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# Formative Graphing with Templates for Microsoft Excel 2013

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**Formative Graphing with Templates for Microsoft Excel 2013**

by

David M. Cole

A Thesis

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

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### **Abstract**

Observant practitioners of behavior analysis graph data formatively, or at least once per session, because graphs improve analysis and dissemination of data (Bushell & Baer, 1994; Cooper, Heron, & Heward, 2007; Johnston & Pennypacker, 2009). In service settings, practitioners commonly use Microsoft Excel to graph. Although numerous field-specific tutorials explain how to create new graphs with Microsoft Excel (e.g., Carr & Burkholder, 1998), tutorials rarely encourage formative graphing with procedures that would make updating graphs easy and efficient. Templates with programming code could address this limitation. With Microsoft Excel 2013 and a single-subject design, I compared graphing with a template to graphing with a typical textual task analysis. Four graduate students created and updated three types of graphs more accurately and efficiently with the template than with the task analysis. Moreover, the four students reported that graphing was easier with the template than with the task analysis. I conclude by discussing how these improvements might improve clinical practice when multiplied by days, weeks, and years.

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## Chapter 1: Introduction

Practitioners of behavior analysis record data to isolate and preserve dimensions of behavior, like count and duration, for analysis (Johnston & Pennypacker, 2009). Sometimes, practitioners base clinical decisions on the raw data. Yet, they might make more efficient and effective decisions if they first transform the data, if they display the data graphically (Cooper, Heron, & Heward, 2007; Greer & Ross, 2008; Johnston & Pennypacker; Nicol & Pexman, 2010). Graphs are also superior over raw data for communicating with stakeholders, who may not suffer inspecting a series of numbers; for recruiting praise for practitioners whose accomplishments are showcased with graphic displays; and for delivering habilitating feedback to the people whose behavior is graphed (Bushell & Baer, 1994; Cooper et al.; Davis, 2011).

In addition to the form in which practitioners contact data (i.e., numerical versus graphic), frequency of contact is paramount to the applied analysis of behavior (Hayes, Barlow, & Nelson-Gray, 1999). Only when practitioners maintain “close, continual contact with relevant outcome data” can client behavior finely and reliably influence clinical decisions (Bushell & Baer, 1994, p. 9; see also Cooper et al., 2007; Johnston & Pennypacker, 2009; Skinner, 1956). By graphing data at least once per session, ineffective treatments are less likely to be prolonged, effective treatments are less likely to be interrupted, and more effective treatments can be designed as variability is systematically eliminated (Cooper et al.; Greer & Ross, 2008; Sidman, 1960; Skinner, 1956). The analytic practice described above, referenced here as formative graphing, John Tukey referred to as *exploratory data analysis* (as cited in Johnston & Pennypacker), Cooper, Heron, and Heward (2007) as *formative assessment*, and Bushell and Baer as definitive of applied behavior analysis (see also Greer & Ross).

Despite its established advantages, Bushell and Baer (1994) lamented that formative graphing does not typify service practices. They proposed that it may not be perceived as “useful, cheap, and easy” (p. 6; see also Hayes et al., 1999). Given their criteria and with special consideration to graphing formatively, I discuss the merits of graphing with software relative to pencil-and-paper graphing, describe broad characteristics of Microsoft Excel as a software platform for graphing, and introduce a graphing template for Microsoft Excel 2013<sup>1</sup> that addresses limitations of alternative graphing solutions.

