Master Tutorial

TITLE

Interactive Dashboards with R and Shiny

SHORTENED TITLE

Interactive Dashboards with R and Shiny

ABSTRACT

Many people use R to generate publication-ready plots, reproducible analyses, and custom simulations. R code can also support interactive dashboards with auto generated HTML, CSS, and JSON. This tutorial session will explore using the Shiny package to create custom dashboards as well as several add on packages that allow users the flexibility of interacting with data. Make sure to bring your laptops!

CITATION

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**Interactive Dashboards with R and Shiny**

R (R Core Team, 2021) is an open-source programming language that is designed for statistical computing (Hornik, 2013). R is commonly used to run reproducible data analyses, such as hypothesis testing, machine learning, natural language processing, and even highly specialized computations that may be unique to a scientific field. R is not just a set of tools for statistical analyses but a fully-fledged programming *language* with the ability to generate APIs (e.g., plumber, jsonlite), interact with databases (e.g., DBI, odbc, RMariaDB), interact with servers (e.g., RCurl, ssh, openssl), as well as run code in parallel and asynchronously (e.g., snow, parallel, foreach, future). By some measures, R has become one of the most popular programming languages of any form (Cass, 2018), partly due to the large ecosystem of support pages, books, blogs, tutorials, and R specific conferences.

Many data scientists and practitioners can contribute to R by writing new software, called “packages” in R. At the time of writing, the Comprehensive R Archive Network (CRAN) contains 18,093 available packages, including packages to read data in varying formats (e.g., readr, openxlsx, haven, rjson, officer, vroom), access databases (e.g., DBI, odbc, RMariaDB), clean data (e.g., dplyr, tidyr, stringr), perform data analyses and machine learning (e.g., tidymodels, infer, caret, xgboost, randomForest, survival), visualize results (e.g., plotly, ggplot2), and interface with other programming languages (e.g., Rcpp, cpp11, reticulate). These packages, just like R itself, are free of charge.

R has been most often used to generate reproduceable analyses and basic reports, often through simple scripts, Sweave integration with LaTeX (Leisch, 2002), or R Markdown files. These types of static reports can easily demonstrate what has already been done but makes it difficult for consumers to explore data and generate their own insights. People less familiar with technical analyses often prefer to consume data using dashboarding tools (such as PowerBI or Tableau). These tools allow users to easily explore data but provide limited and/or difficult integration with how the data was originally generated, cleaned, and/or analyzed. Moreover, the implementations of these tools are often proprietary, black box, and not easily customizable.

This Master Tutorial will teach attendees how to generate professional, insightful, and fully customizable dashboards in R using the web-development framework “shiny” (Chang, et al., 2021b) as well as several Shiny extensions. We will show users how to generate simple, working applications from Shiny building blocks as well as how to modularize and isolate parts of these applications and reason about how each application works. Special attention will be paid to the reactive programming paradigm whereby interacting with an app determines which parts of the code should be run and whether certain parts should be run again. We will also peak under-the-hood to show how Shiny creates and interacts with HTML, CSS, and JavaScript as well as provide tools to extend Shiny by integrating Shiny with custom JavaScript libraries or CSS frameworks. Attendees should be familiar with R and have both R and RStudio installed prior to the workshop. We will walk through and explain each line of code in detail, but we will have little time to review the basics of R itself.

*Proposed Session*

Many researchers are adept at determining research questions, collecting data, and deciding how to analyze that data. However, the results of studies are often presented as static analyses and reports. Yet larger questions often preclude simple answers or easy analyses. Moreover, several organizations (e.g., Open Data Research Network; Journal of Open Psychology Data; see Wilkinson et al., 2016 for the FAIR principle) have promoted making research data fully open and available so that people can independently verify research findings. These procedures can reduce the file drawer problem when determining effects in meta-analyses (e.g., Dalton, Aguinis, Dalton, Bosco, & Pierce, 2012; Lane, Luminet, Nave, & Mikolajczak, 2016; Yarkoni, 2009).

Most consumers are not adept at manipulating and analyzing datasets. One way of simplifying the handoff between researchers/producers of data and the public is to create easy-to-use dashboards to explore data within pre-specified boundaries. Dashboarding tools allow consumers to dig into their questions of interest, such as the hiring rates in certain regions for combinations of diversity variables at different levels of an organization or the demographic breakdowns of responses to a job analysis. R has many tools designed to generate easy to develop and use dashboards with a modern interface and integration with standard web infrastructure, all built around the R package “shiny” (Chang, et al., 2021) Hundreds of packages depend on or extend Shiny, and countless applications and dashboards have been developed in Shiny. Building on several R-based master tutorials over the last few years (e.g., Jones, Nydick, & Wiseman, 2019a; Jones, Nydick, & Wiseman, 2019b; Jones, Nydick, & Wiseman, 2021a; Jones, Nydick, & Wiseman, 2021b), this tutorial aims to break down useful R methods for I/O psychologists. Specifically, this tutorial can be seen as an extension of our introductory tutorials (e.g., Jones, Nydick, & Wiseman, 2019a; Jones, Nydick, & Wiseman, 2021a) that explain useful and underused R tools for researchers and practitioners.

