INSTITUTE FOR DEFENSE ANALYSES

DATAWorks 2022: Analysis Apps for the Operational Tester

Vincent Lillard, Project Leader

William Whitledge

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DATAWorks 2022: Analysis Apps for the Operational Tester

Vincent Lillard, Project Leader

William Whitledge

Executive Summary

In the world of Department of Defense (DOD) and Homeland Security (DHS) acquisition and testing, researchers and data analysts repeatedly encounter certain types of data, metrics, and research questions. For example, researchers often estimate a system's reliability as a function of usage (e.g., time or distance until a failure, alert, or detection), and they often estimate the probability that a system will detect, destroy, or survive a threat depending on range or other variables. And researchers often use surveys to assess system usability, user satisfaction, training adequacy, and other human factors related to the system's effectiveness or suitability. Although common in testing of new systems, these types of analyses are generally not trivial, quick, or easy, especially when it comes to visualizing the data intuitively.

Researchers and analysts need tools that enable them to produce *and reproduce* quality and timely analyses of the data they acquire during testing. This document includes slides and a poster describing four web-based apps designed to enable researchers to answer these types of questions or evaluate these types of metrics. The slides and poster are for presentation at the April 2022 Defense and Aerospace Test and Analysis Workshop (DATAWorks). The poster presentation will include live demonstration of the web-based apps using randomly generated imaginary data.

The apps are designed to assist analysts and researchers with simple repeatable analysis tasks, such as building summary tables and plots for reports or briefings. The first app calculates summary statistics and produces plots of groups of Likert-scale[1] survey question responses. The second calculates the system usability scale (SUS) scores[2]

[1] A Likert scale survey response is a multiple-choice numeric response (e.g., 1 through 7) indicating level of agreement or confidence with a survey question or statement. The response 1 often indicates "strong disagreement," and 7 often indicates "strong agreement."

[2] The SUS is a scale with range [0, 100]. Ten 5-point Likert scale survey questions are used to calculate a single SUS score from the questions. The SUS score is a metric of usability that is comparable across different systems. See https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/.

for SUS survey responses and lets the app user plot scores versus an independent variable. The third app fits a logistic regression model to binary data with one or two independent continuous variables as predictors. The fourth app models reliability of a system or component by fitting parametric statistical distributions to interval-to-failure data (e.g., time to failure, miles to breakdown, etc.).[3]

These four apps are a subset of about 30 interactive web-based apps and downloadable spreadsheet tools maintained by the IDA Test Science group and are available for public use on the Test Science Interactive Tools webpage https://testscience.org/interactive-tools/.[4] Figure 1 shows how to access the apps directly.[5] It is worth noting that apps and tools hosted on the Test Science Tools webpage are free, easy to use, and available to anyone with a modern web browser and Internet connection.

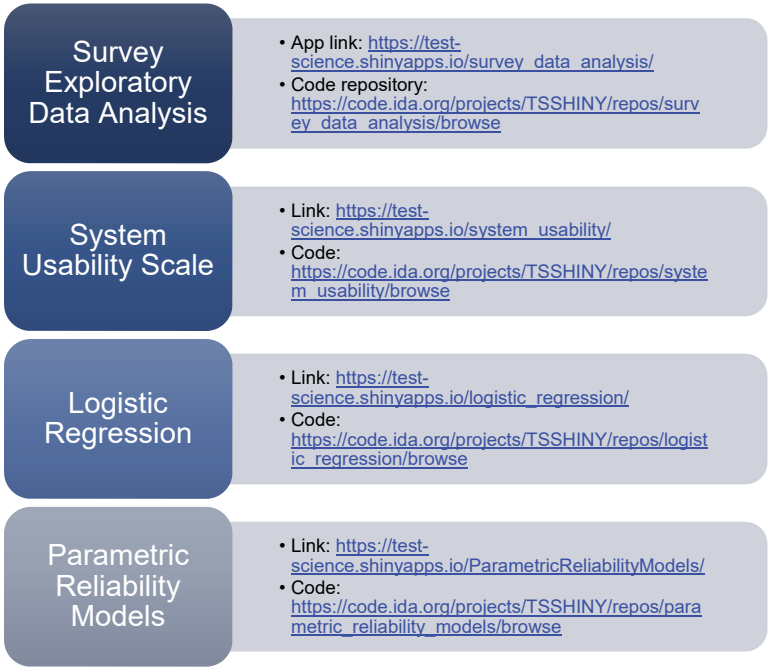

Figure 1. Four data analysis apps with locations

Using software tools like these apps can increase reproducibility and accuracy of results, timeliness of analysis and reporting, and attractiveness and standardization of aesthetics in figures. Reproducibility of

[3] The reliability app is designed to use time or interval length data to fit and plot reliability distributions. It has limited ability to plot reliability distributions based only on a parameter, such as mean time to failure or α and β.

[4] IDA Test Science applications cover topics such as reliability, Bayesian analysis, t-tests, calculating statistical power in designed experiments, and generating binomial operating characteristic curves. They are designed to be intuitive with sufficient internal documentation to enable an analyst with basic or intermediate statistical knowledge to use them.

[5] Apps are available for public use via the Internet. Source code repositories are only available for IDA-internal use at this time.

results is important, because separate analysts may need to review or modify an analysis of the same data set years or miles apart. The ability to reproduce the same result (e.g., a graph or table) increases credibility and confidence in the conclusions and recommendations drawn by the separate analysts from the common data. Timeliness and accuracy of results need no explanation, and figures and tables with standard and attractive aesthetics enable communication of results with less explanation needed.

Each app is designed to read a data table in a simple commonly-used format and produce downloadable images and spreadsheets, such as box plots, histograms, scatter plots, and tables of summary statistics. For example, the System Usability Scale app produces an output shown in Figure 2, which includes a histogram of usability scores and a table of summary statistics for data categories. The table is sortable, searchable, and filterable, and it can be downloaded as a new spreadsheet file. The user can also download the histogram in multiple image formats, such as .png, .svg, and .pdf.

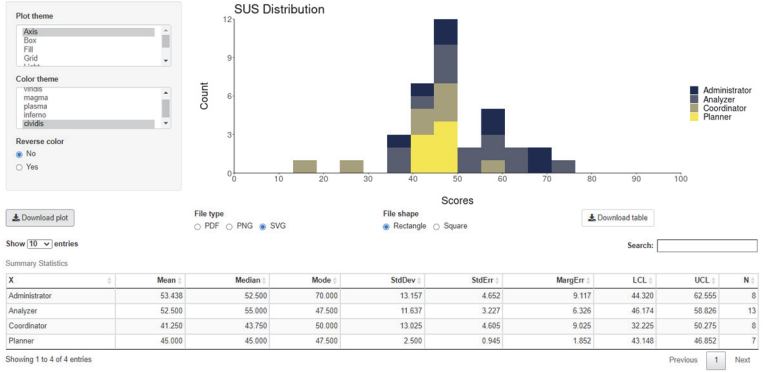

Figure 2. Sample output from System Usability Scale

Figure 3 shows an example from the Parametric Reliability Models app. This app lets the user analyze time-to-failure data and produce estimates of reliability over time like the chart shown here. This type of chart is also downloadable in the three common formats (.png, .svg, and .pdf), and the app contains features that enable the user to change chart elements such as color, labels, legends, equations, and grid lines. (Both Figure 2 and Figure 3 show plots of imaginary randomly generated data.)