### **1.1 Graphing Electronically**

Pencil-and-paper graphing, on the surface, may appear to meet Bushell and Baer’s (1994) criteria: A pencil-and-paper graph can be more useful than a series of numbers; pencils and paper are cheap and accessible; and in grade-level mathematics and science courses, students are acquainted with plotting data by hand, so doing so may seem easy. Yet, properties of pencil-and-paper graphs render them demanding and rigid tools that are not readily manipulated for data analysis. Meticulousness (e.g., drawing uniformly sized data points, using a straight edge to draw data paths) can determine the effectiveness of pencil-and-paper graphs (Davis, 2011; Lo & Konrad, 2007; Publication Manual, 2010). The importance of meticulousness increases with the number of variables concurrently plotted, the variability of data, and the size of data sets. Prescience may be required for pencil-and-paper graphs to accommodate future data without significant, recurring investment.<sup>2</sup> Adjusting axis scales on a pencil-and-paper graph, for example, would require laboriously re-plotting data. If such manipulations are avoided, analysis could suffer. Options for preserving, reproducing, and disseminating pencil-and-paper graphs—

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<sup>1</sup> While this study only examined graphing acquisition with Microsoft Office Excel 2013, the templates are mostly compatible with Microsoft Office Excel 2007 and 2010.

<sup>2</sup> Save, perhaps, for the standard acceleration chart (Pennypacker, Gutierrez, & Lindsley, 2003).

as ethically and legally mandated (Behavior Analyst Certification Board, 2012; Health Insurance Portability and Accountability Act, 1996)—are costly and scant, short of digitalization (Barton, Reichow, & Wolery, 2007; Vanselow & Bourret, 2012).

Electronic graphs share the properties of pencil-and-paper graphs that make them more useful than a series of numbers; however, electronic graphs are more useful than pencil-and-paper graphs insofar as visually cleaner graphs are more useful graphs (Lo & Konrad, 2007; Publication Manual, 2010). Electronic data points and data paths are free of mechanical inconsistencies. They also render unnecessary the distracting gridlines that increase precision of pencil-and-paper plotting. Moreover, electronic graphs increase the easiness and efficiency of manipulations that prove laborious with pencil and paper. For example, electronic axes can be rescaled with a few clicks of a mouse if not automatically; every data point and data path need not be re-plotted by hand.

Benefits of electronic graphing may appear to come at a high cost of entry. The latest version of Microsoft Office, which includes Microsoft Excel, costs either a one-time fee of \$140 or a subscription fee of \$7 per month for a single license and \$10 per month for 5 licenses—and this does not include the cost of compatible hardware. Yet, added expense for software and hardware may prove negligible or null for the majority of practitioners who already have access to these resources or can obtain cheap to free versions or alternatives (e.g., LibreOffice). Moreover, the combined upfront and ongoing costs for electronic graphing must be compared to the ongoing labor and record-keeping costs required by frequent pencil-and-paper graphing. The latter could dwarf the former. Future researchers could consider a formal cost-benefit analysis.

## 1.2 Graphing with Microsoft Excel

Subsequent discussion pertains to graphing specifically in Microsoft Excel. This discussion will be aided by the introduction of five terms to describe features in Microsoft Excel: dynamic, static, basic, advanced, and ad-hoc. See Appendix A for definitions and examples of these terms.

As the most common spreadsheet program and perhaps graphing platform (Walkenbach, 2013), Microsoft Excel is widely available and familiar to many practitioners. It is also relatively cheap, and with sufficient training, capable of producing graphs consistent with behavior-analytic standards (Lo & Starling, 2009; see Appendix B for standards). Barton and Reichow (2012) noted that online graphing platforms (e.g., [chartgo.com](http://chartgo.com), [onlinecharttool.com](http://onlinecharttool.com), [chartgizmo.com](http://chartgizmo.com)) are available for free; however, these tools cannot produce essential elements like condition lines or labels. Other authors have described feature-rich graphing platforms marketed to institutions (e.g., GraphPad Prism, SigmaPlot, GrapherSix, and DeltaGraph; Barton et al., 2007; Vanselow & Bourret, 2012); however, their cost inhibits practitioner adoption (e.g., a single-user license for the commercial edition of SigmaPlot costs \$799; see Sysstat Software, 2014). Moreover, capitalizing on the features of these specialized programs requires a skill set that practitioners are unlikely to prepossess (Barton et al., 2007; Vanselow & Bourret, 2012).

