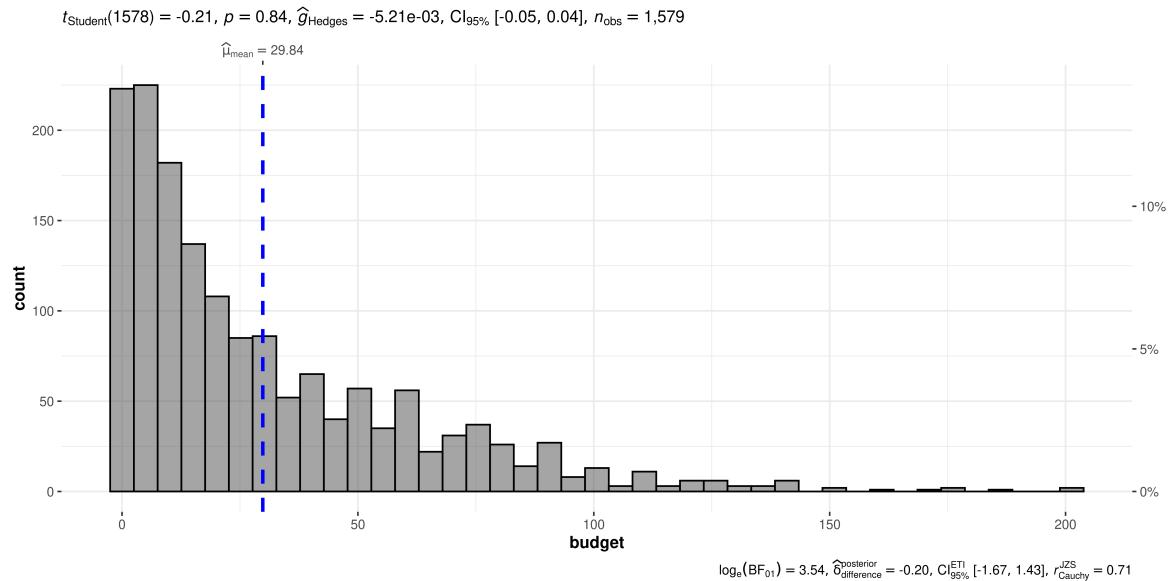
## Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

# gghistostats()

Distribution of a numeric variable

```
1 gghistostats(  
2   data = movies_long,  
3   x = budget,  
4   test.value = 30  
5 )
```



## ! Important

### Defaults

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

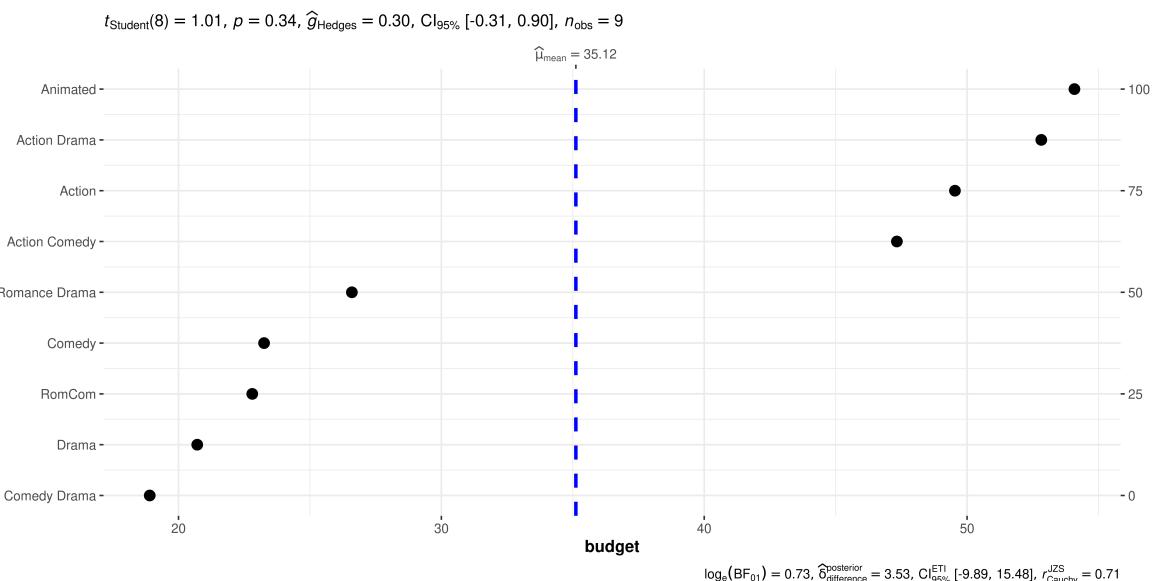
### Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