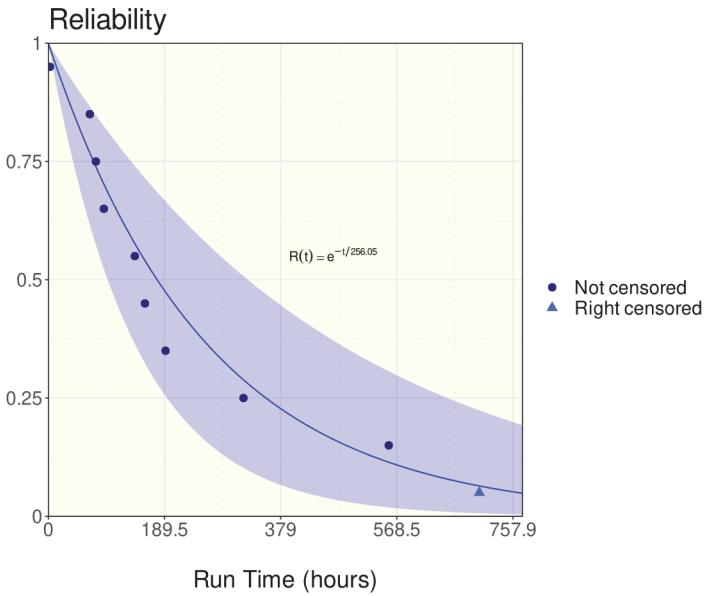

Figure 3. Sample output from Parametric Reliability Model

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Analysis Apps for the Operational Tester

William R. Whitledge

Defense and Aerospace Test and Analysis Workshop (DATAWorks)
April 26-28, 2022
Presented on April 27, 2022

Institute for Defense Analyses
730 East Glebe Road ● Alexandria, Virginia 22305

Since 2012, I have worked at IDA on test and evaluation projects for both the departments of Defense (DOD) and Homeland Security (DHS), including as an operational tester for DHS. In that time, I have repeatedly encountered certain types of data, metrics, and research questions that are analyzed during test and evaluation on acquisition programs.

This briefing describes four web-based tools that I developed to automate analyses that IDA routinely does during test and evaluation work. These tools are free, easy to use, and available for public use at IDA's Test Science Tools webpage.

https://testscience.org/interactive-tools/

Recurring research questions and data in operational testing

- Human factors
  Often measured with Likert scale survey responses

- Usability of a system or interface
  Measured with a specific Likert-like survey in which responses form a single-number metric or usability score

- Probability of success, target detection, etc.
  Estimated from binary event data: something either happens or does not

- Reliability of a system or component
  Often estimated using service tickets and other sources of event times, durations, distances traveled, etc.

One way to answer recurring research questions or analyze recurring data consistently and quickly is using tailored software tools.

```r
# Source the file 'config.R'.
source("config.R")


# 2. User Interface ----------------------------


# Source the file 'UI.R'.
source("UI.R")


# 3. Server Function ---------------------------


# Define server logic to provide the application
server <- function(input, output, session){⟺}


# 4. Execute Application -----------------------


# Run the whole R Shiny application
shinyApp(ui = ui, server = server)
```

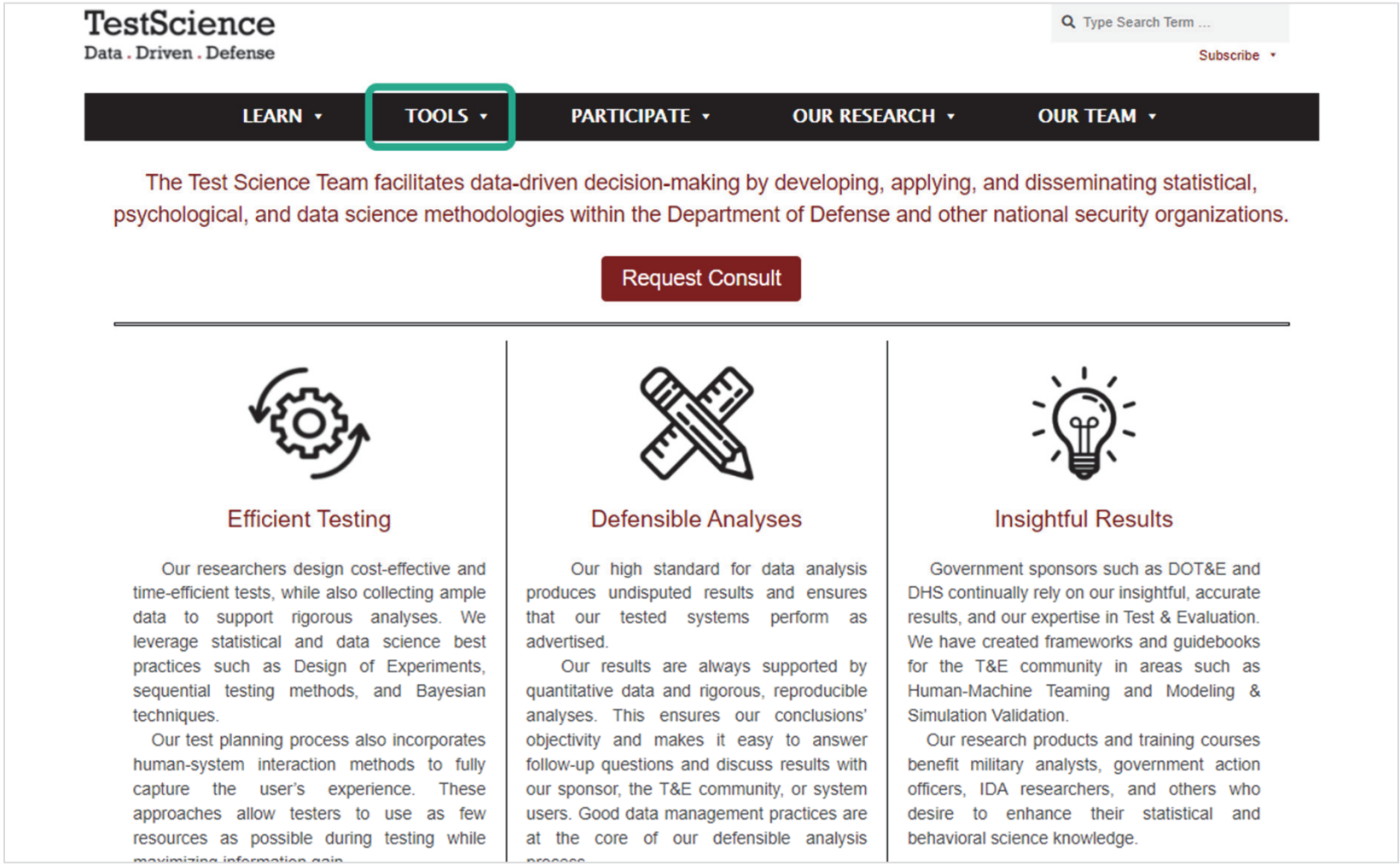
```r
# This is a function to name a plot file for downloading
download_name <- function(ID, Fshape, Ftype){
  if(Fshape == shape_values[1]){paste(ID, '_plot_rect.', switch(Ftype, pdf = dow
  else if(Fshape == shape_values[2]){paste(ID, '_plot_sq.', switch(Ftype, pdf =
}

# This is a function to write a ggplot object to an image file
download_write <- function(File, FUN, Fshape, Ftype){
  if(Fshape == shape_values[1]){
    switch(Ftype, pdf = pdf(File, width = 15, height = 8), png = png(File, width
    FUN()
    dev.off()
  }
  else if(Fshape == shape_values[2]){
    switch(Ftype, pdf = pdf(File, width = 9, height = 7), png = png(File, width
    FUN()
    dev.off()
  }
}
```

