Master Tutorial

TITLE

Web Scraping with R

SHORTENED TITLE

Web Scraping with R

ABSTRACT

A lot of data exists on the web! Accessing that data requires understanding HTTP requests, security tokens, data transfer file formats, and data cleaning. This tutorial session will walk you through how to access and process web-based data using the powerful statistical language R. Bring your laptop for this interactive session (download session materials here: <https://bit.ly/2QfaYRw>).

PRESS PARAGRAPH

Gathering data no longer relies solely on handing out questionnaires or setting up experiments. Many interesting questions can be answered by accessing data on the web. The statistical computer language R allows scientists and practitioners to scrape the web and obtain a world of data without leaving one’s seat, including the distribution of the population, the sentiment of consumers and employees, and the change in stock prices. This session will give a hands-on and step-by-step tutorial on how to access and process web-based data for the purposes of analyses.

WORD COUNT: 1888

**Web Scraping with R**

R (R Core Team, 2018) is an open-source programming language that is designed for statistical computing (Hornik, 2013). R can perform anything from standard data analysis (e.g. Multiple Regression, Hierarchical Linear Modeling, or Structural Equation Modeling) to highly specialized computations that may be unique to a scientific field. R is a programming *language* and not just a statistical analysis package. By some measures, R has become one of the ten most popular programming languages (Cass, 2018) and is growing in popularity nearly as quickly as the general-purpose programming language Python (Robinson, 2017). R’s popularity may be partly due to the large ecosystem of support pages, books, blogs, tutorials, and R specific conferences. Several R packages, including dplyr (Wickham, François, Henry, and Müller), ggplot2 (Wickham, 2009), and data.table (Dowle and Srinivasan, 2018) have over 12,000 mentions on Stack Overflow (Robinson, 2017).

Many data scientists and practitioners can contribute to R by writing new and unique software, called “packages” in R. At the time of this writing, the Comprehensive R Archive Network (CRAN) contains 12,959 available packages, including packages to read data in varying formats (e.g., readr, open.xlsx, haven, rjson, officer), access databases (e.g., DBI, odbc, RSQLite), clean data (e.g., dplyr, tidyr, stringr, reshape2), perform data analyses and machine learning (e.g., caret, xgboost, randomForest, caret, survival), visualize results (e.g., shiny, ggplot2), and interface with other programming languages (e.g., Rcpp, reticulate, RJava). These packages, just like R itself, are free of charge.

The Master Tutorial is a continuation of previous tutorials attempting to simplify R for the I/O community and will teach attendees how to leverage R and several packages to access data from various websites and put that data into a form useful for data analysis. We will show users how to request information from servers, access web APIs (including those that require authentication keys), extract useful information from web requests, and process online data for the purposes of further analyses. 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*

Considerable information is contained on the internet. These data are often behind APIs, on unstructured HTML pages, or in particular formats such as XML or JSON. Putting this data into usable format for analyses can be difficult and require specific knowledge. R now has a wide variety of tools to access, process, and analyze web-based data (Munzert, Rubba, Meißner, and Nyhuis, 2015). Unfortunately, I-O psychologists often lack the training to be able to access this data for their own research purposes without tedious, manual processes or help from computer programmers. Building on several R-based master tutorials over the past few years (e.g., Schwall, Lustenberger, Beatty, and Jones, 2014; Schwall, Beatty, & Jones, 2015; Goebl, Jones, & Semmell, 2016; Goebl, Jones, & Semmell, 2018), this tutorial aims to bridge the gap between the typical I/O psychologist’s experience and R’s ability to solve research problems. We will explain web-scraping as implemented by R in two parts.

The first part of the tutorial will introduce packages that pull data from the web and put that data into a usable format within the R working session. We will introduce the terminology of web requests (such as PUT, POST, GET) and show how to construct appropriate requests to pull data from websites and translate that data for appropriate analysis. Our discussion will emphasize several packages that make pulling data from the web (such as httr; Wickham, 2017), and translating that data for use in further analyses (such as xml2; Wickham, Hester, and Ooms, 2018; and rjson; Couture-Beil, 2014) easier and consistent.

