Integrating Visual and Statistical Analysis With R: Fast, Efficient, Pixel-Perfect Charting with the fxl R Package
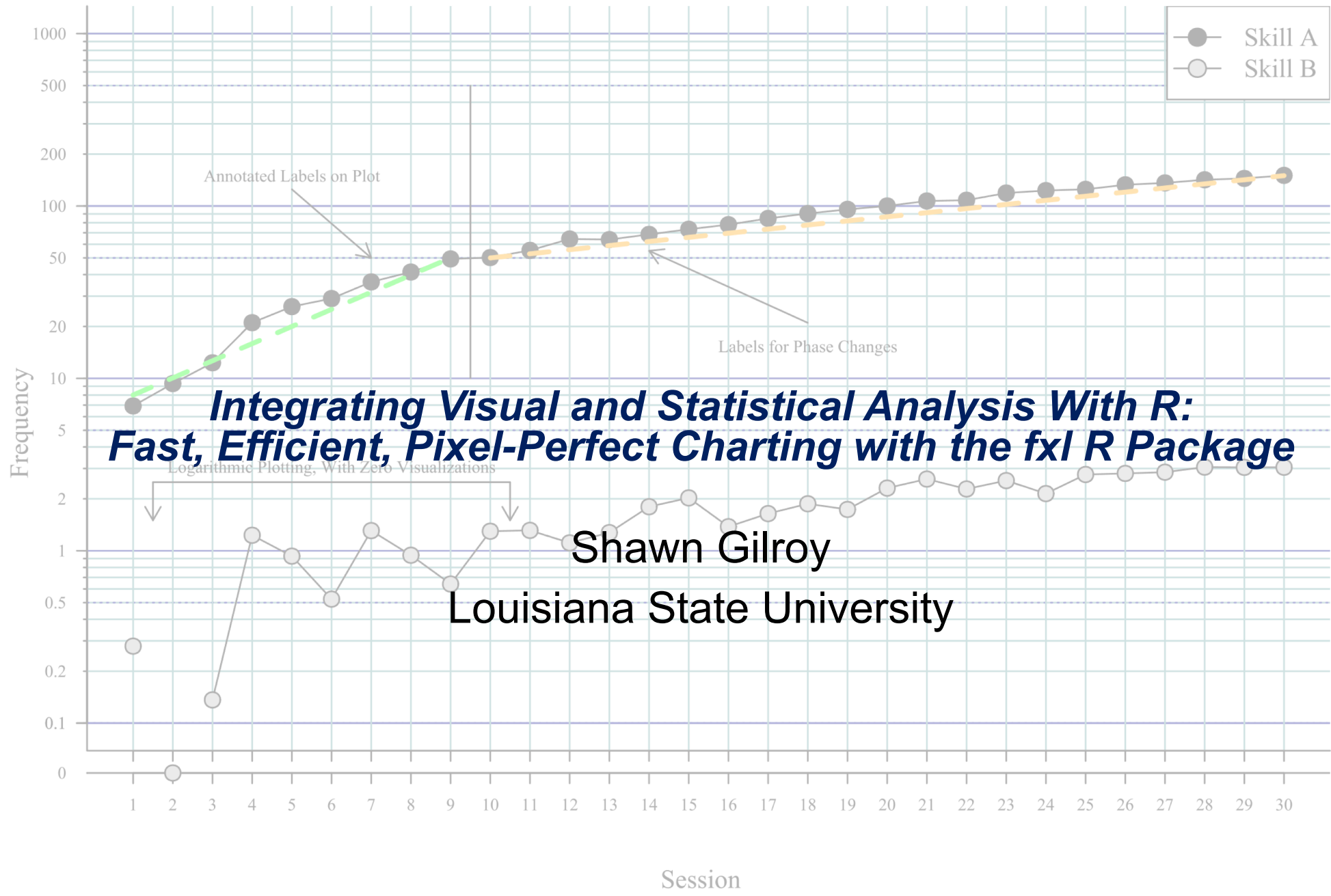
Some of the authors of this publication are also working on these related projects:

Project   Supports for Graduate Students and Clinicians using Technology in Behavior Analysis View project

Integrating Visual and Statistical Analysis With R:
Fast, Efficient, Pixel-Perfect Charting with the fxl R Package

Shawn Gilroy

Louisiana State University

Background

About Me

Shawn P. Gilroy

Behavior Analyst
Licensed Psychologist

- Professor of School Psychology, Louisiana State University
- R user in both research as well as in clinical practice
- Developer of various programs, tools, and supports using technology