Sample app run code (left) and a download function (above)

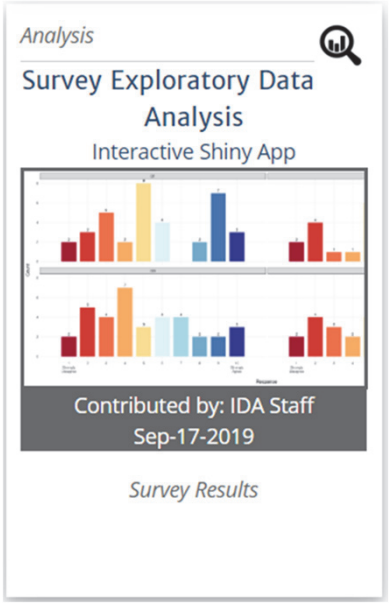
The R “Shiny” package enables development of web-based applications suitable for data analysis and visualization.

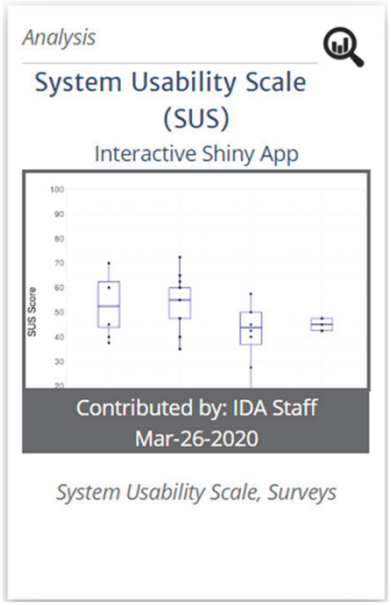
R logo downloaded on February 8, 2022 from https://www.pngitem.com/middle/ibwTimx_r-studio-icon-png-transparent-png/.

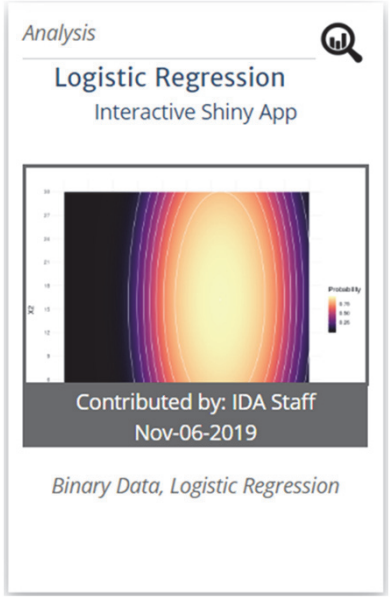
You can find useful analysis apps and tools on the Test Science Tools webpage.

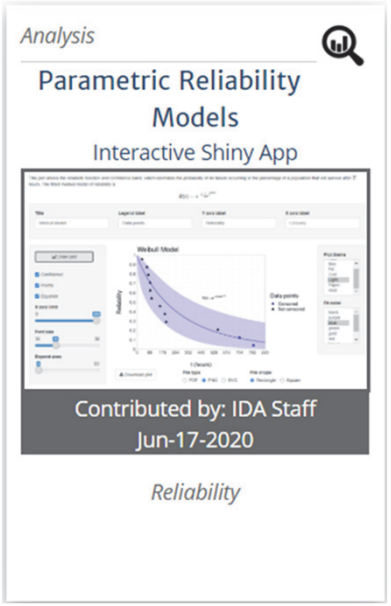


Examples









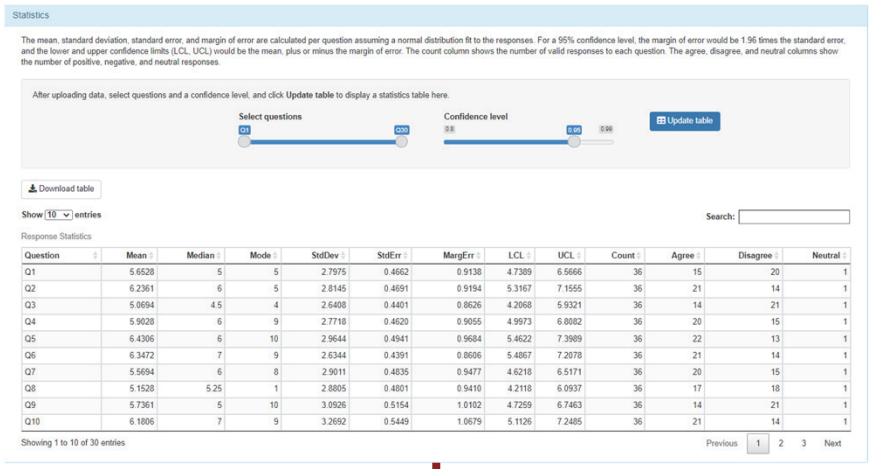
Survey Exploratory Data Analysis | System Usability Scale | Logistic Regression | Parametric Reliability Models

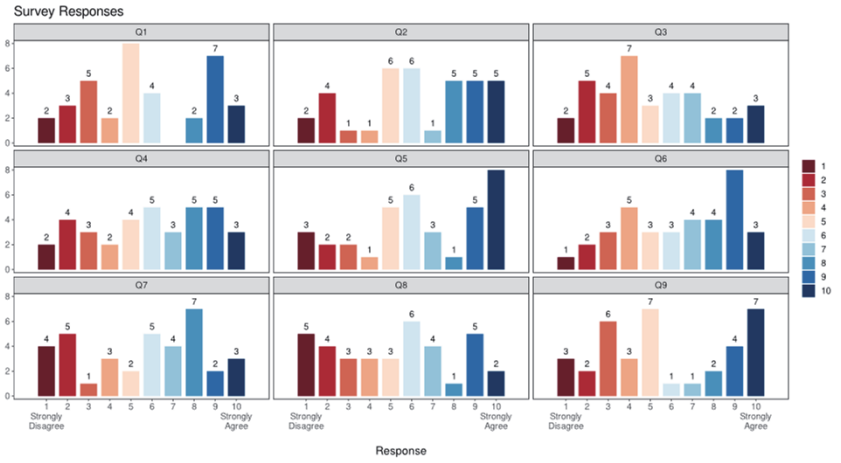
These apps are a subset of roughly 30 free interactive apps and downloadable spreadsheet tools available through the Test Science Tools public webpage covering topics in test planning, design, and analysis. They ingest simple numeric values and text-based tables of survey responses and series of numbers. No coding or special software required!