The second part of the tutorial will guide participants in setting up a developer platform on Twitter and using API requests to pull data referencing a particular company within a window. At the same time, we will pull financial data on that company using different APIs during the same window and compare the sentiment of Tweets (e.g., Silge and Robinson, 2018) with the financial data of the company. Although our example relates Twitter to financial performance, the principles behind our demonstration apply to any web scraping activity.

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://bit.ly/2QfaYRw>. 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. All packages are free-of-charge and complete.

**Topic #1: Web Requests and Data Formats (30 minutes)**

In principle, data on a website can be stored in the same format as data on one’s own hard drive. A website is hosted on a server, and that server can contain any types of files. Unfortunately, standard file formats are not amenable for efficiently representing data with complex structure. For instance, a flat file would not easily be able to depict hierarchical relationships between a company, its teams, the individuals on those teams, the traits of those individuals, and connections with other teams. One could have separate columns for “company”, “team”, “individuals”, etc., but the elements of those columns would need to be repeated more times than necessary to adequately capture all relationships in a flat format.

Two formats that typically represent web-based data are XML (Extensible Markup Language) and JSON (JavaScript Object Notation). XML was developed by the World Wide Web Consortium (the same group that has set the standard for many other web-based formatting languages, including CSS and HTML). XML is written in a similar style to HTML, with tags, attributes, and elements. However, HTML tags are fixed and not mutable (without changes to the standards), whereas XML tags are customizable. This capacity allows XML to capture a similar structure to HTML-based documents (and easy insertion into HTML-type webpages and applications) with the flexibility of self-defined groupings. One can also set a schema so that XML must conform to a pre-specified structure. This capacity provides predictability, so that users know the format of any data they encounter, and code written to process that data can also process new data that adheres to the same schema.

Similarly, JSON is a standard-based data transfer format that allows for pre-defined schemas so that data structures are easily predictable and processable. However, JSON format was designed to work in JavaScript and is, thus, object-based rather than tag-based. JSON files are simply a nested array of either arrays or values that are either named or ordered. For instance, JSON formats can easily represent an individual person (see <https://en.wikipedia.org/wiki/JSON>) with a named value “firstName”, a named value “lastName”, an array of named values for “address” (where the array includes “streetAddress”, “city”, “state”, and “postal code”), and an array of arrays for “phoneNumbers” (where the each sub-array contains individual phone numbers marked by “type”, and “number”). Note that this format is easily extensible. If we want to create a list of people, we simply need to add the JSON representing this person as a sub-array of one representing all people in a particular group. Both XML and JSON formats are common methods of online data transfer, but each has a particular structure and, thus, required methods to efficiently extract parts of that structure.

To extract data from webpages, we need to enable R to communicate with websites. When accessing websites from a browser, we simply type the webpage into the search bar, and the browser immediately extracts and renders the relevant information. The browser communicates with the web using a language called Hypertext Transfer Protocol (HTTP). After typing a domain name into a search bar, the browser asks a Domain Name System (DNS) server the relevant IP address. Then the search bar sends a relevant request for information to the server assigned IP address, and the server sends a response, which the browser displays as a functioning website. Often, one needs to login to a website or communicate appropriate credentials before the server will release data. Browsers do all of this automatically. To access the same data in R, one needs a way of communicating with servers using the appropriate protocols and then consuming and processing that information. R contains the “curl” package (Ooms, 2018) that provides R users an access point to the the C library libcurl and the “httr” package (Wickham, 2017) with verbs (such as GET, POST, PUT, etc.) that simplify accessing HTTP data by formatting appropriate requests with “curl”.

**Topic #2: API Setup (10-15 minutes)**

Many websites do not simply allow people to make a data request and receive unlimited data hosted on the appropriate servers. Often, users must setup an application on the desired website and then provide authentication credentials in R for use with the particular application. Examples of websites requiring users to setup applications include Twitter (<https://developer.twitter.com/>) and Facebook (https://developers.facebook.com/).

This section will simply walk participants through creating the appropriate (free) application on Twitter and extracting the appropriate credentials from the application to access the developer interface from R. Information from this section would be useful in setting up R to extract data from websites with developer credentials and authentication keys. For participants wanting to explore the web scraping example but do not want to setup an application from scratch, we will also provide already-created authentication keys. We will also explain functionality of the “twitteR” (Gentry, 2015) and “rtweet” (Kearney, 2018) packages in formulating and sending requests for Tweets that fall within a particular date range or contain particular words.