Background

Translational Research

Behavior Analytic Intervention

Technology in Behavior Analysis

Open Source/Open Science

Examples

Economic theory, reinforcer value, function-based intervention
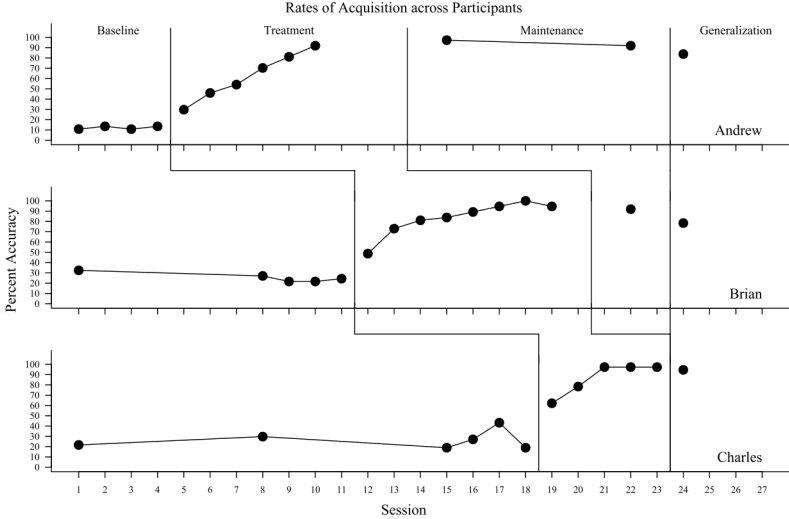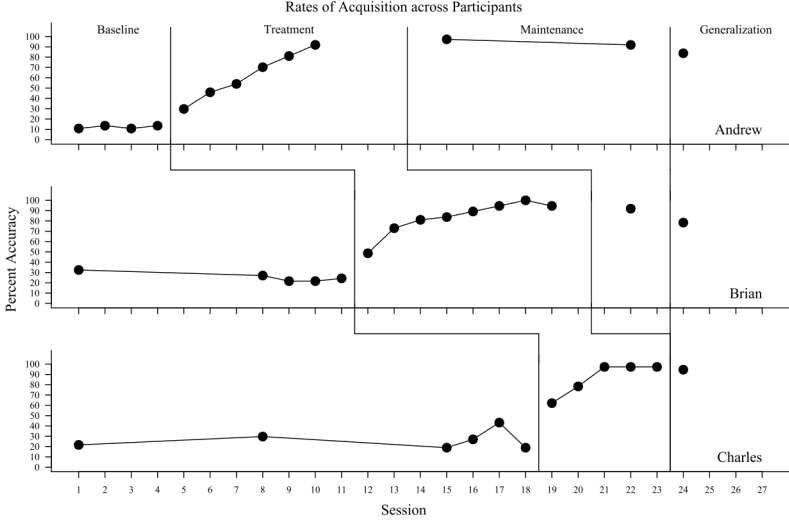
Early and Intensive Behavior Intervention (EIBI) for autism

Development and evaluation of technology for research and practice

Preregistration, archiving study methods and data, transparency in single-case research designs

Applied Behavior Analysis and Spreadsheet Software

A Case for *Less* Spreadsheets in Behavior Analysis

Some Pro's of Spreadsheet Software

- **Cost**: Spreadsheet software is often included in suites purchased by individuals, organizations

- **Flexibility**: Considerable freedom in how to enter data, chart and visualize data

- **Stability**: Mature products exist and have existed for decades

|	A	B	C	D	E
1	Session #	Attention	Alone	Demand	Control
2	1	5			
3	2		1		
4	3			3	
5	4				0
6	5	8			
7	6			4	
8	7				1
9	8		2		
10	9			3	
11	10	7			
12	11			3	

Many Con's of Spreadsheet Software

- High potential for human error (i.e., copy/paste errors)

- All operations must be performed by hand via the user interface and cannot be automated*

- Extension macros present security risks, and most organizations disable these by default

- Workbooks are typically individualized, requiring the coordination of numerous individual files

- Limited means of version control, documenting incremental changes within tracked files

- Limited range of built-in methods, options for analyzing data

Types of Headaches

Migraine   **Hypertension**
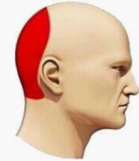
Stress

Some *Limited* Alternatives to Available Spreadsheet Software

GraphPad Prism for Charting

- General templates can be constructed

- Plotting/drawing options are more refined that traditional spreadsheet software

- Basic frequentist statistics can be performed

- Generally an extra cost in single-case research just to access the charting functionality

Visual Basic Macro's, Custom Defined Functions

- Essentially a spreadsheet with some embedded programming to simplify operation (e.g., drawing phase change lines in select designs)

- Not officially supported by manufacturer, high risk to security and typically disabled by default

- Generally limited, users on their own with Visual Basic (considered a dead language)

Spreadsheets, Behavior Analysis, and What Comes Next

Current Needs in Applied Behavior Analysis

- Free/affordable, accessible, flexible means of organizing large amounts of consumer data

- Graphical engines designed to facilitate visual analysis and support other behavior analytic applications

- Access to modern and appropriate statistical tools, e.g. Bayesian/frequentist multilevel models

The R Statistical Program

- A statistical language and interpreter that supports various analyses and methods

- Wide arrange of appropriate modules, each free of charge as free/open source software

- Provides low-level access to plotting devices

- Supports various modern statistical tools amenable to time-series intervention data