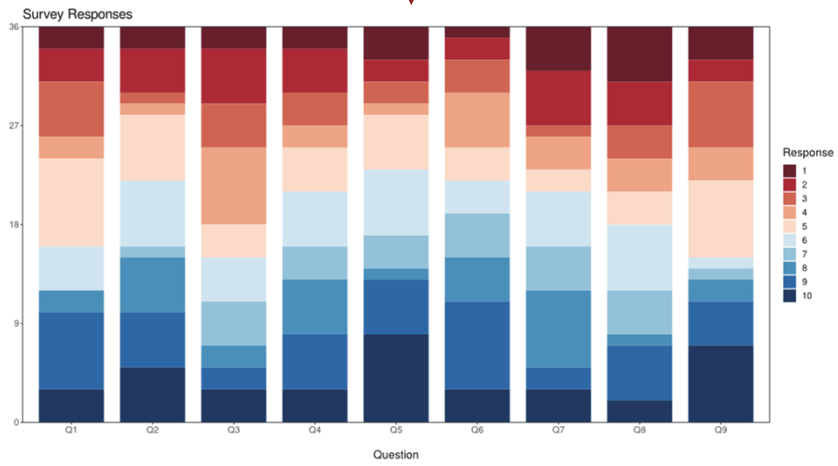
Analyze Likert scale survey responses

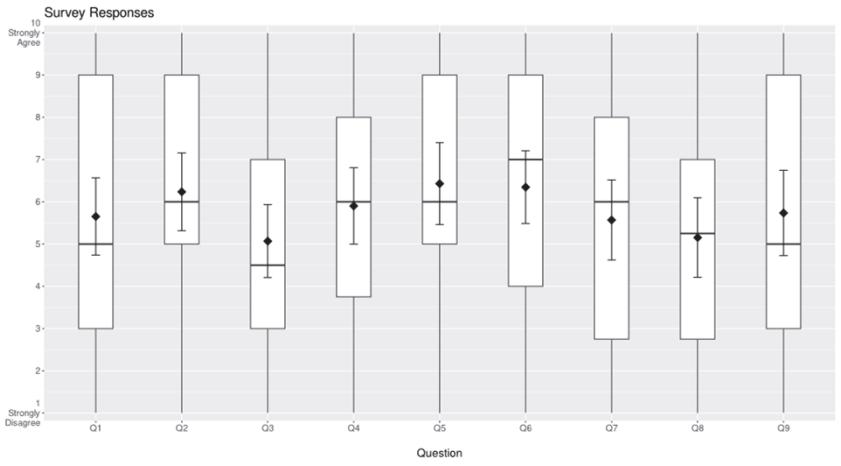
Quickly review and plot groups of Likert scale survey responses as column graphs, histograms, and box plots to assess user satisfaction, training adequacy, and other human factors.

Use the app to do early exploratory analysis of Likert-response survey data.[1]









Graphs show imaginary randomly generated data.

[1] A Likert scale survey response is a multiple choice numeric response (e.g., 1 through 7) indicating level of agreement or confidence with a survey question or statement. The response 1 often indicates "strong disagreement," and 7 often indicates "strong agreement."

Assess usability using the system usability scale (SUS)

Review survey responses, calculate SUS scores, sort tables, and plot scores by independent variables to assess system usability.

Use the app to analyze and plot system usability[1] data.

After uploading data, a table of SUS scores will appear. Each row of the displayed table is a single score for one survey respondent.

The SUS score, S, has a range $[0, 100]$ and is calculated with the formula

$$S = 2.5 \times \left((Q_1 - 1) + (5 - Q_2) + (Q_3 - 1) + (5 - Q_4) + (Q_5 - 1) + (5 - Q_6) + (Q_7 - 1) + (5 - Q_8) + (Q_9 - 1) + (5 - Q_{10})\right)$$

where Q_n has a domain of $[1, 5]$.

Update table

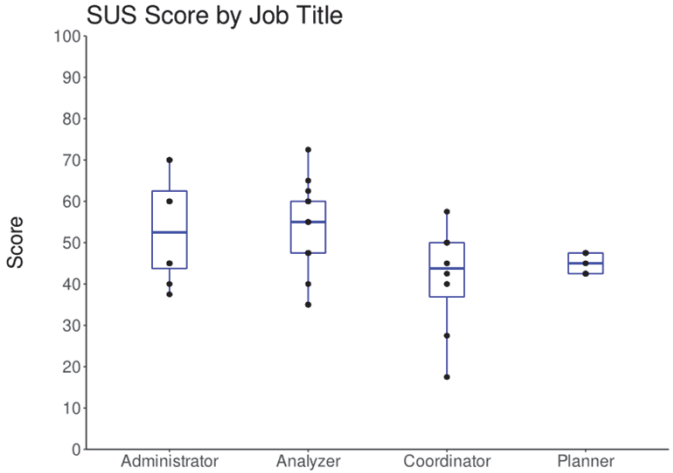
Download table

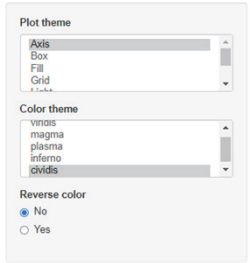
Show 10 entries Search:

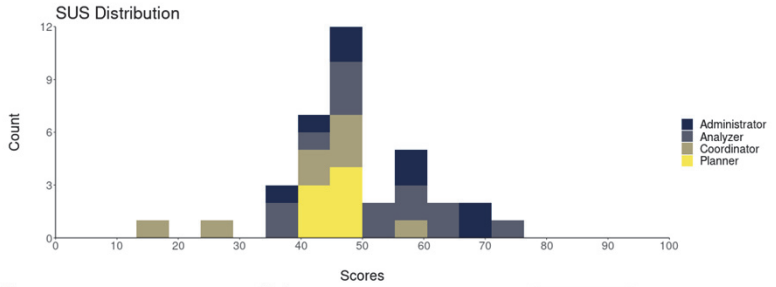
SUS Scores

Name	Date	Department	Section	Job	Experience	Govt_Exp	Score
Alex	2018-10-01	DoC	Administration	Administrator	11	30	40
Bill	2018-10-02	DoC	Administration	Administrator	30	12	37.5
Charlie	2018-10-03	DoC	Administration	Administrator	8	30	70
Dave	2018-10-04	DoC	Administration	Administrator	19	20	70
Eva	2018-10-05	DoC	Administration	Administrator	30	15	60
Frances	2018-10-06	DoC	Administration	Administrator	3	20	60
Gary	2018-10-07	DoC	Administration	Administrator	18	19	45
Holly	2018-10-08	DoC	Administration	Administrator	18	8	45
Ian	2018-10-09	DoC	Administration	Planner	3	30	47.5
John	2018-10-01	DoC	Administration	Planner	6	29	42.5