The proposed tutorial is an attempt to explain simple web development and dashboarding tools in R, how those tools interact with HTML, CSS, and JSON, and why those tools engage consumers to better explore and understand psychological theory and study results. This tutorial will be interactive. Audience members are strongly encouraged to bring laptops and to have downloaded the materials ahead of time. For those who wish to follow along, we will make available all materials and R scripts at <https://github.com/swnydick/siop-2022-interactive-shiny>. We request 80 minutes for the tutorial, with the approximate time for each topic as well as additional information provided below. Note that none of the authors are affiliated with the producers of any of the packages described and that there are no material gains (financial or otherwise) for them.

**Topic #1: Basic Dashboards (35 minutes)**

The most commonly used dashboarding tool in R is “shiny” (Chang, et al., 2021), originally developed by the R Studio team and released in 2012. Shiny applications contain two parts. The UI portion of any application indicates where the buttons, boxes, and displays should be placed on any page, what they should be called and what they should look like. Shiny integrates with the bootstrap library for visualization and customization and allows additional CSS modifications. However, users only need to know R code: the Shiny interface takes care of generating the right HTML chunks and displaying those chunks to the user. An added benefit is that the web pages generated by the Shiny UI look professional without additional customization.

The server portion of an application determines what to do behind the scenes when interacting with the UI. Pressing a button might generate a plot, add data to a database, perform a simulation, modify an existing UI, or even create a new UI. To make the application adjust to user input, Shiny uses a lot of R tricks, including an ample use of R6 (a modern version of reference classes in R). Nonetheless, this complicated infrastructure allows for relatively straightforward development. For instance, the input object is a read-only object that contains information from the UI, such as the specific value of a dropdown menu. Anything taken from the UI is extracted from input with the element equal to the assigned ID. The output object is a write-only object that contains rendered information to display to the user. Anything assigned to the output object must be rendered with the appropriate rendering function and assigned to an ID specified in the UI. Finally, several objects, including the input, are reactive: they change in response to user input, and that change can trigger other things to happen. Defining those reactive contexts and the links between them is the objective of the Shiny server.

The first portion of the tutorial will provide the general tools for creating a basic Shiny app, including how to structure the UI, how to link the UI to the server, and how to generate customizable and updateable plots and tables.

**Topic #2: Understanding Reactivity (15 minutes)**

After presenting a brief overview of Shiny as well as the techniques for generating simple apps, we will discuss how reactivity works in Shiny as well as some of the pitfalls of developing in a reactive context. For instance, unlike standard R scripts, reactive objects can cyclically depend on each other. Manually changing a UI element can trigger an observer to execute, which could then update the same UI element, resulting in an infinite loop. Special attention will be paid to methods of visualizing the reactive graph (using the reactlog package; Schloerke, 2020) as well as tricks for debugging observers, including simple techniques such as print statements and browser calls (although see Wickham, 2021, for alternative methods). Following best practices for Shiny development can prevent inefficient apps that seem to respond in unpredictable and unintended ways.

**Topic #3: Extensions (20-25 minutes)**

The Shiny package is only a framework for web applications and dashboards in R. Many developers have written packages that add additional UI elements and style (e.g., shinydashboard, bs4Dash, shinyWidgets, shinyBS), user notifications (e.g., shinyFeedback, shinyalert), table displays (e.g., DT, reactable), as well as those that give app creators better access to the underlying javascript (e.g., shinyjs, shinyjqui, htmlwidgets). (See <https://github.com/nanxstats/awesome-shiny-extensions> for an extensive list of Shiny extensions.) We will present some of our favorite Shiny extensions for producing professional quality dashboards. For instance, shinyjs (Attali, 2020) contains functions to easily hide and show UI elements without needing to manually render parts of the UI.

Finally, researchers who find a javascript library online that provides desired functionality not offered by standard shiny addons can manually create a shiny extension using the htmltools package (Chang et al., 2021). Describing the specific process for creating a Shiny extension is well beyond the scope of this tutorial. However, we will provide additional references for those interested in taking their shiny apps in new and creative directions.

**Topic #4: Wrap-up (5-10 minutes)**

Finally, the presenters will answer audience questions and help with technical problems encountered during previous sections. The presenters will also provide materials for participants to read for self-study and include links to useful materials for developing creative applications and dashboards.