Student Performance
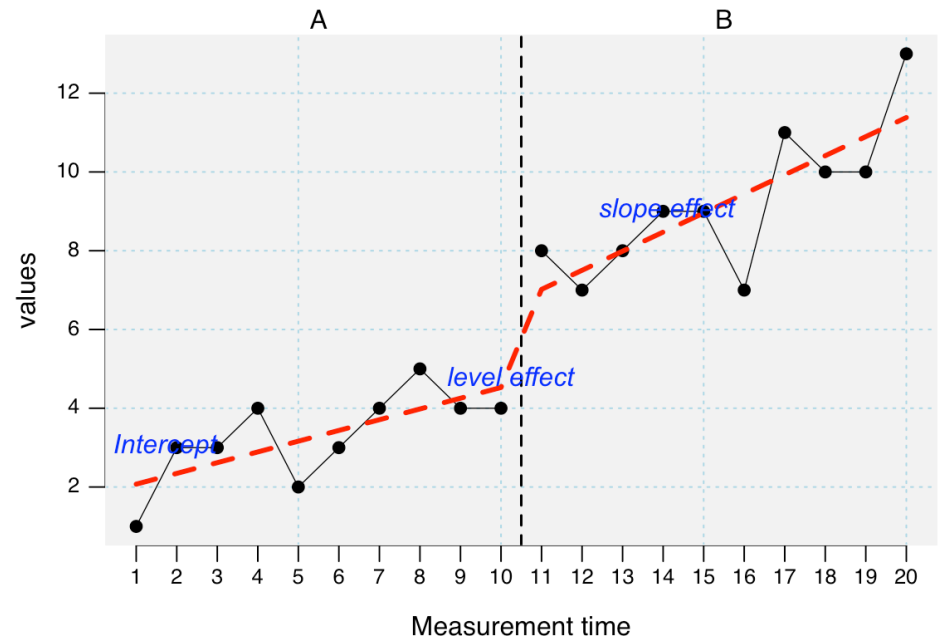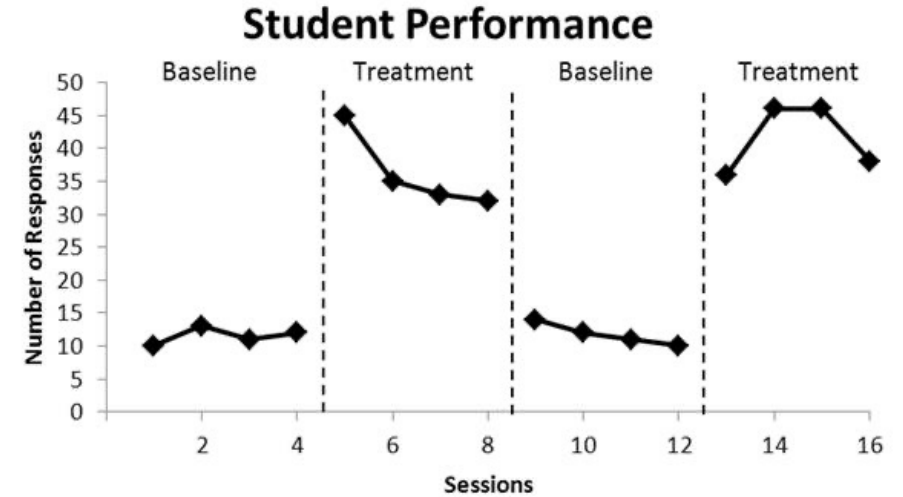
A Facsimile of Excel in R, a *Faux Excel* (fxl)

Goals of the *fxl* package in R

- Develop a free, open-source system of creating clinic- and publication-quality figures in behavior analysis

- Facilitate transparency and openness though archiving study data, figures, etc. via online repositories

- Support for the designs, conventions, and features expected in single-case designs (we are very particular)

- Automate options that behavior analysts (or RBTs) have historically had to perform continuously by hand

- Construct a syntax for R that is simple enough for graduate students and those with R training to learn and to apply to generate figures
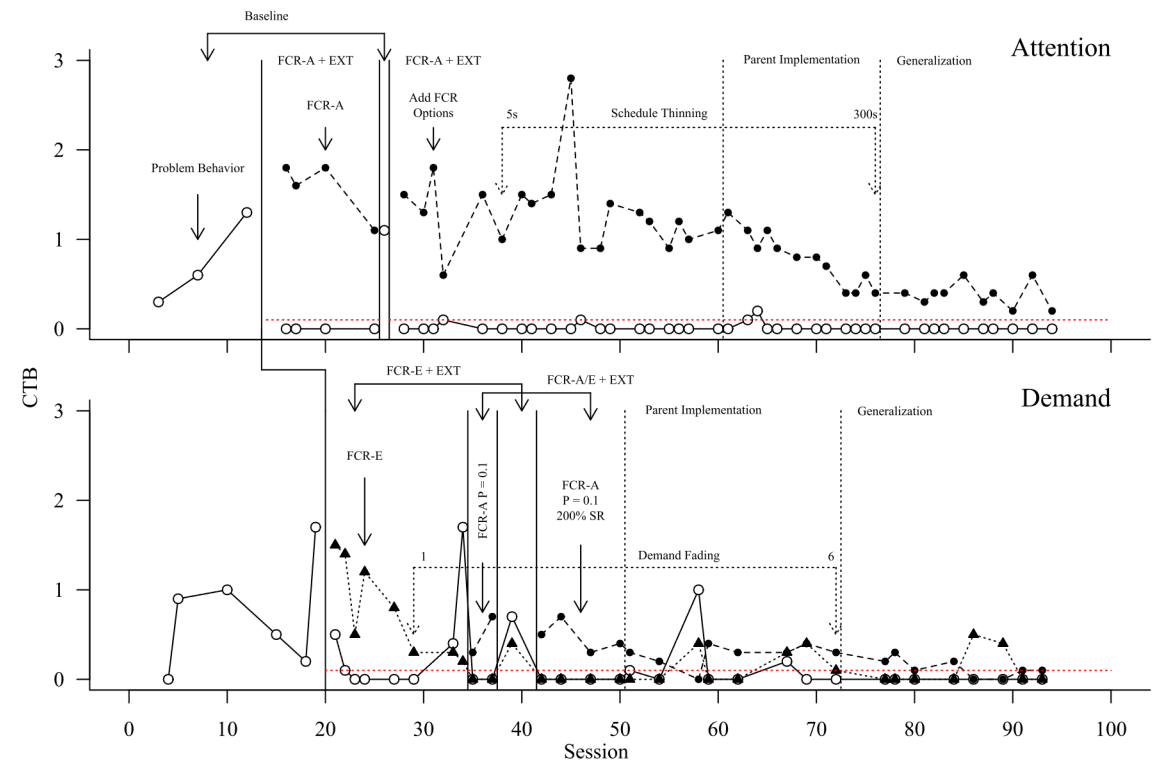