# ggdotplotstats()

## Labeled numeric variable

```
1 ggdotplotstats(  
2   data = movies_long,  
3   x = budget,  
4   y = genre,  
5   test.value = 30  
6 )
```



### ! Important

#### Defaults

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

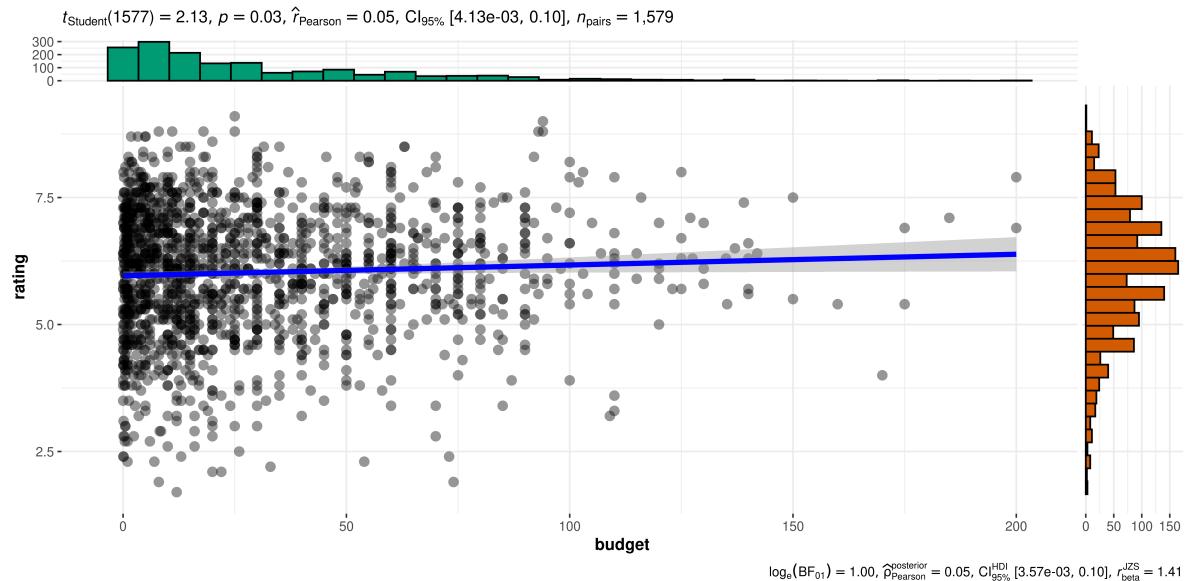
#### Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

# ggscatterstats()

Hypothesis about correlation: Two numeric variables

```
1 ggscatterstats(  
2   data = movies_long,  
3   x = budget,  
4   y = rating  
5 )
```