Microsoft Excel is not without its limitations. Su (2008) complained that many desirable graphing conventions are not default in Microsoft Excel (e.g., data points and paths are not grayscale; see Appendix B for behavior-analytic graphing standards). Modifying its default settings, Su added, often requires idiosyncratic behavior chains (e.g., disconnecting data points requires six mouse clicks in Microsoft Excel 2013). Still, the basic feature set of Microsoft Excel accommodates many behavior-analytic standards in a way that is conducive to formative



graphing. For example, although data paths must be manually reformatted to black on creating a graph, data paths are dynamic and automatically reposition on axes being rescaled.

Where basic features are lacking, ad-hoc solutions may substitute (e.g., to create condition lines, condition labels, criterion lines, *y*-axis floating). Ad-hoc solutions require little technical skill but discourage formative graphing because they cannot produce dynamic chart elements. For example, inserting condition lines with drawing tools, a commonly described procedure (e.g., Carr & Burkholder, 1998; Dixon et al., 2009; Grehan & Moran, 2005; Hillman & Miller, 2004), may not improve on pencil-and-paper graphing. Precisely placing uniform condition lines with the drawing tools requires meticulousness. If the *x*-axis is scaled to accommodate only existing data, condition lines must be manually repositioned whenever new data are entered; if the *x*-axis is scaled to accommodate future data like a pencil-and-paper graph (which is inconsistent with behavior-analytic graphing standards; Manuscript Preparation, 2000), underestimating of the number of future data points will still demand re-scaling axes eventually and, thus, still demand manually repositioning condition lines (or patching together multiple graphs). If dozens of condition lines must be repositioned on new data being graphed, practitioners might avoid frequent graphing or graphically indicating all relevant condition changes.<sup>3</sup>

Alternatively, advanced solutions may substitute for missing basic features and unwieldy ad-hoc solutions. Given sufficient technical skill, chart elements (e.g., condition lines, condition labels, *y*-axis floating) may be inserted precisely and, on chart parameters being modified (e.g., new data being entered), resized and repositioned automatically. Advanced solutions can reduce

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<sup>3</sup> Analogously, on his dissatisfaction with a large-*n* experiment, Skinner (1956) wrote, “You cannot easily make a change in the conditions of an experiment when twenty-four apparatuses have to be altered” (p. 228); you cannot easily make a change in a graph when dozens of chart elements have to be altered.

the recurring frustration and expense of updating static elements; they offer significant and ongoing improvements in usefulness, efficiency, and easiness of graphing. Advanced solutions also may be costly and difficult to set up. They often require complex formulas and programming code. If the cost and difficulty of their design can be mitigated (e.g., via templates), advanced solutions should be preferred over ad-hoc solutions.

### **1.3 Graphing Templates**

I depart from prior behavior-analytic tutorials by proposing that practitioners graph from a template rather than blank spreadsheets. The advantages of templates are many: templates decrease repetitive tasks (e.g., deleting gridlines), they can be vehicles for complex equations and code that further decrease repetitive tasks as well as increase computational power (e.g., for calculating the correct placement of condition labels), and they decrease the number of steps in which users must be trained (e.g., floating of the y-axis; Pierce & Evelyn, 2011; cf. Lo and Starling, 2009, which examined the utility of a 17-page graphing guide). Perhaps most importantly, generating graphs from blank spreadsheets may not replicate typical service practices. When generating new graphs, practitioners may use preexisting graphs as makeshift templates. When adding data to an existing graph, a defining feature of formative graphing, practitioners certainly do not generate graphs from blank spreadsheets.