A true, purpose-built graphical engine specific to behavior analytic research and practice

Replicating the Behavior of Excel in R: A Faux Excel (fxl) Package

Supporting Existing Conventions in SCR

- Built-in support for multiple baseline, reversal, blended designs (e.g., multiple baseline + individual reversals)

- Source-level control over drawing markers, lines, phase lines, labels, and other aspects of single case designs

- Complete, pixel-perfect control over plot and sub-plot placement and design
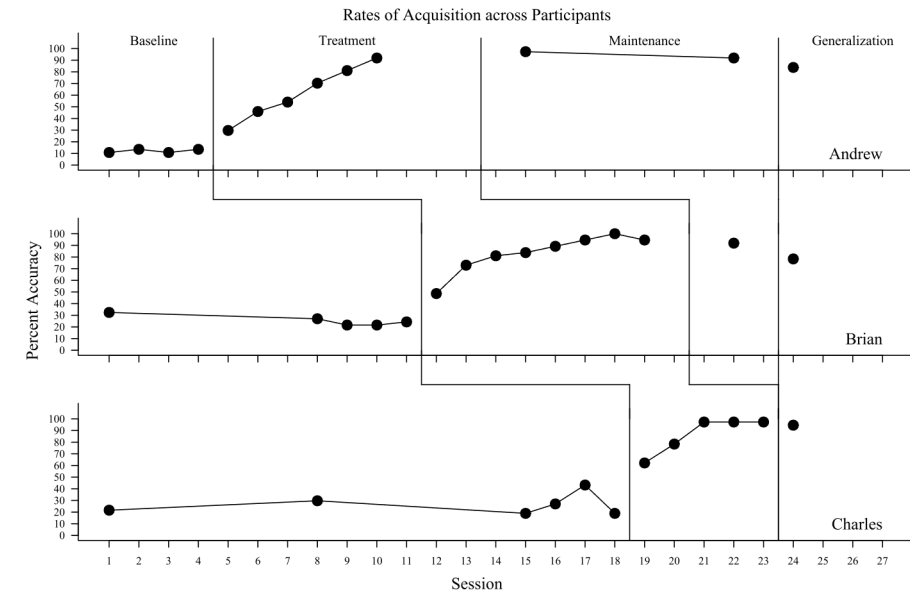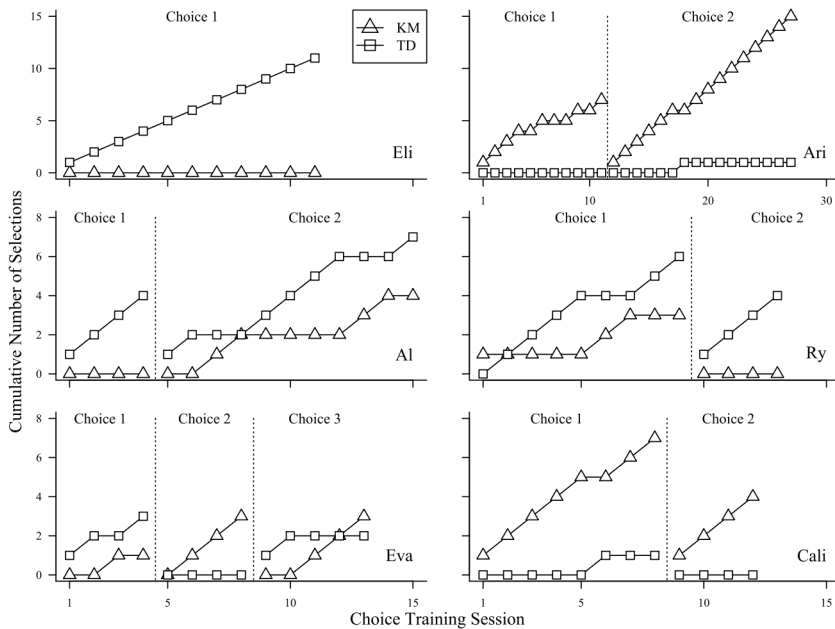
Support for New Conventions in SCR

- Use of R to automate drawing of figures for individuals within groups, entire centers using Rmarkdown/RNotebooks

- Access to appropriate statistical methods for evaluating times-series data (e.g., multilevel modeling)

- Don't Repeat Yourself (DRY) programming philosophy (i.e., no more repetitive line dragging)

- Readily archived to version control support transparency

Example 1: Replicating Existing Single-Case Design Conventions

Gilroy et al. (2021)

- Multiple Baseline Design applied across three participants

- Comparison #1: Evaluation of Baseline vs. Reinforcement Condition

- Comparison #2: Parametric difference from varying schedules (e.g., Inelastic, Unit Elastic, Elastic price)

Common Conventions

- Multiple baseline figure, with individual participant subpanels

- Styling of lines, markers, table as desired

- Dynamic placement and drawing of facet- and condition-level labels

- Built-in mechanisms for drawing individual and across participant phase change lines