## ! Important

### Defaults

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

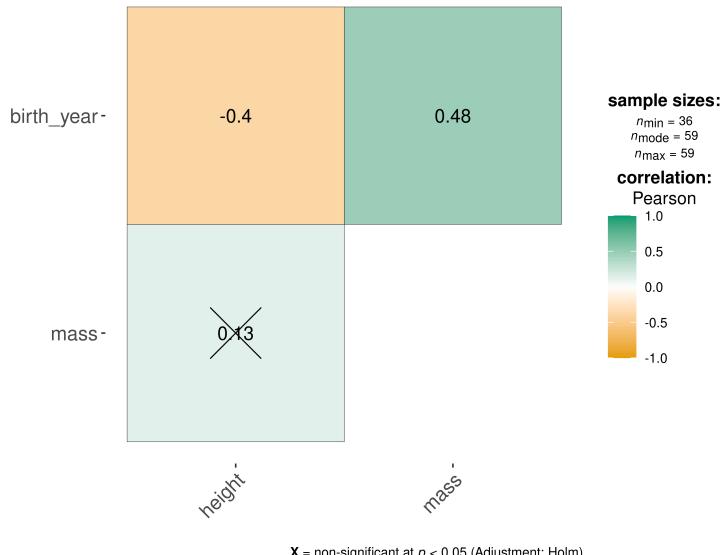
### Statistical approaches available

- 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 [NAs](#)
- partial correlations

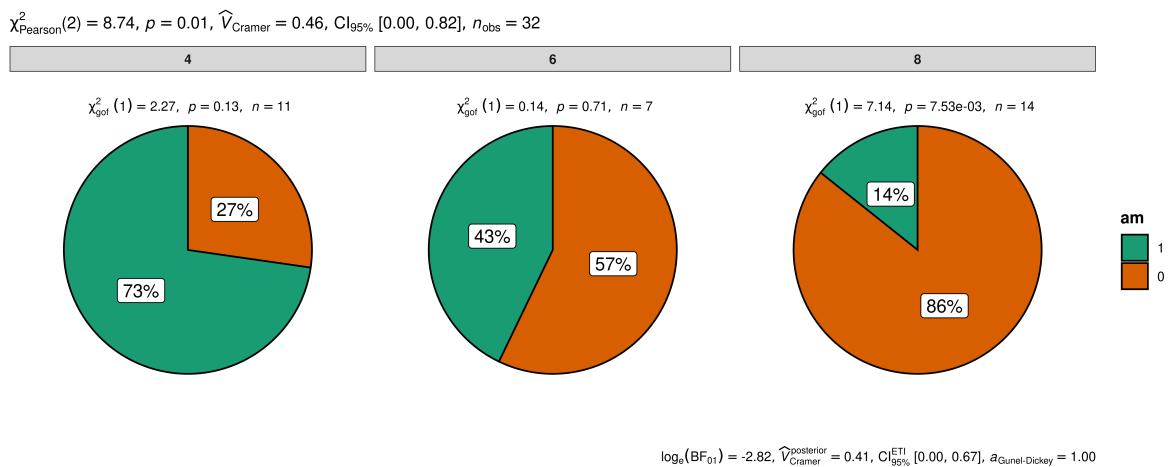
### Statistical approaches available

- parametric
- parametric
- robust
- Bayesian

# ggpiestats()

Hypothesis about composition of categorical variables

```
1 ggpiestats(  
2   data = mtcars,  
3   x = am,  
4   y = cyl  
5 )
```