Showing 1 to 10 of 36 entries Previous 1 2 3 4 Next







Download plot

File type PDF PNG SVG

File shape Rectangle Square

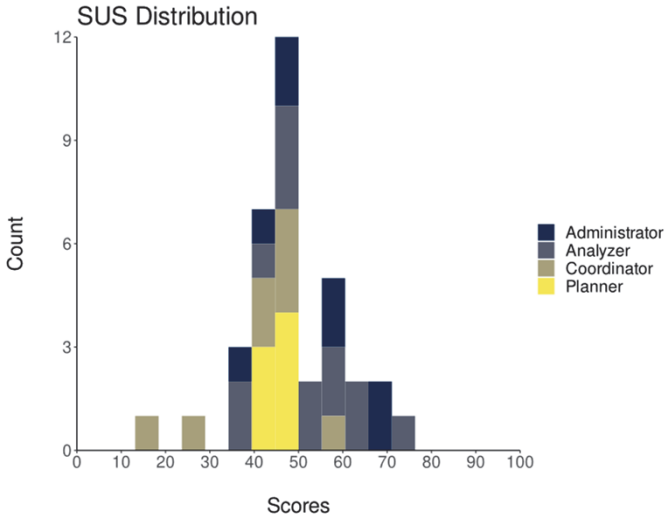
Download table

Show 10 entries Search:

Summary Statistics

X	Mean	Median	Mode	StdDev	StdErr	MargErr	LCL	UCL	N
Administrator	53.438	52.500	70.000	13.157	4.652	9.117	44.320	62.555	8
Analyzer	52.500	55.000	47.500	11.637	3.227	6.326	46.174	58.826	13
Coordinator	41.250	43.750	50.000	13.025	4.605	9.025	32.225	50.275	8
Planner	45.000	45.000	47.500	2.500	0.945	1.852	43.148	46.852	7

Showing 1 to 4 of 4 entries Previous 1 Next



SUS – System Usability Scale

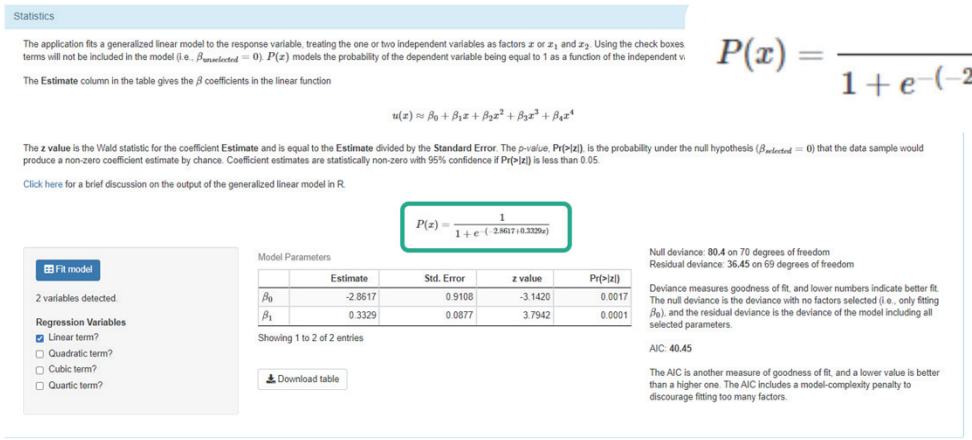
Graphs show imaginary randomly generated data.

[1] The SUS is a scale with range [0, 100]. Ten 5-point Likert scale survey questions are used to calculate a single SUS score from the questions. The SUS score is a metric of usability that is comparable across different systems. See https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/.

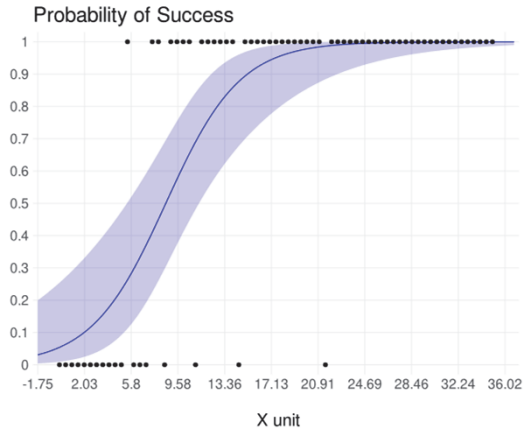
Estimate the probability of an event occurring

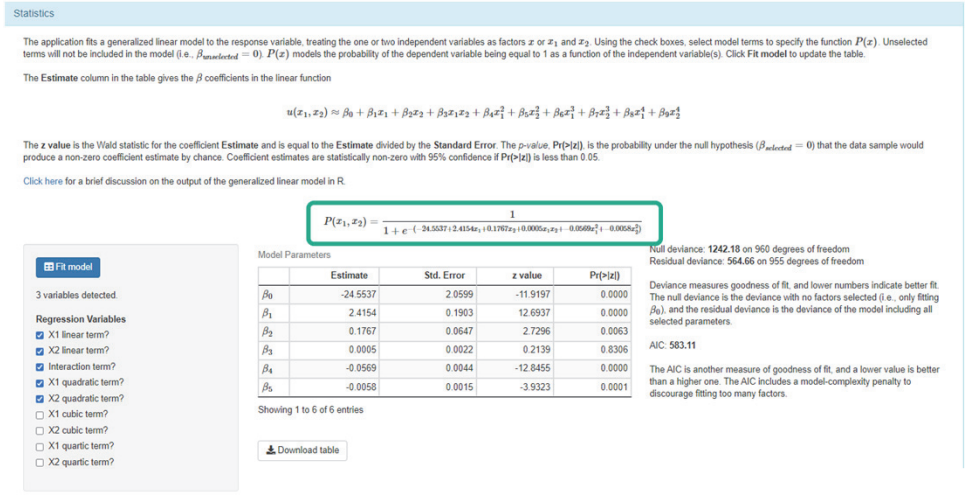
Fit a logistic regression model to one or two independent continuous variables and plot the probability of mission success, threat detection, target destruction, or other success (1) or failure (0).