Individual Evaluations of Reinforcer Efficacy and Elasticity across Reinforcers
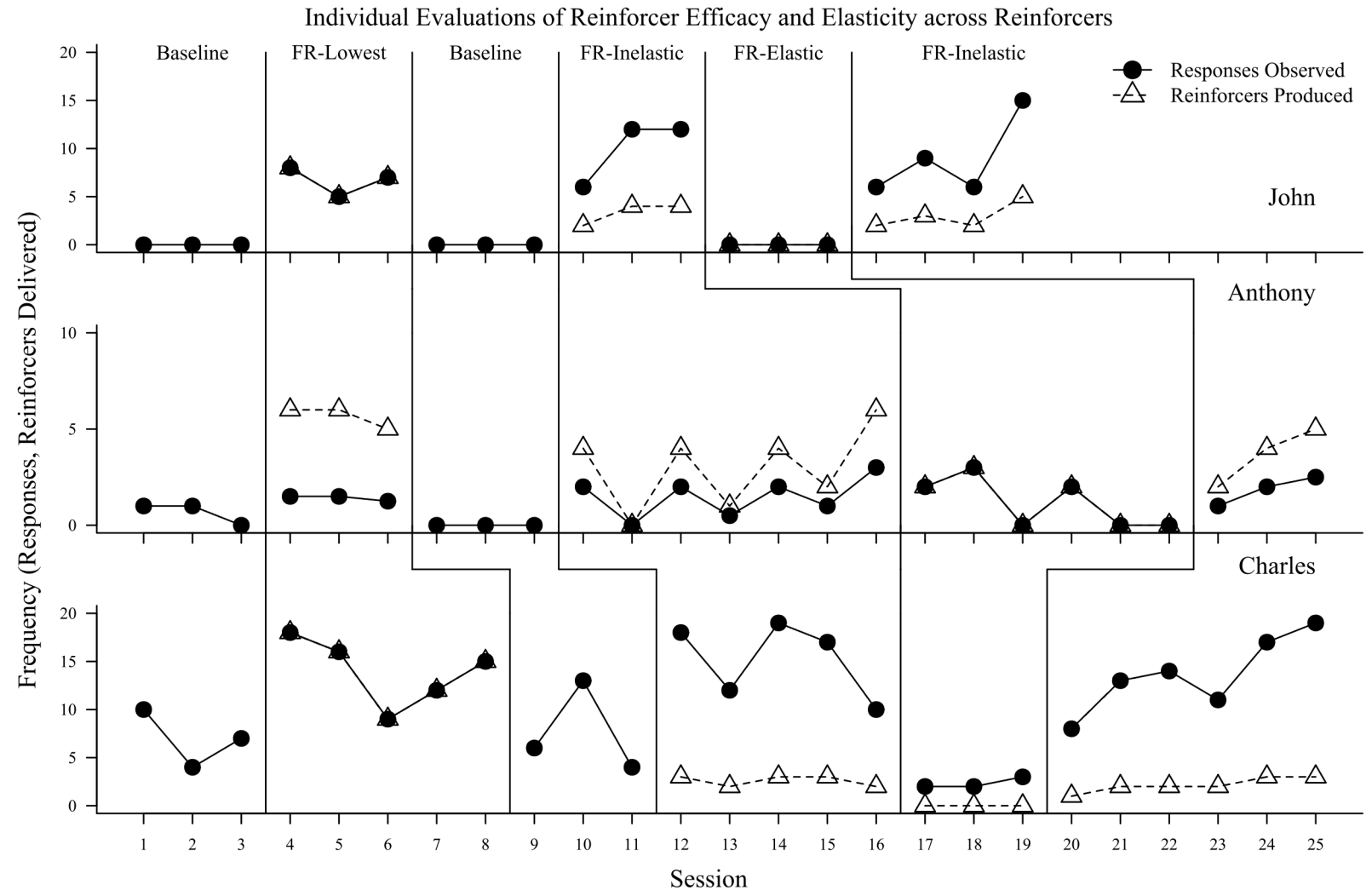
Link to Source to Draw Figure

Example 1: Some New Conventions, Embedded Statistical Analyses

Embedded Statistical Analyses

- Multilevel modeling approach applied and predictions drawn alongside empirical data

- Accommodates a crossed random effect structure (i.e., data nested within participants, across conditions)

- Designed to evaluate fixed effects for changes in level and/or trend (original, full model)

Statistical Results

- Likelihood Ratio Tests supported modeling changes in level alone (i.e., trend factor)

- Contrasts for Level:
Intercept[Baseline] = 2.556 (2.404), ns
Phase[FR-Lowest] = 4.821 (2.051), ns
Phase[FR-Inelastic] = 5.866 (2.423), ns
Phase[FR-Elastic] = -1.372 (2.031), ns

Takeaways: Statistical and visual analyses suggest a relative superiority of FR-Inelastic (though underpowered of course)