## ! Important

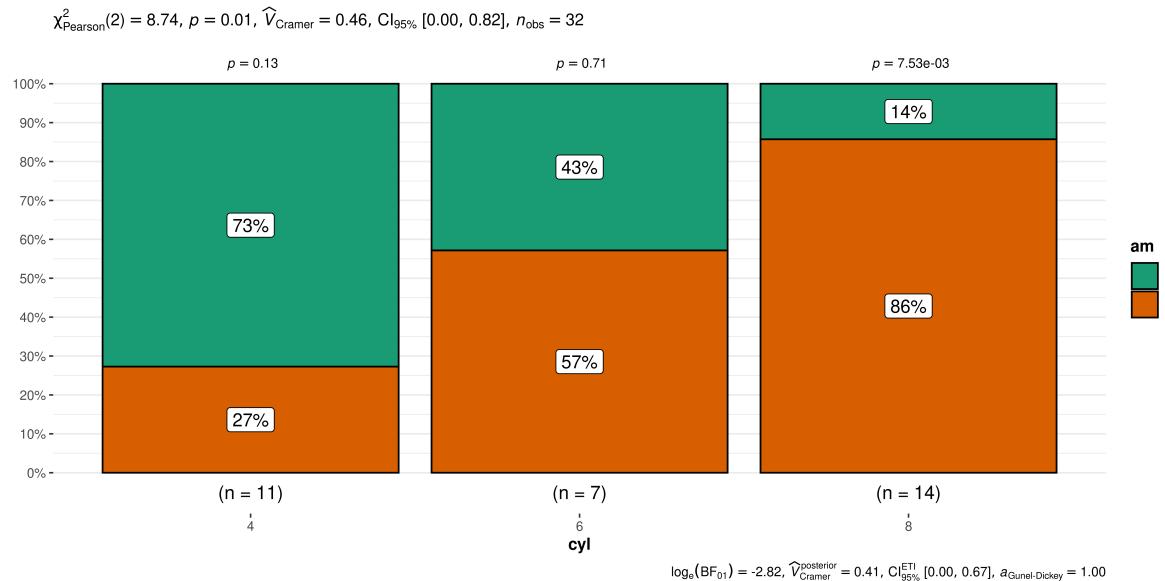
### Defaults

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

# ggbarnstats()

Hypothesis about composition of categorical variables

```
1 ggbarnstats(  
2   data = mtcars,  
3   x = am,  
4   y = cyl  
5 )
```



## ! Important

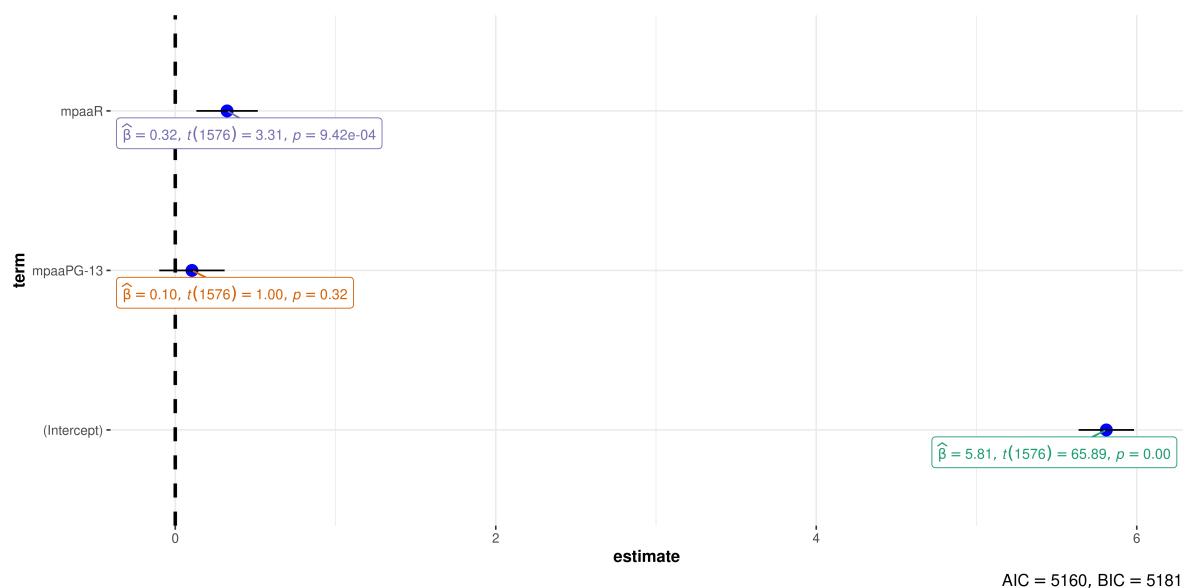
### Defaults

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

# ggcoefstats()

## Hypothesis about regression coefficients

```
1 mod <- lm(  
2   formula = rating ~ mpaa,  
3   data = movies_long  
4 )  
5  
6 ggcoefstats(mod)
```



### ! Important

#### Defaults

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

Supports all regression models supported in `{easy stats}` ecosystem.