**Learning Objectives**

This workshop is designed to help you:

1. Create simple dashboards using R and R Shiny that can allow people to easily explore data built on your research and ideas.
2. Understand how to reason about Shiny applications and how to debug and modularize those applications for easy maintainability.
3. Be able to adopt the best Shiny extensions as well as integrate Shiny with custom CSS and JavaScript.

**Presenter Information**

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**Presenter Bios**

Steven Nydick is a Senior Manager of Measurement, Data, and Automation at the Korn Ferry Institute, where he designs R-based tools and scoring algorithms. He is the lead author and maintainer of the catIrt R package as well as several internal R packages helping with everything from plotting to powerpoint generation to interfacing with servers. He has contributed to developing psychometric models and corresponding estimation algorithms that have been published in *Applied Psychological Methods* and the *Journal of Educational and Behavioral Statistics*. Steven received his Ph.D at the University of Minnesota in Psychometrics and Quantitative Psychology, where he primarily studied IRT-based adaptive tests for selection and classification. He also has an M.S. in Statistics from the University of Minnesota.

Fiona Lodge is a Data Scientist at the Korn Ferry Institute, within client analytics, where she is responsible for delivery of client analytics solutions/reports. Using R, she has contributed to both scalable and impromptu requests from clients so that organizations can better understand their talent. Fiona holds a P.S.M. in Applied and Industrial Mathematics from the University of Wisconsin Stout and a B.A. in Mathematics from the University of St. Thomas.

YuAnn Wang is a Senior Data Scientist at Korn Ferry Institute. She participates in new services development, IP creation, as well as existing product QA activities. She develops in-house R-based applications and PowerBI dashboards with customized visualizations. Yu-Ann holds an MBA from the Melbourne Business School and an MSc in Natural Sciences (Physics) from the University of Cambridge.

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Jones, J. A., Nydick, S. W., & Wiseman, B. (2019a, April). Effective data wrangling and visualization with R. Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, National Harbor, MD.

Jones, J. A., Nydick, S. W., & Wiseman, B. (2019b, April). Web scraping with R. Master Tutorial at the annual meeting of the Society of the Industrial and Organizational Psychology, National Harbor, MD.

Jones, J. A., Nydick, S. W., & Wiseman, B. (2021a, April). Big Data Systems with R. Master Tutorial at

the annual meeting of the Society of the Industrial and Organizational Psychology, New Orleans, LA (Virtual Meeting).

Jones, J. A., Nydick, S. W., & Wiseman, B. (2021b, April). Text Analytics and NLP with R.

Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, New Orleans, LA (Virtual Meeting).

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intranasal oxytocin research on humans? Opening the file drawer of one laboratory. *Journal of Neuroendocrinology*, *28*.

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**Appendix**

CV Steven Nydick

CV Fiona Lodge

CV Yu-Ann Wang

Steven Nydick

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**Education:**

PhD, University of Minnesota, Psychometrics/Quantitative Psychology, 2013.

Advisor: Niels Waller

MA, University of Minnesota, Psychometrics/Quantitative Psychology, 2012.

Advisor: Niels Waller

MS, University of Minnesota, Statistics, 2011.

Advisor: Sanford Weisberg

BS, Syracuse University, Mathematics and Psychology, 2006.

**Professional Experience:**

Senior Manager, Measurement, Data, and Automation, 2021 - Present

Data Scientist Developer, Korn Ferry, 2018 – 2021.

Senior Psychometrician, Pearson VUE, 2016 – 2018.

Psychometrician, Pearson VUE, 2013 – 2016.

Research Assistant, University of Minnesota, 2013 –2019.

Intern in Psychometrics, ARRT, 2012 – 2013.

Intern in Psychometrics, ACT, 2011.

Graduate Instructor/Section Leader, University of Minnesota, 2007 – 2013.

**Awards:**

Doctoral Dissertation Fellowship, 2013

Graduate Research Partnership Program, 2010

Archimedes Prize in Mathematics, 2006

**Manuscripts Published and In Press:**

Wang, C. & Nydick, S. W. (2020). On longitudinal item response theory models: A didactic. *Journal of*

*Educational and Behavioral Statistics*, *45*, 339-368.

Wang, C. & Nydick, S. W. (2015). Comparing two algorithms for calibrating the restricted non-

compensatory multidimensional IRT model. *Applied Psychological Measurement*, *39*, 119-134.

Nydick, S. W. (2014). The sequential probability ratio test and binary item response models. *Journal of*

*Educational and Behavioral Statistics*, *39*, 203-230.