Individual Evaluations of Reinforcer Efficacy and Elasticity across Reinforcers
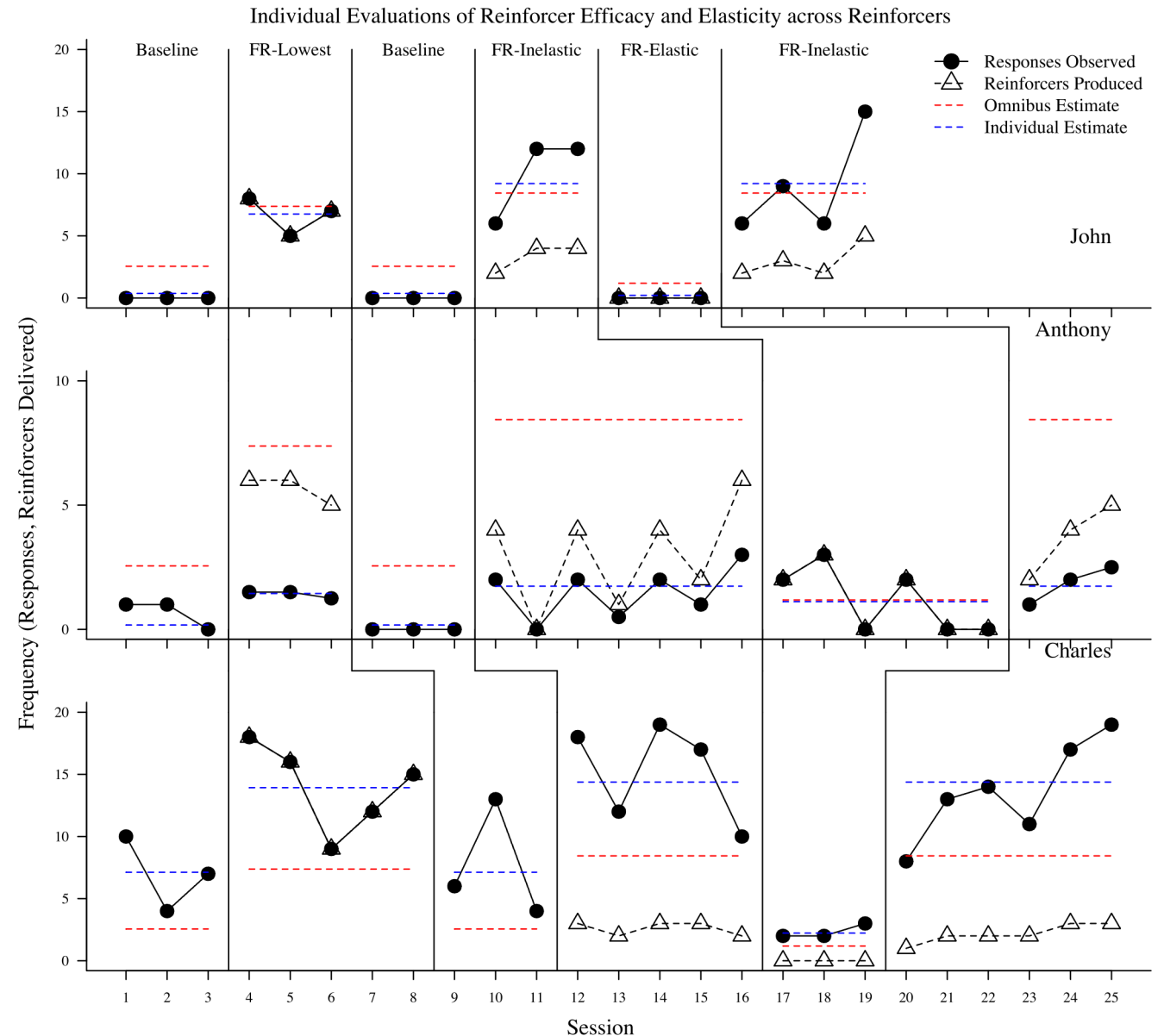
Example 2: Conducting Single-Case Research Synthesis

Single Case Research Synthesis

- Synthesis refers to the aggregation of effects of intervention across individuals, studies

- Estimate overall effects, potential influence of moderators

Three Simulated MBL Studies (n = 9 cases)

- Multilevel modeling approach as applied in Example 1

- Crossed random effect structure (i.e., data nested within participants and studies, but across conditions)

- Evaluate variance for individual-, condition-, and study-level factors and fixed effects for changes in level/trend

Parameters of Single-case Simulations

- Pre-set variation in variance at the individual-, condition-, and study-level (to recover later)

- Specified effects representing changes in level and slope of responding across sessions