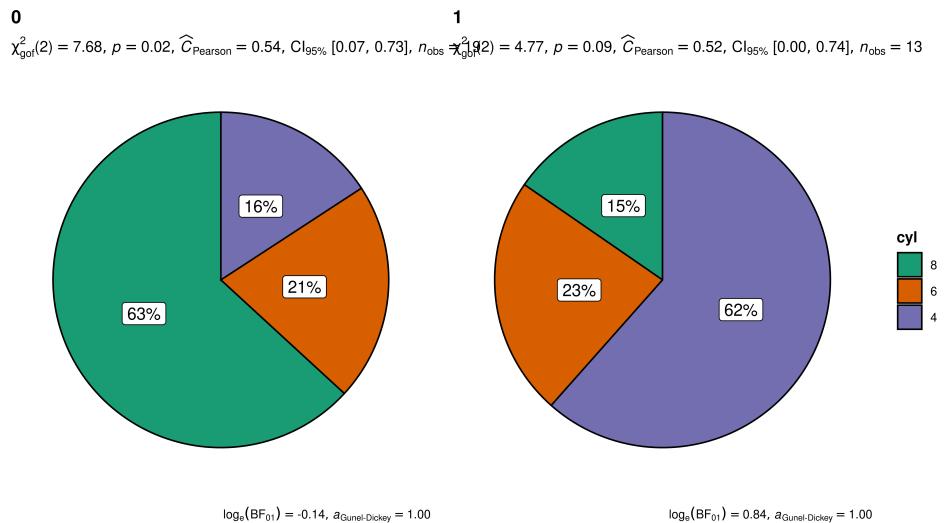
Meta-analysis is also supported!

# *grouped\_* variants

Iterating over a grouping variable

# *grouped\_* functions

```
1 grouped_ggpiestats(  
2   data = mtcars,  
3   x = cyl,  
4   grouping.var = am  
5 )
```



## Available **grouped\_** variants:

- [grouped\\_ggbetweenstats\(\)](#)
- [grouped\\_ggwithinstats\(\)](#)
- [grouped\\_gghistostats\(\)](#)
- [grouped\\_ggdotplotstats\(\)](#)
- [grouped\\_ggscatterstats\(\)](#)
- [grouped\\_ggcormat\(\)](#)
- [grouped\\_ggpiestats\(\)](#)
- [grouped\\_ggbarstats\(\)](#)

# Customizability

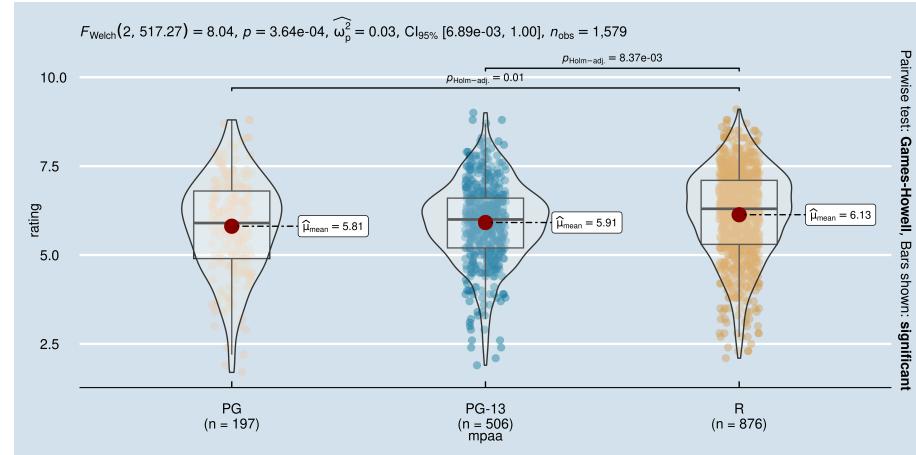
“What if I don’t like the default plots?” 🤔