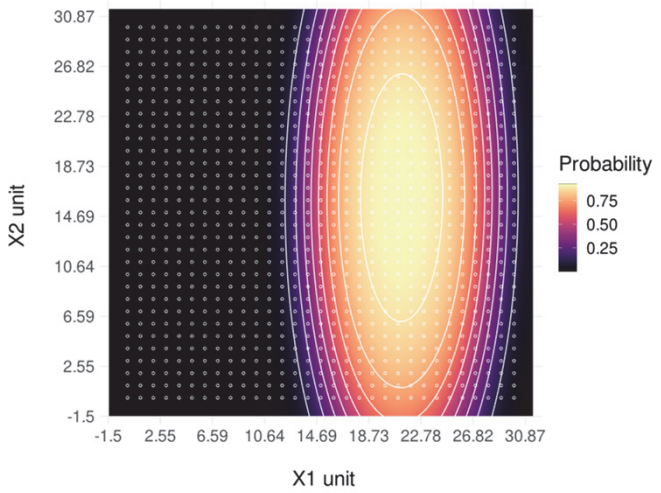
Use the app to build a logistic regression model of probability for one or two independent variables.



$$P(x) = \frac{1}{1 + e^{-(-2.8617 + 0.3329x)}}$$







$$P(x_1, x_2) = \frac{1}{1 + e^{-(-24.5537 + 2.4154x_1 + 0.1767x_2 + 0.0005x_1x_2 + -0.0569x_1^2 + -0.0058x_2^2)}}$$

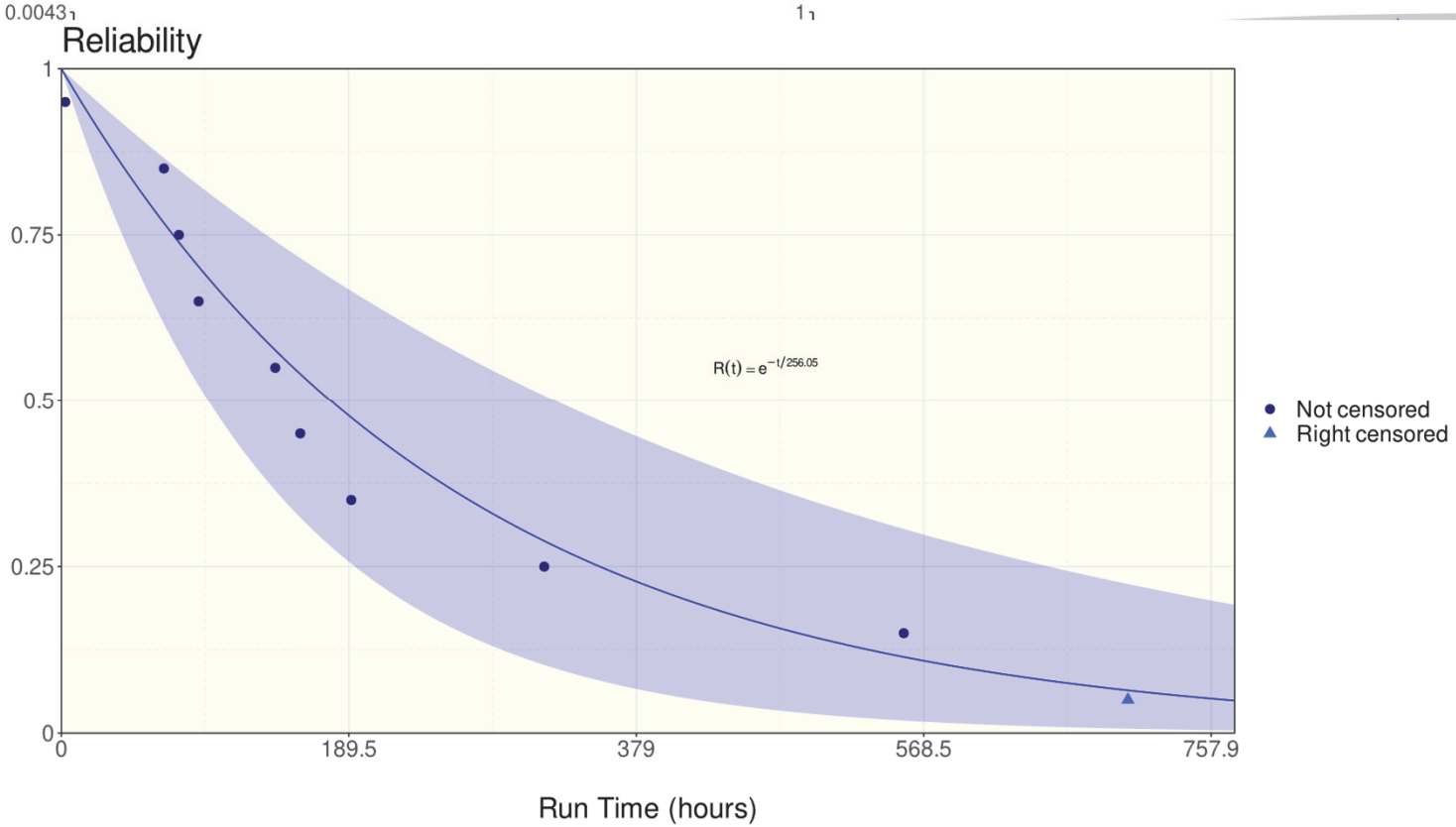
Graphs show imaginary randomly generated data.

Model reliability using simple parametric distributions

Review and sort data, fit and compare reliability models (Exponential, Weibull, and Lognormal), and plot system reliability.

Use the app to compare, analyze, and plot parametric reliability models.[1]

The model comparison table contains information to help select the best-fitting model. Three distributions - the **exponential**, **Weibull**, and **lognormal** - can be compared using the **K-S** test, the **AICc**, the **BIC**, and the **loglikelihood** value. A nonsignificant K-S test means that the observed data are consistent with the fitted distribution. For information criteria (AICc, BIC, loglikelihood), a lower value indicates a better fit to the data, and a



Create final plot of reliability
Compare models

Graphs show imaginary randomly generated data.

[1] This app is designed to use time or interval length data to fit and plot reliability distributions. It has limited ability to plot reliability distributions based only on a parameter, such as mean time to failure.

Use these apps to answer specific research questions, save time, improve aesthetics, and increase reproducibility of your results.

Human Factors → Survey Exploratory Data Analysis
(Often measured with Likert scale survey responses)

Usability → System Usability Scale
(Measured with a specific Likert-like survey in which responses form a single-number metric or usability score)

Probability of Success → Logistic Regression
(Estimated from binary event data: something either happens or does not)

Reliability → Parametric Reliability Models
(Often estimated using service tickets and other sources of event times, durations, distances traveled, etc.)

Why use the software tools presented here?

- Better reproducibility of results
- Faster analysis of new similar data
- Standard and more beautiful aesthetics in figures
- Easier data uploads and table and figure downloads
- Smaller workloads in future analyses
- Free and web-accessible

Apps are available for public Internet use, and the source code is currently available for IDA-internal use.

Survey Exploratory Data Analysis	•App link: https://test-science.shinyapps.io/survey_data_analysis/ •Code repository*: https://code.ida.org/projects/TSSHINY/repos/survey_data_analysis/browse
System Usability Scale	•Link: https://test-science.shinyapps.io/system_usability/ •Code: https://code.ida.org/projects/TSSHINY/repos/system_usability/browse
Logistic Regression	•Link: https://test-science.shinyapps.io/logistic_regression/ •Code: https://code.ida.org/projects/TSSHINY/repos/logistic_regression/browse
Parametric Reliability Models	•Link: https://test-science.shinyapps.io/ParametricReliabilityModels/ •Code: https://code.ida.org/projects/TSSHINY/repos/parametric_reliability_models/browse

* Source code repositories are only available for IDA-internal use at this time.

Use the Test Science software tools to improve the efficiency, aesthetics, and reproducibility of your analysis. Just bring your own web browser and simple text data files.