**Software:**

Wiseman, B., Nydick, S. W., & Jones, J. A. (2018). roperators: Additional operators to

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**Presentations and Workshops:**

Jones, J. A., Nydick, S. W., & Wiseman, B. (2021, April). Big Data Systems with R. Master Tutorial at the

annual meeting of the Society of the Industrial and Organizational Psychology, New Orleans, LA (Virtual Meeting).

Jones, J. A., Nydick, S. W., & Wiseman, B. (2021, April). Text Analytics and NLP with R.

Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, New Orleans, LA (Virtual Meeting).

Jones, J. A., Nydick, S. W., & Wiseman, B. (2019, April). Web scraping with R. Master Tutorial at the

annual meeting of the Society of the Industrial and Organizational Psychology, National Harbor, MD.

Jones, J. A., Nydick, S. W., & Wiseman, B. (2019, April). Effective data wrangling and visualization with R.

Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, National Harbor, MD.

Nydick, S. W. (2016, April). The expected likelihood in computerized classification testing. Paper

presented at the annual meeting of the National Council on Measurement in Education, Washington, DC.

Nydick, S. W. (2014, April). Multidimensional mastery testing with CAT. Paper presented at the annual

meeting of the National Council on Measurement in Education, Philadelphia, PA.

Nydick, S. W., Wang, C., & Xiong, X. (2014, April). Measuring multidimensional growth—a higher-order

IRT perspective. Paper presented at the annual meeting of the American Educational Research Association, Philadelphia, PA.

Nydick, S. W., Nozawa, Y., & Zhu, R. (2012, April). Accuracy and efficiency in classifying examinees using

computerized adaptive tests: An application to a large scale test. Paper presented at the Annual Meeting of the National Council on Measurement in Education, Vancouver, BC.

Nydick, S. W., & Weiss, D. J. (2010, June). Accepting the null: No change in change CAT. Paper presented

at the IACAT conference on CAT, Arnhem, NL.

Nydick, S. W., & Weiss, D. J. (2009). A hybrid simulation procedure, evaluated for the development of

CATs. In D. J. Weiss (Ed.) *Proceedings of the 2009 GMAC Conference on Computerized Adaptive Testing.*

**Unpublished Manuscripts:**

Nydick, S. W. (2013). *Intro to R for Psychologists.* Minneapolis, MN: Author.

**Courses Taught:**

Introduction to Data Analysis/Statistics for Undergraduates

Honors Introduction to Data Analysis/Statistics for Undergraduates

Analysis of Psychological Data for Graduate Students

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Education:

PSM, University of Wisconsin Stout, Applied and Industrial Mathematics, 2018

BA, University of St. Thomas (MN), Mathematics, 2008

BA, University of St. Thomas (MN), Secondary Education, 2008

Professional Experience

Data Scientist, Korn Ferry Institute, Korn Ferry, 2020-Present

Client Data Analyst, Korn Ferry Institute, Korn Ferry, 2020

Intern, Korn Ferry Institute, Korn Ferry, 2019- 2020

Data Science Intern, Securian Financial, 2018

High School Mathematics Teacher, Saint Paul Public Schools, 2009-2016

Awards

Dean’s list, University of St. Thomas, (Fall 2005, 2007, 2008 and Spring 2006, 2007, 2008)

Honors: *cum laude*, University of St. Thomas (2008)

Member of National Championship Softball Team, University of St. Thomas, (2005)

Member of Great Britain National Softball Team (2005-2006)

Presentations

Lodge, F.L. 2019 Explanation of the tf-idf statistic and applications in modeling. League of Extraordinary Algorithms Meetup Group, Minneapolis, MN

Lodge, F.L. 2019 Introduction to caret through classification problems. League of Extraordinary Algorithms Meetup Group, Minneapolis, MN

Lodge, F.L. 2021 R Shiny Introduction. noRth R users conference, Minneapolis, MN

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**Education:**

MBA, University of Melbourne, Melbourne Business School, 2011

MSc MA, Natural Sciences (Experimental & Theoretical Physics), University of Cambridge, 2001

**Professional Experience:**

Senior Data Scientist, Korn Ferry Institute, Korn Ferry, 2021 – Present

Data Scientist, Korn Ferry Institute, Korn Ferry, 2018 – 2021

Knowledge Manager, Global Technology Market Asia Pacific, Korn Ferry, 2014 – 2018

Associate, Booz & Company, 2011 – 2014

Assistant Director, Strategic Planning (and other roles prior), Science Centre Singapore, 2002-2009

**Awards:**

Dean’s List, Melbourne Business School, 2011

Helen MacPherson Smith Fellowship, 2010-2011

Cambridge Commonwealth Trust Fellowship

**Courses Taught:**

Teaching Assistant for Data & Decisions for MBA candidates