# Modify the look



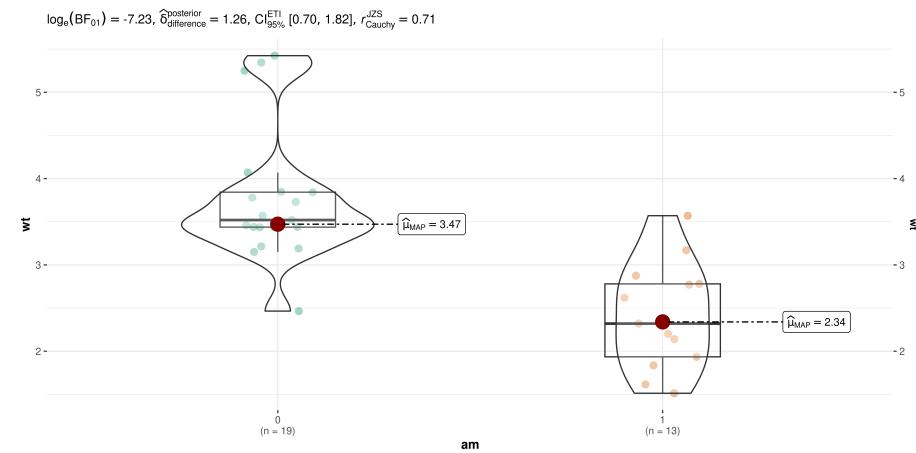
By changing **theme** and **palette**

```
1 ggbetweenstats(  
2   data = movies_long,  
3   x = mpaa,  
4   y = rating,  
5   ggtheme = ggthemes::theme_economist(),  
6   palette = "Darjeeling2",  
7   package = "wesanderson"  
8 )
```



By using `{ggplot2}` functions

```
1 ggbetweenstats(  
2   data = mtcars,  
3   x = am,  
4   y = wt,  
5   type = "bayes"  
6 ) +  
7   scale_y_continuous(sec.axis = dup_axis())
```