Most importantly, after analyzing the data you have, say *what you know* and *what you think* as directly and succinctly as possible.

Or else, no one will listen or care about your figures.

Special thanks to:

Technical reviewers for this presentation:

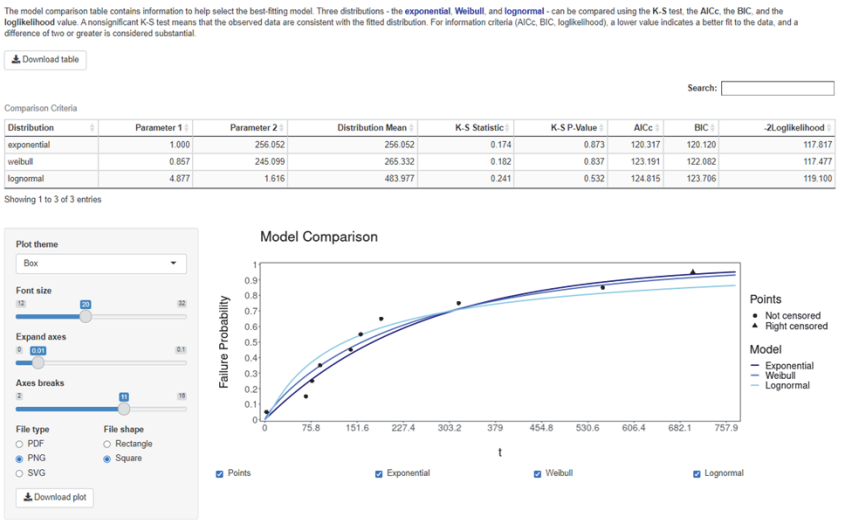
Kelly Avery, Brian Conway, John Haman, Bram Lillard, Kelly Tran

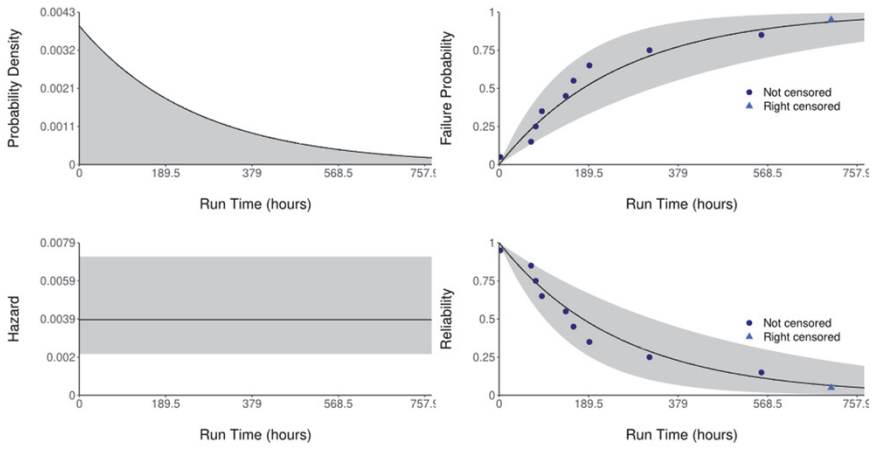
Prior app reviewers:

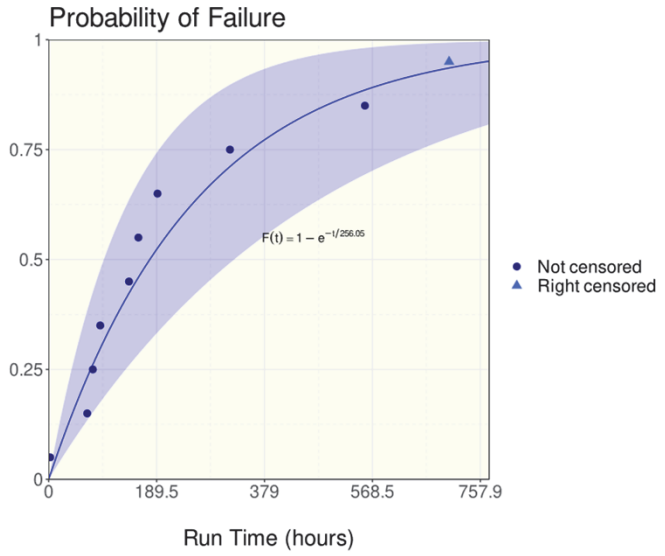
Lee Allison, Kelly Avery, Jonathan Bell, Rose Clark, Brian Conway, Caitlan Fealing, Thomas Johnson, Curtis Lansdell, Peter Mancini, Keyla Pagan-Rivera, Conor Schlick, Jason Schlup, Jason Sheldon, Kelly Tran, Brian Vickers

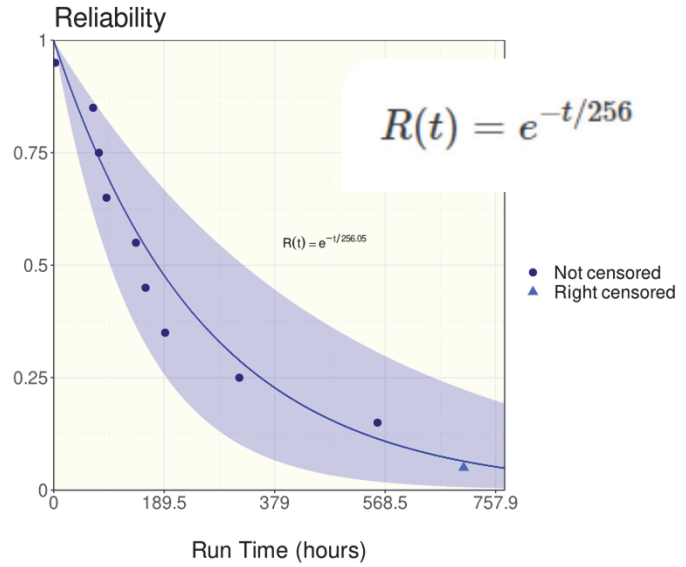
Backup

[RELIABILITY ALTERNATE SLIDE] Use the app to compare, analyze, and plot parametric reliability models.









Graphs show imaginary randomly generated data.

Appendix A
Abbreviations and Acronyms

DATAWorks	Defense and Aerospace Test and Analysis Workshop
DHS	Department of Homeland Security
DOD	Department of Defense
IDA	Institute for Defense Analyses
SUS	System Usability Scale

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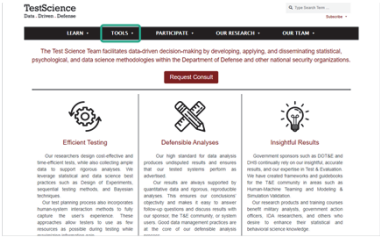
Institute for Defense Analyses

Test Science Apps

In operational testing and evaluation of Departments of Defense (DOD) and Homeland Security (DHS) acquisition systems, analysts repeatedly encounter certain types of data, metrics, and research questions. For example, researchers often estimate a system's reliability as a function of usage or the probability that it will detect or destroy a target depending on range or other variables. And researchers often use surveys to assess system usability, user satisfaction, training adequacy, and other human factors related to the system's effectiveness or suitability.