Hypothetical Study A

Hypothetical Study B

Hypothetical Study C
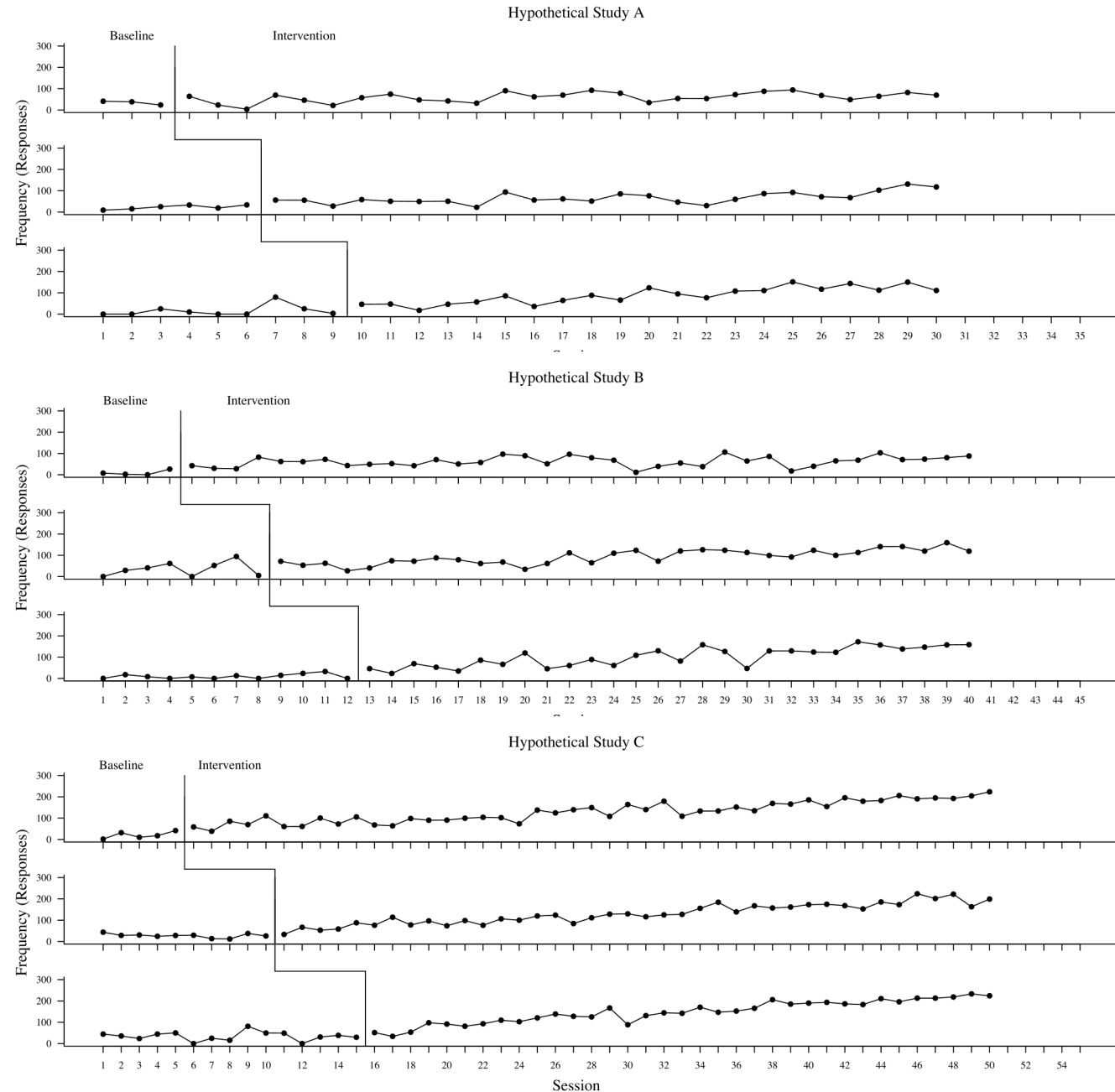
Example 2: Visualizing Single-case Research Synthesis

Analytical Strategy

- Multilevel modeling approach applied across various single-case studies (common units of behavior)

- Crossed random effects (i.e., data nested within participants, conditions, studies)

- Evaluate effects for changes in level and/or trend

Statistical Results

- Omnibus Level Change: 24.70 (23.54), ns; Slope Change: 2.76 (0.82), $p < .05$

- Interpretation: Overall, intervention produced population-level change in slope of change

- Individual-level effect sizes can be estimated from Level/Slope change and evaluated in meta analysis (i.e., point estimates and variance)

Takeaways: Both visual and statistical analysis support the determination of changes in trend

Example Multi-level Research Synthesis: Fixed and Random Effects and Observed Data
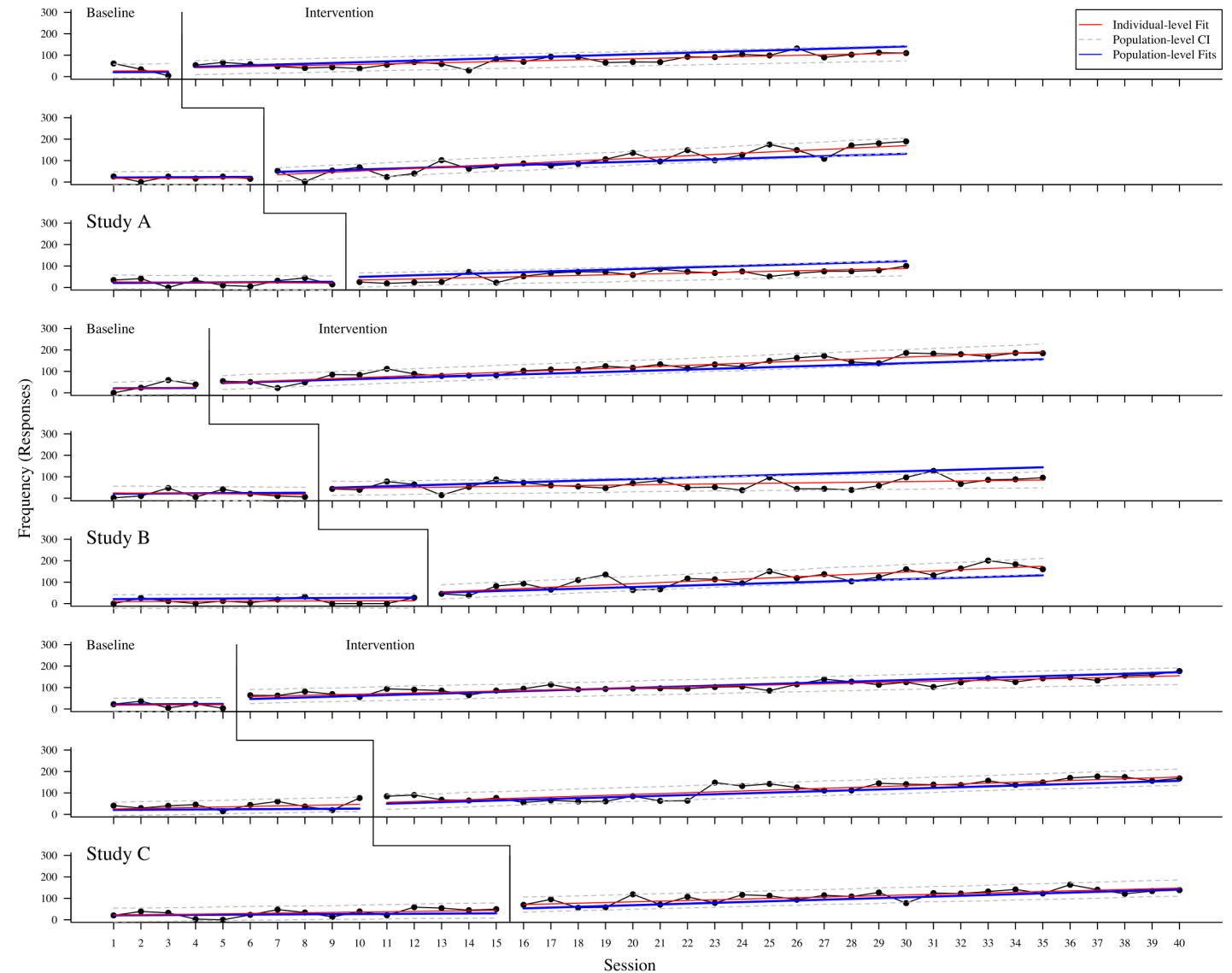
Example 3: Living Behavior Plans/Treatment Evaluations