Graphing templates are not without disadvantages; however, their disadvantages may be shared or exceeded by graphing task analyses. First, without additional training, template users may be limited to graphing features embedded in a template (e.g., line graphs for a template designed exclusively for line graphs). By the same token, task-analysis users may be limited. Researchers have not reported that, following exposure to graphing task analyses, participants

could manipulate graphs in ways beyond those procedures taught with the task analyses.<sup>4</sup> In other words, researchers have not demonstrated that their task analyses imparted generalized graphing repertoires. Moreover, practitioners may find that the graphing template described below expands expand their options insofar as it permits easy and efficient implementation of features outside of their technical repertoires (e.g., floating of the y-axis). Second, templates will be compatible with a limited range of software solutions and versions thereof. While feature-rich templates will tend to be software-specific (e.g., elements of a Microsoft Excel template may not be compatible with Numbers for Mac), task analyses will be similarly specialized because user interfaces vary widely among software solutions. Moreover, because Microsoft Excel user interfaces tend to change more rapidly than its data functions or programming engine (Walkenbach, 2013), task analyses may be the more sensitive to version changes for a given software solution (Dixon et al., 2009).

#### **1.4 Acquisition of Electronic Graphing Skills**

Three studies have reported to experimentally evaluate graphing skill acquisition by behavior-analytic standards with Microsoft Office—two evaluated lengthy task analyses and one evaluated lengthy, computer-based tutorials for their effects on graphing from blank spreadsheets. Lo and Starling (2009) used a multiple probe across participants design to examine the effects of a prerequisite skill checklist, graphing glossaries, illustrated instructions, a model graph to control for variation in participant experience, and a written prompt (e.g., specifying the y-axis scale) on the graphing accuracy of 3 graduate students. Students were provided up to 30 min to graph a three-tiered multiple baseline design with Microsoft Excel 2007 (Lo & Starling, 2009). In the pre-baseline condition, an author spent 15 min reviewing with students the essential

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<sup>4</sup> Teaching generalized graphing repertoires might be accomplished by technologies like programmed instruction (see Skinner, 1958; e.g., Davis, 2011).

characteristics of multiple baseline designs (Lo & Starling). Immediately prior to treatment conditions, an author reviewed the task-analysis glossary with each student. On 50 criteria, the graphing accuracy of all students increased in mean level (Lo & Starling). Lo and Starling showed that a treatment package of in-person trainings and comprehensive in-vivo training materials may moderately improve accuracy of copying model graphs with Microsoft Excel 2007.

Dixon et al. (2009) improved on Lo and Starling (2009) by including graphing duration, controlling for practice effects, and controlling for procedural fidelity. Dixon et al. used a randomized group design to examine the relative effects of two illustrated technical articles—those developed by Carr and Burkholder (1998) and the one created for their investigation—on graphing accuracy and efficiency by 22 graduate students. Students were provided with unlimited time to graph reversal, multielement, and multiple baseline designs with Microsoft Excel 2007 (Dixon et al., 2009); students were not provided with a model graph identical to the target graph. On 13, 15, and 16 criteria, respectively, students in the test group completed a mean of 12.91 steps (control = 10.00 steps), 11.45 steps (control = 6.64 steps), and 11.27 steps (control = 10.27 steps) correctly (Dixon et al.). Students in the test group took a mean of 24.7 min (control = 31.1 min), 13.6 min (control = 27.3 min), and 30.4 min (control = 35.0 min), respectively (Dixon et al.), to complete their graphs. Dixon et al. showed that an up-to-date task analysis, written for the correct version of Microsoft Excel, resulted in more accurate and efficient graphing.

Vanselow and Bourret (2012) described an alternative approach to teaching graphing accuracy: pre-treatment interactive tutorials. The authors used a randomized group design to examine the relative effects of pre-treatment interactive tutorials and pre-treatment videos on

graphing accuracy by 10 practitioners who were novice graphers (Vanselow & Bourret, 2012). Practitioners in their study were provided with a written prompt and unlimited time to graph a reversal design with Microsoft Excel 2010. On 35 criteria, Vanselow and Bourret showed that both treatments increased the number of steps correctly completed from approximately 35% to approximately 65%. There was no statistical difference in improvement between the groups.

Several limitations were apparent in the reviewed literature. Only Lo and Starling (2009) included single-subject data, albeit without controlling for practice effects, and participant satisfaction data. Vanselow and Bourret (2012), moreover, did not include interobserver agreement data. Only Dixon et al. (2009) provided a measure of graphing efficiency by reporting duration data. Both Dixon et al. and Vanselow and Bourret reported low graphing accuracy. None of these studies evaluated the effects of their independent variable on formative graphing.