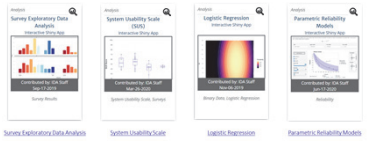
This poster describes four web-based tools I developed to automate analyses that IDA routinely does during test and evaluation work. These tools are available for use at IDA's Test Science Tools webpage:

https://testscience.org/interactive-tools/



Source: https://testscience.org/

Examples



These apps are a subset of roughly 30 free interactive apps and downloadable spreadsheet tools available through the Test Science Tools public webpage covering topics in test planning, design, and analysis. They ingest simple numeric values and text-based tables of survey responses and series of numbers. No coding or special software required!

Analysis Apps for the Operational Tester

Use Test Science web apps to improve the efficiency, aesthetics, and reproducibility of your analysis.

Apps presented here are coded in R using the Shiny package.

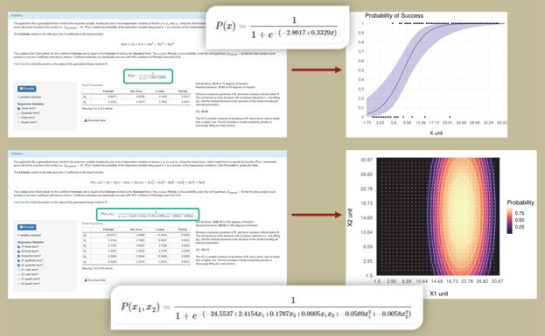
Analyze Likert scale survey responses[1]

Quickly review and plot groups of Likert scale survey responses as column graphs, histograms, and box plots to assess user satisfaction, training adequacy, and other human factors.

[1] A Likert scale survey response is a multiple choice numeric response (e.g., 1 through 7) indicating level of agreement or confidence with a survey question or statement. The response 1 often indicates "strong disagreement," and 7 often indicates "strong agreement."

Estimate the probability of an event occurring

Fit a logistic regression model to one or two independent continuous variables and plot the probability of mission success, threat detection, target destruction, or other success (1) or failure (0).

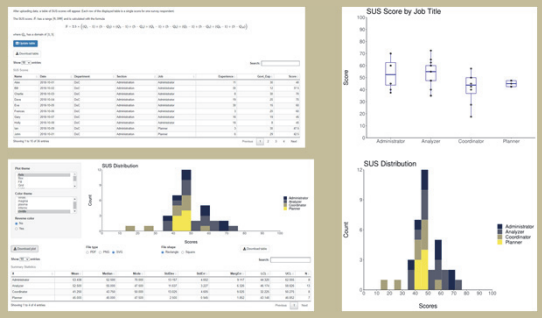


All graphs on this poster show imaginary randomly-generated data.

R logo downloaded on February 8, 2022 from https://www.pngitem.com/middle/ibwTimx_r-studio-icon-png-transparent-png/

Assess usability using the system usability scale (SUS)[2]

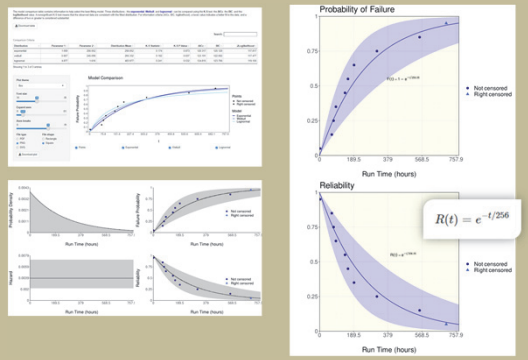
Review survey responses, calculate SUS scores, sort tables, and plot scores by independent variables to assess system usability.



[2] The SUS is a scale with range [0, 100]. Ten 5-point Likert scale survey questions are used to calculate a single SUS score from the questions. The SUS score is a metric of usability that is comparable across different systems. See https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/.

Model reliability using simple parametric distributions[3]

Review and sort data, fit and compare reliability models (Exponential, Weibull, and Lognormal), and plot system reliability.



[3] This app is designed to use time or interval length data to fit and plot reliability distributions. It has limited ability to plot reliability distributions based only on a parameter, such as mean time to failure.

The right app for the right research question

- Human Factors (Often measured with Likert scale survey responses) → Survey Exploratory Data Analysis
- Usability (Measured with a specific Likert-like survey in which responses form a single-number metric or usability score) → System Usability Scale
- Probability of Success (Estimated from binary event data: something either happens or does not) → Logistic Regression
- Reliability (Often estimated using service tickets and other sources of event times, durations, distances traveled, etc.) → Parametric Reliability Models

Why use these apps?

- Better reproducibility of results
- Faster analysis of new similar data
- Standard and more beautiful aesthetics in figures
- Easier data uploads and table and figure downloads
- Smaller workloads in future analyses
- Free and web-accessible

Where do these apps live?

Apps are available for public Internet use, and the source code is currently available for IDA-internal use.

Survey Exploratory Data Analysis	•App link: https://test-science.shinyapps.io/survey_data_analysis/ •Code repository: https://code.ida.org/projects/TSSHINY/repos/survey_data_analysis/browse
System Usability Scale	•Link: https://test-science.shinyapps.io/system_usability/ •Code: https://code.ida.org/projects/TSSHINY/repos/system_usability/browse
Logistic Regression	•Link: https://test-science.shinyapps.io/logistic_regression/ •Code: https://code.ida.org/projects/TSSHINY/repos/logistic_regression/browse
Parametric Reliability Models	•Link: https://test-science.shinyapps.io/ParametricReliabilityModels/ •Code: https://code.ida.org/projects/TSSHINY/repos/parametric_reliability_models/browse

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14. ABSTRACT
In the acquisition and testing world, data analysts repeatedly encounter certain categories of data, such as time or distance until an event (e.g., failure, alert, detection), binary outcomes (e.g., success/failure, hit/miss), and survey responses. Analysts need tools that enable them to produce quality and timely analyses of the data they acquire during testing. This poster presents four web-based apps that can analyze these types of data. The apps are designed to assist analysts and researchers with simple repeatable analysis tasks, such as building summary tables and plots for reports or briefings. Using software tools like these apps can increase reproducibility of results, timeliness of analysis and reporting, attractiveness and standardization of aesthetics in figures, and accuracy of results. The first app models reliability of a system or component by fitting parametric statistical distributions to time-to-failure data. The second app fits a logistic regression model to binary data with one or two independent continuous variables as predictors. The third calculates summary statistics and produces plots of groups of Likert-scale survey question responses. The fourth calculates the system usability scale (SUS) scores for SUS survey responses and enables the app user to plot scores versus an independent variable. These apps are available for public use on the Test Science Interactive Tools webpage https://testscience.org/interactive-tools/.

15. SUBJECT TERMS
Survey; System Usability Scale (SUS); Reliability; Test Science; Logistic Regression; Binary Response; Likert Response; Interactive Web Application; Reproducibility; Shiny

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