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 the shiny package for custom dashboards as well as several add on packages that allow users the flexibility of interacting with data. Make sure to bring your laptops!

PRESS PARAGRAPH

Dashboards allow users to easily explore data. However, many commonly used software to generate dashboards are black boxes with little integration into how analyses are performed. The R package “shiny” provides tools to easily create dashboards in the same environment commonly used for processing and analyzing the data. Yet shiny can be tricky to master for someone familiar with standard R programing due to concepts such as “reactivity”, “observers”, and “dependency graphs”. This session will provide users with the tools to confidentially create, understand, and debug shiny apps as well as some tricks (and add on packages) to make those apps customizable, beautiful, and functional.

WORD COUNT: ####

**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 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. Shiny is a powerful framework for producing professional dashboards in R. We will explain how to best adopt this framework to allow users to discover their own insights. 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. Moreover, unlike standard web development, 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). However, the 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 are 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 the shiny extensions.) We will present some of the most useful 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 as well as 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.

Ben Wiseman is a Senior Manager of Data Science and AI at the Korn Ferry Institute responsible for maintaining and developing R-based automation tools, models, reports, and user interfaces. He has publications in entomology, ecology, and molecular evolution and has worked with and trained numerous clients in the military, public, and private sectors on a wide range of applications. Ben received his MSc from Lincoln University (New Zealand) in applied statistical modelling where he developed a user-facing geospatial AI platform for DOCs predator monitoring and control systems.

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

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**Appendix**

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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:**

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.

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

**Software:**

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**Presentations and Workshops:**

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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.

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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:**

MS, Lincoln University, Applied Statistics, 2015.

BS, Lincoln University, Biostatistics, 2013.

**Professional Experience:**

Senior Manager, Data Science and AI, Korn Ferry, 2021 – Present.

Data Scientist Developer, Korn Ferry, 2018 – 2021.

Owner, Wiseman Analytics, 2016 – 2018.

Information Services, DHS, 2015 – 2016.

Instructor, Lincoln University, 2013 – 2014.

Research Assistant, Lincoln University, 2011 – 2015.

Research Assistant, Seoul National University, 2011.

**Awards:**

Freemasons university scholarship

Forest and Bird research award

AGLS research scholarship

**Manuscripts Published and In Press:**

Wiseman, BH., Fountain, ED., Bowie, MH. He, S., Cruickshank, RH. 2016. Vivid molecular divergence over volcanic remnants: the phylogeography of Megadromus guerinii on Banks Peninsula, New Zealand. New Zealand Journal of Zoology

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Wiseman, B. W. (2015) Geofriendly: Easy Spatial Application of Artificial Neural Networks

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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).

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

Wiseman, B. H. 2017 Data Science with Python. ESRI Developer Summit, Palm Springs, CA.

Wiseman, B. H. 2013 Messy data, messy models and applied statistics. Presented for Bio-Protection seminar, Lincoln University, New Zealand.

Marris, J. and Wiseman, B. H. 2012. Islands in the snow: Ecology, systematics and biogeography of the New Zealand beetle genus Protodendrophagus (Coleoptera:Silvanidae:Brotini). Presented at the New Zealand Ecological Society conference.

Cripps, M., McNeil, M., Patrick, H., Wiseman, B., Nobilly, F., Edwards, G. 2012. Invertebrate abundance and diversity in intensively managed dairy pastures. New Zealand Plant Protection Society Conference.

Wiseman, B. H., Cruickshank, R. H., Bowie, M. H., Fountain, E. D. 2011. Unexpected genetic variation in an endemic ground beetle: The molecular mystery of Megadromus guerinii (Coleoptera: Carabidae). 3rdAnnual Combined Australian and New Zealand Entomological Societies Conference

Wiseman, B. H. (2011). The curious case of Megadromus guerinii: phylogeographic oddities on Bank’s Peninsula. Presented to the Canterbury branch of the New Zealand Entomological Society.

**Courses Taught:**

Research and Analytical Skills

Geospatial Information Systems with Arc GIS

Business Statistics

Intermediate Statistics for Commerce