**Topic #3: Example Web Scraping (30 minutes)**

To integrate the first several sections (on data format, APIs, and web requests), we will provide a complete example that includes scraping data from Twitter that mentions particular companies and financial data of those companies. We will explain how to process and clean the data using tools in R, and we will use sentiment analysis to compare the type of Tweet with financial information from the companies. The latter topic is not intended for in-depth exploration but, rather, provides a more complete example of a question one might ask as well as how to go about trying to answer that question. If time permits, we will allow groups to explore the data (and the Twitter API) on their own and walk around to help answer questions they might have about approaching certain problems.

**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 provide additional materials for participants to read for self-study and include links to useful materials for approaching different web-scraping problems.

**Learning Objectives**

This workshop is designed to help you:

1. Explain online data formats and data transfer protocols to colleagues and understand why data on the web differs from commonly used data formats.
2. Setup applications to access web APIs from R, including knowing how to find and use authentication keys.
3. Formulate questions that require online data sources and know how to approach answering those questions without trepidation or fear.

**Presenter Information**

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**Presenter Bios**

Jeff Jones is the Director of Talent Analytics and Data Systems at Korn Ferry where he oversees the organization’s production scoring services, designs scoring algorithms, and is a subject matter expert for psychometrics and statistical methodology. He has published many R routines in theoretical and methodological journals such as *Psychometrika* and *Psychological Methods*, and is a coauthor on several CRAN and internal R packages. Jeff received his Ph.D. at the University of Minnesota in Psychometrics and Quantitative Psychology where he focused on creating new statistical methodology, asymptotic statistics, and higher-order geometry of statistical methodology.

Steven Nydick is a Data Scientist Developer 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 test for selection and classification. He also has an M.S. in Statistics from the University of Minnesota.

Ben Wiseman is a Data Science developer 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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**Appendix**

CV Jeff Jones

CV Steven Nydick

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Jeff Jones

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**Education:**

Doctorate in Quantitative Psychology and Psychometrics, University of Minnesota, October, 2013. Advisor: Dr. Niels Waller.

Bachelor of Science, Psychology, University of California, Davis, June 2006.

Bachelor of Arts, Japanese Language and Literature, University of California, Davis, June 2006.

Minor in Mathematics, University of California, Davis, June 2006.

**Employment History:**

Director, Talent Analytics and Data Systems, Korn Ferry, 2017 – Present.

Adjunct Professor, University of Minnesota, 2017 – Present.

Senior Manager of Analytics, Korn Ferry, 2015 – 2017.

Manager of Research and Analytics, Korn Ferry, 2013 – 2015.

Adjunct Professor, Hamline University, Fall 2013.

Graduate Instructor/Section Leader, University of Minnesota, 2006 – 2013.

**Awards:**

Korn Ferry Founder’s Award for Innovation, 2015.

Eva O. Miller Fellowship, 2012.

Graduate Summer Research Fellowship, 2009.

Graduate Research Partnership Program Fellowship, 2007.

**Publications:**

Jones, J. A. & Waller, N. G. (2016). Fungible weights in logistic regression. *Psychological Methods, 21,*

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functions. R package version 1.3.

**Presentations and Workshops:**

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*tutorial and jam session.* Master Tutorial at the annual meeting of the Society of

Industrial and Organizational Psychology, Chicago, IL.

Thompson, I. B., Song, Q. C., Goebl, A. P., Hall, S., Meade, A. W., Newman, D. A.,

Wee, S., & Jones, J. A. (2018, April). *Machine learning techniques for multiple*

*criteria optimization.* Alternative Session at the annual meeting of the Society of

Industrial and Organizational Psychology, Chicago, IL.

Wendt, H., Goff, M., Jones, J. A., & Hezlett, S. A. (2017, May). *Examining relationships*

*between the Korn Ferry personality inventory and job engagement across*

*countries.* In S. Dilchert and D. Ones (Chairs), *An IRT based approach to*

*personality measurement: Some cross cultural examinations.* Paper presented at

the annual meeting of the European Association of Work and Organizational

Psychology, Dublin, Ireland.