Individual-, Class-, School-wide Visual Analysis

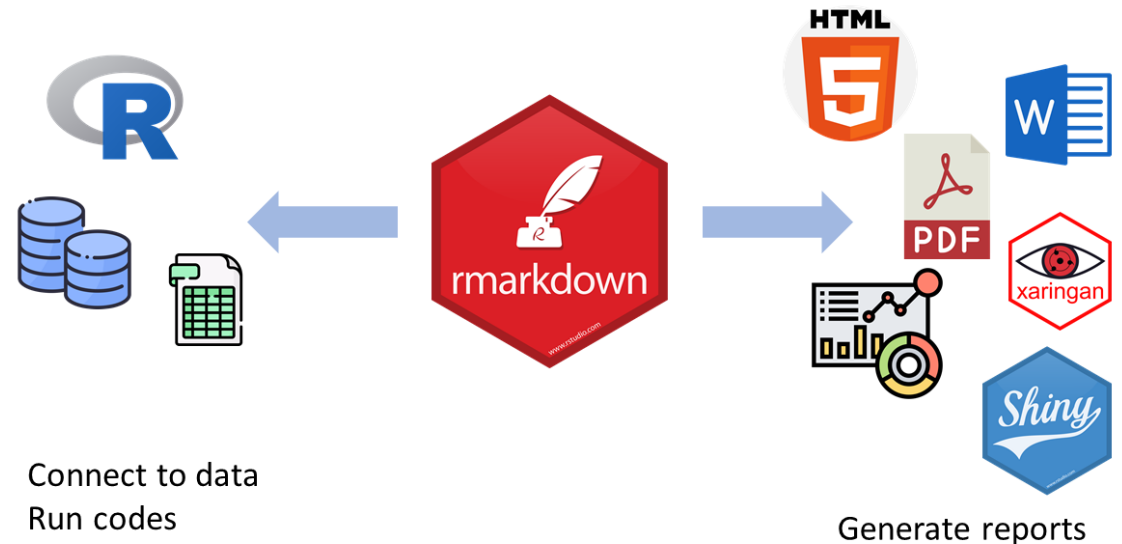- Rmarkdown: a general format for creating reports, plans, manuscripts, etc. from R and Markdown (Rmarkdown = R + Markdown)

- Individual Reports: Construct *living* behavior plans, written and updated as new data are entered

- Class-/School-wide Reports: Generate individualized plans, plots across *all* individuals in a single operation

Addressing Scaling Challenges in Behavior Analysis

- DRY-Don't Repeat Yourself and visual analysis/charting

- Integrate various data sources into a single, living report using a single platform (i.e., stop juggling between Excel/Word)

- Develop in-house templates to meet the unique needs of individuals and funders (e.g., Medicaid updates, IEP plan goals)

- Spend less time 'tinkering' with Excel, more time consulting, training/supporting staff, other behavior analytic activities

- Save resources if paying to construct/update figures by hand

- Reclaim your early Monday mornings/weekends!

Connect to data
Run codes

Generate reports

New Opportunities, New Challenges

Supporting Current Practices

- Single-case research designs will always need a flexible means to visualize individual data

- Current practices for creating/updating figures are tedious, do not scale well with complexity

- Time spent charting is time spent away from direct service, consultation

Some (Not So) New Challenges

- Limited opportunities for training, mentorship in statistics and programming

- R is free, but the learning curve can be steep

- Learning new skills requires considerable investment

- R/*fxl* not a solution to most challenges in behavior analysis, but a worthwhile option to explore

Enhancing Behavior Analytic Research, Practice

- Open source tools and open science are consistent with evidence-based practice and ethical research

- Complex phenomena require sophisticated tools, R succeeds where Excel, Prism fall short

- Methods provided by *fxl* support an interface between modern statistics and visual analysis

Contact Information, Questions

Contact Information

- Email: sgilroy1@lsu.edu

- Github: https://github.com/miyamot0

- OrcID: https://orcid.org/0000-0002-1097-8366

Presentation Materials, Source Code

- Github Repositories:
    https://github.com/miyamot0/fxl (R Graphing Engine)

    https://github.com/miyamot0/AnalyticPmaxSource (R Manuscript Example)

- ResearchGate: https://www.researchgate.net/profile/Shawn_Gilroy

Future Directions, Next Steps

- Expanding upon charting options

- Developing documentation for users to develop behavior analytic manuscripts, behavioral programming using R

Questions?