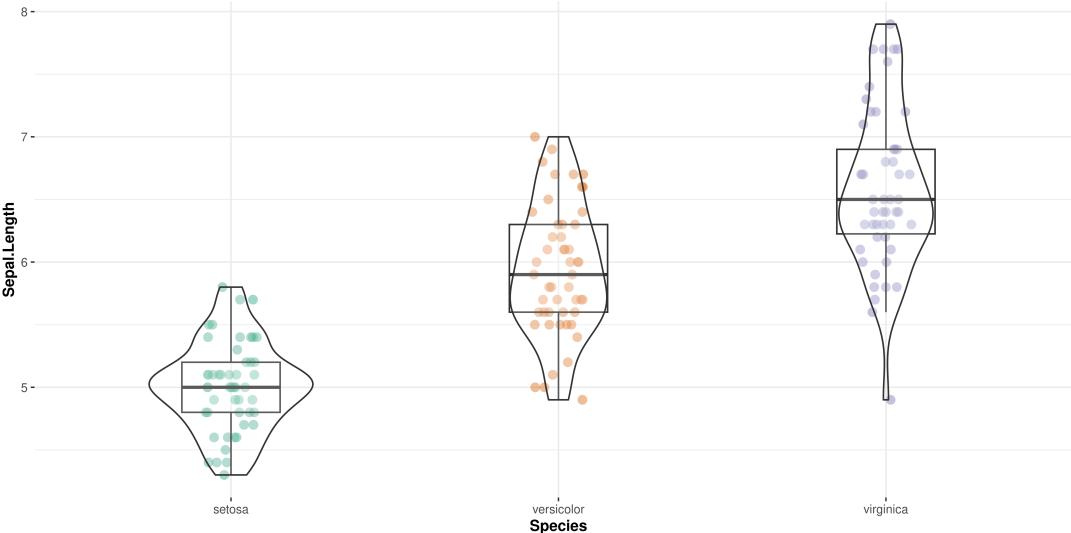


# Too much information



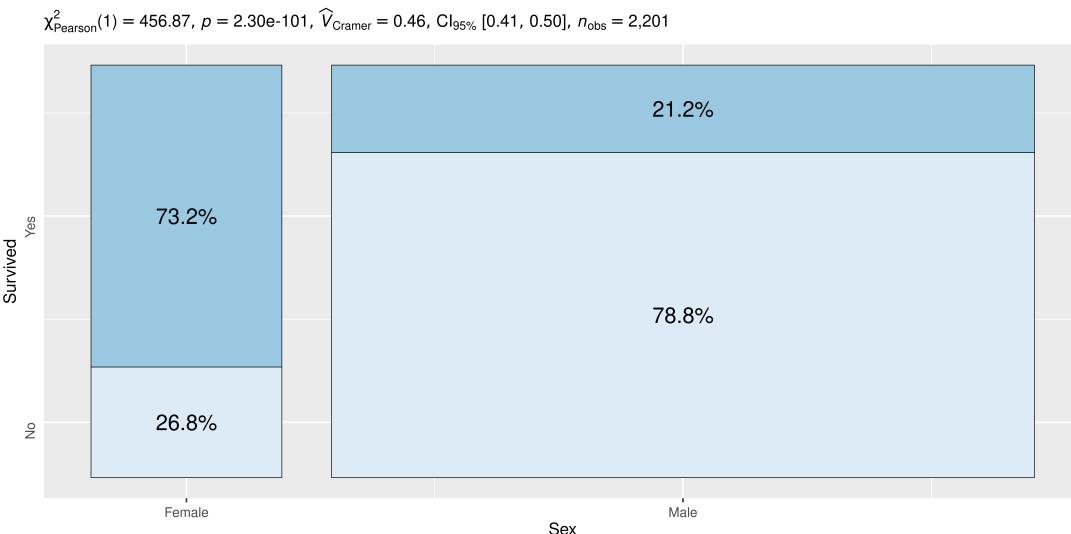
Get only plots:

```
1 ggbetweenstats(
2   data = iris,
3   x = Species,
4   y = Sepal.Length,
5   # turn off statistical analysis
6   centrality.plotting = FALSE,
7   results.subtitle = FALSE,
8   bf.message = FALSE,
9   # turn off pairwise comparisons
10 pairwise.display = "none"
11 )
```



Get only expressions:

```
1 stats_expr <- ggpiestats(
2   Titanic_full, Survived, Sex,
3 ) %>%
4   extract_subtitle()
5
6 ggiraphExtra:::ggSpine(
7   data = Titanic_full,
8   aes(x = Sex, fill = Survived)
9 ) +
10 labs(subtitle = stats_expr)
```



# {ggstatsplot}: Details about statistical reporting

# Supports different statistical approaches

## Note

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

# Toggling statistical approaches



## Parametric

```
1 # anova
2 ggbetweenstats(
3   data = mtcars,
4   x = cyl,
5   y = wt,
6   type = "p"
7 )
8
9 # correlation analysis
10 ggscatterstats(
11   data = mtcars,
12   x = wt,
13   y = mpg,
14   type = "p"
15 )
16
17 # t-test
18 gghistostats(
19   data = mtcars,
20   x = wt,
21   test.value = 2,
22   type = "p"
23 )
```

## Non-parametric

```
1 # anova
2 ggbetweenstats(
3   data = mtcars,
4   x = cyl,
5   y = wt,
6   type = "np"
7 )
8
9 # correlation analysis
10 ggscatterstats(
11   data = mtcars,
12   x = wt,
13   y = mpg,
14   type = "np"
15 )
16
17 # t-test
18 gghistostats(
19   data = mtcars,
20   x = wt,
21   test.value = 2,
22   type = "np"
23 )
```

# 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 `NAs`?
- 🤔 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!

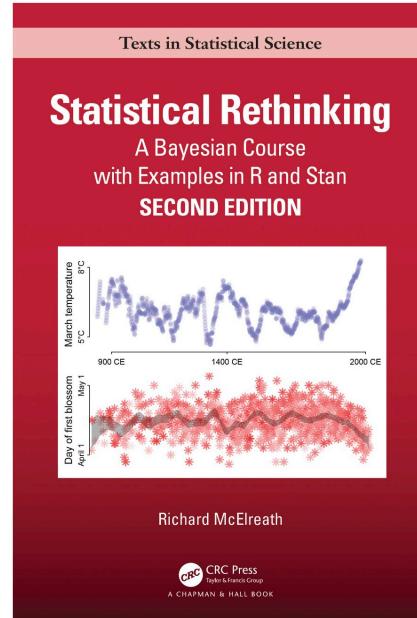
# Community Involvement

- 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