I will address limitations of prior research by (a) comparing lengthy instructions to a graphing template with a one-page user guide<sup>5</sup>, (b) using single-subject designs embedded within a randomized group design to control for practice effects, (c) including interobserver agreement and participant satisfaction data, (d) including exact duration data to measure the effects of treatment on graphing efficiency, and (e) measuring the effects of the treatment on formative graphing (i.e., adding data to existing graphs).

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<sup>5</sup> With minimal user input beyond raw data entry, the template addresses all nine of the applicable common graphing errors Lo and Konrad (2007) sought to address with their graphing task analysis.

## **Chapter 2: Method**

### **2.1 Participants, Setting, and Materials**

Eight students studying applied behavior analysis were invited to participate because of their status as on-campus master's degree students enrolled in a BACB-approved practicum. All students agreed to participate; however, two students lacked prerequisite materials (i.e., an updated version of Microsoft Excel 2013). The remainder were female, first-year graduate students, who reported to be somewhat familiar with behavior-analytic graphing standards, to have graphed with Microsoft Excel between 11 and 50 times, which implicitly constituted the main of their graphing experiences, and to vary in their familiarity with Dixon et al. (2009) on which the task analysis in this investigation was based (see Appendix B).

The faculty advisor met with prospective participants in a classroom to describe the purpose and the requirements of the study, obtain informed consent, obtain a signed agreement from participating students to abide by all rules of the study, and present printed materials to these participants. As the remainder of the study was completed by the students remotely, hardware and software requirements were: access to a personal computer, an updated version of Microsoft Excel 2013, which was available for free to all students as holders of a St. Cloud State University e-mail address, a compatible version of Microsoft Windows, and Apowersoft Free Online Screen Recorder. Printed materials included a study checklist. The study checklist directed the students to an online pre-trial survey (see Appendix C), illustrated and hyperlinked instructions for installing and operating required software, the download page for the study spreadsheets (which were either blank or pre-loaded with a template or data per the experimental condition), and an online post-trial survey (see Appendix D). Printed materials also included a one-page description of the rules for each of the five experimental conditions, an 11-page,

illustrated graphing task analysis shown in Appendix G, a one-page, illustrated reference sheet for the graphing template shown in Appendix H, and 15 different hypothetical data sets exemplified in Appendix I.

The data sets were characterized by systematic changes in level, trend, and/or variability between hypothetical conditions and held graphing difficulty (e.g., number of sessions, number of discontinuities in data paths) constant across experimental conditions. For each experimental condition, the data sets specified the sequential creation of three types of graphs: (1) a cumulative record for a reversal design with an  $x$ -axis scale break, (2) an “arithmetic” line graph for a multielement design, and (3) semi-logarithmic line graph for a changing-criterion design embedded in a reversal design with a missed session. Each of these graph types was illustrated with a miniature, stylized graph that was common to all experimental conditions.

## **2.2 Dependent Measures and Interobserver Reliability**

I scored all graphs as satisfying or failing to satisfy each relevant criterion from the possible 52 criteria listed in Appendix B. These criteria were derived from Cooper et al. (2007), Lo and Starling (2009), Manuscript Preparation Checklist (2000), Preparation of Manuscripts for JEAB (2012), and Publication Manual of the American Psychological Association (2010), guidelines that are collectively relevant for all practitioners. If students omitted a chart element, their scores were docked only one point (e.g., if the  $y$ -axis label was omitted, criterion 15 was scored as incorrect and criteria 16 and 17 were not scored).

A board-certified assistant behavior analyst of 1.5 years scored 21% of items accordingly. I trained the secondary observer to score a criterion by presenting her with graphs that met and did not meet the criterion, describing how the graphs did or did not meet the criterion, and describing how the graphs could be altered to not meet or meet the criterion. I answered any

questions by the secondary observer, following which she immediately scored selected graphs for the target criterion. This training procedure was repeated for each criterion. Reliability of graphing accuracy was calculated using an item-by-item analysis by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100.

