




# Visualizations with statistical details: The 'ggstatsplot' approach

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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.

## Statement of Need

In a typical data analysis workflow, data visualization and statistical modeling are two different phases: visualization informs modeling, and in turn, modeling can suggest a different visualization method, and so on and so forth ([Wickham & Grolemund, 2016](#)). The central idea of `{ggstatsplot}` is simple: combine these two phases into one in the form of an informative graphic with statistical details.

Before discussing benefits of this approach, we will show an example (Figure 1).

```
library(palmerpenguins) # for 'penguins' dataset

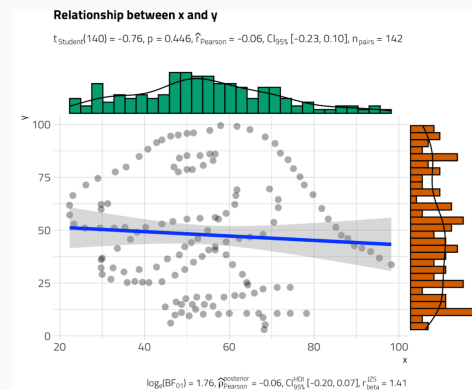
ggbetweenstats(penguins, species, body_mass_g)
#> Error in ggbetweenstats(penguins, species, body_mass_g): could not find function
```

As can be seen, with a single line of code, the function produces details about descriptive statistics, inferential statistics, effect size estimate and its uncertainty, pairwise comparisons, Bayesian hypothesis testing, Bayesian posterior estimate and its uncertainty. Moreover, these details are juxtaposed with informative and well-labeled visualizations. The defaults are designed to follow best practices in both data visualization ([Cleveland, 1985](#); [Grant, 2018](#); [Healy, 2018](#); [Tufte, 2001](#); [Wilke, 2019](#)) and (frequentist/Bayesian) statistical reporting ([American Psychological Association, 2019](#); [van Doorn et al., 2020](#)). Without `{ggstatsplot}`, getting these statistical details and customizing a plot would require significant amount of time and effort. In other words, this package removes the trade-off often faced by researchers between ease and thoroughness of data exploration and further cements good data exploration habits.

#### Standard approach

Pearson's correlation test revealed that, across 142 participants, variable  $x$  was negatively correlated with variable  $y$ :  $t(140) = -0.76, p = .446$ . The effect size ( $r = -0.06, 95\%CI[-.23, .10]$ ) 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  $y$ ).

#### ggstatsplot approach



**Figure 1:** Comparing the 'Standard' approach of reporting statistical analysis in a publication/report with the 'ggstatsplot' approach of reporting the same analysis next to an informative graphic. Note that the results described in the 'Standard' approach are about the 'Dinosaur' dataset plotted on the right. Without the accompanying visualization, it is hard to evaluate the validity of the results. The ideal reporting practice will be a hybrid of these two approaches where the plot contains both the visual and numerical summaries about a statistical model, while the narrative provides interpretative context for the reported statistics.

Internally, data cleaning is carried out using the `tidyverse` (Wickham et al., 2019), while statistical analysis is carried out via the `{statsExpressions}` (Patil, 2021) and `easystats` (Ben-Shachar et al., 2020; Lüdtke et al., 2019, 2020, 2021; Makowski et al., 2019, 2020) packages. All visualizations are constructed using the grammar of graphics framework (Wilkinson, 2012), as implemented in the `{ggplot2}` package (Wickham, 2016).

## Benefits

In summary, the benefits of `{ggstatsplot}`'s approach are the following. It:

- produces charts displaying both raw data, and numerical plus graphical summary indices,
- avoids errors in and increases reproducibility of statistical reporting,
- highlights the importance of the effect by providing effect size measures by default,
- provides an easy way to evaluate *absence* of an effect using Bayes factors,
- encourages researchers and readers to evaluate statistical assumptions of a model in the context of the underlying data (Figure 2),
- is easy and simple enough that someone with little to no coding experience can use it without making an error and may even encourage beginners to programmatically analyze data, instead of using GUI software.

## Future Scope

This package is an ambitious, ongoing, and long-term project. It currently supports common statistical tests (parametric, non-parametric, robust, or Bayesian  $t$ -test, one-way ANOVA, contingency table analysis, correlation analysis, meta-analysis, regression analyses, etc.) and corresponding visualizations (box/violin plot, scatter plot, dot-and-whisker plot, pie chart, bar chart, etc.). It will continue expanding to support an increasing collection of statistical analyses and visualizations.

## Licensing and Availability

`{ggstatsplot}` is licensed under the GNU General Public License (v3.0), with all source code stored at [GitHub](#). In the spirit of honest and open science, requests and suggestions for fixes, feature updates, as well as general questions and concerns are encouraged via direct interaction with contributors and developers by filing an [issue](#) while respecting [Contribution Guidelines](#).

## Acknowledgements

I would like to acknowledge the support of Mina Cikara, Fiery Cushman, and Iyad Rahwan during the development of this project. `{ggstatsplot}` relies heavily on the [easystats](#) ecosystem, a collaborative project created to facilitate the usage of R for statistical analyses. Thus, I would like to thank the [members](#) of [easystats](#) as well as the users. I would additionally like to thank the contributors to `{ggstatsplot}` for reporting bugs, providing helpful feedback, or helping with enhancements.

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