Hezlett, S. A., Jones, J. A., Lewis, J., Goff, M., & Stirling, E. (2017, April). *What*

*motivates may alienate: Linking motivational factors to derailment risks.* In S.

Hezlett (Chair), *Maladaptation: Building the nomological net of derailing traits and behaviors.* Paper presented at the annual meeting of the Society of Industrial and Organizational Psychology, Orlando, FL.

Jones, J. A., Goebl, A. P., & Semmel, S. G. (2017, April). *Modern methods for I-O*

*psychologists: An interactive tutorial in R.* Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, Orlando, FL.

Schwall, A., Beatty, A., & Jones, J. A. (2017, April). *Data visualization with R.* Master

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Psychology, Orlando, FL.

Semmel, S. G., Jones, J. A., & Goebl, A. P. (2017, April). *What is machine learning?*

*Foundations and introductions to useful methods.* Master Tutorial at the annual meeting of the Society of Industrial and Organizational Psychology, Orlando, FL.

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*personnel selection.* Poster presented at the annual meeting of the Society of

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Blazek, S. & Jones, J. A. (2016, April). *A year on the job: Simulations-based*

*assessments’ versatile utility.* In D. Guangrong (Chair), *The art and science of executive assessment: Research and practice.* Paper presented at the annual meeting of the Society of Industrial and Organizational Psychology, Anaheim, CA.

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program: Automating survey follow-ups, panel updates, and reports. Presentation given at Qualtrics Insight Summit, Salt Lake City, UT.

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monthly meeting of Minnesota Professionals for Psychology Applied to Work, Minneapolis, MN.

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Society of Industrial and Organizational Psychology, Philadelphia, PA.

D’Mello, S. & Jones J. A. (2015, May). *Demographic Differences in the Motivational*

*Drivers of Leaders*. Poster presented at the annual meeting of the Society of

Industrial and Organizational Psychology, Philadelphia, PA.

Goebl, A., Jones J. A., & Sharpe, E. (2015, May). *Relative Criteria Importance Depends*

*on Predictor Choices*. Poster presented at the annual meeting of the Society of

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**Courses Taught:**

Introduction to Data Analysis/Statistics for Undergraduates

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Senior Psychometrician, Pearson VUE, 2016 – 2018.

Psychometrician, Pearson VUE, 2013 – 2016.

Research Assistant, University of Minnesota, 2013 – Present.

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. (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.

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help you write cleaner R code. R package version 1.0.1.

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Nydick, S. W. (2014). catIrt: An R package for simulating computerized adaptive tests. R package version

0.5-0).

**Presentations and Workshops:**

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

Benjamin Wiseman

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**Education:**

MS, Lincoln University, Applied Statistics, 2015.

BS, Lincoln University, Biostatistics, 2013.

**Professional Experience:**

Data Scientist Developer, Korn Ferry, 2018 – Present.

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

Fountain, ED., Pugh, AR., Wiseman, BH., Smith, VR., Cruickshank, RH., and Paterson, AM. 2015. On the captive rearing of Hadramphus tuberculatus (Pascoe 1877) (Coleoptera: Curculionidae: Molytinae):is ex-situ conservation the lesser of two weevils? New Zealand Entomologist.

Gillespie, M., Cruickshank, RH., Wiseman, BH., Wratten, S. 2013. Incongruence between morphological and molecular markers in the butterfly genus Zizina (Lepidoptera: Lycaenidae) in New Zealand.Systematic Entomology 38:151-163.

Fountain, ED., Wiseman, BH., Cruickshank, RH., and Paterson, AM. 2013. The ecology and conservation of Hadramphus tuberculatus (Pascoe 1877) (Coleoptera: Curculionidae: Molytinae). Journal of Insect Conservation 17:737-745.

**Software:**

Wiseman, B. W., Nydick, S.W., Jones, J (2018) roperators: Additional Operators to Help you Write Cleaner R Code. R package version 1.0-1).

Wiseman, B. W. (2015) Neurofriendly: Artificial Neural Networks Made Simple

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

**Presentations and Workshops:**

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