I defined duration as the latency between loading the worksheet and either closing the worksheet or opening a save dialogue. I used a frame-by-frame analysis of video screen recordings to measure the duration each student spent on each graph. I modeled for the secondary observer how to advance and retreat the video progress bar until the video displayed the moment a worksheet loaded, a worksheet closed, and a save dialogue opened. She recorded the times displayed at these moments for 25% of graphs. Reliability of graphing duration was calculated using a total-duration analysis by dividing the shorter duration by the longer duration and multiplying by 100.

### **2.3 Experimental Design and Procedure**

Two experimental designs were used: An ABCB'C' design and an ACBC'B' design (Gast & Spriggs, 2010) where Condition A required creating new graphs from a blank spreadsheet without a task analysis or other assistance, Condition B creating new graphs from a blank spreadsheet with a task analysis, Condition C creating new graphs from a blank template with a reference sheet, and Condition B' and Condition C' adding additional data to graphs generated by me per the materials in Conditions B and C, respectively. The students were paired in dyads of similar participant characteristics, and then each dyad was randomly split between the two experimental designs. Due to the un-submitted and unusable data sets, three reported data sets reflect the ABCB'C' design and one the ACBC'B' design.



**2.3.1 Pre-baseline.** The study checklist (see Appendix I) instructed students to complete the pre-trial survey, install the required software per the online instructions, and to download the study spreadsheets.

**2.3.2 Baseline.** The study checklist instructed students to create three graphs with the hypothetical data sets and blank spreadsheets. It instructed that there were no time limits but to graph efficiently and that they could skip any elements they did not know how to generate but to aim for consistency with behavior-analytic standards. It reminded them to start the screen recorder prior to beginning the graphing tasks. No other assistance was provided.

**2.3.3 Graphing Task Analysis.** The graphing task analysis condition was identical to baseline except that students were also permitted to use the task analysis, which was based on Dixon et al. (2009; Appendix G). I revised the task analysis to:

- accommodate changes in interface and default chart settings between Microsoft Excel 2007 and Microsoft Excel 2013,
- replace directions for a multiple baseline design with directions for a changing-criterion design that were consistent with other procedures in Dixon et al. (i.e., inserting criterion lines with static drawing tools),
- remove directions that were superfluous per the criteria in Appendix B (e.g., converting solid condition lines to dotted),
- rename "phase lines" to "condition lines" for continuity with other study materials, and
- instruct participants to use the study data sets versus Dixon et al.'s.

I did not correct procedural errors (e.g., alignment of data points between  $x$ -axis tick marks) or omissions (e.g., instruction on changing the color of data points without specifically instructing users to change them to grayscale).

**2.3.4 Graphing Template.** The graphing template condition was identical to baseline except that the spreadsheets were preloaded with the graphing template and students were permitted to use the reference sheet for using the template (Appendix H). The template included a column for session numbers that was automatically populated based on the first session number inputted, five blank columns for data on up to five variables, and a blank chart indirectly linked to the data that students inputted. As feasible, chart elements were predefined to conform to behavior-analytic standards (e.g., data points were formatted as black, gray, or white).

Non-exhaustively, the template included cells for defining: the  $x$ -axis locus of condition lines; condition label text; the loci of criterion lines; the loci of  $x$ - and  $y$ -axis scale breaks; the  $y$ -axis type (i.e., arithmetic, logarithmic, or cumulative); the data path type (i.e., disconnected across non-contiguous sessions, multielement, or scatterplot); and axis titles, minimums, maximums, and units.<sup>6</sup> The template also included a choice of defining a chart title from a cell, as chart titles are common in service settings wherein graphs may be displayed in the absence of additional text, or defining a figure caption from an embedded, preformatted text box, as consistent with publication standards (e.g., Publication Manual, 2010).

Non-exhaustively, the template included macros and hidden formulae that enabled: precise and dynamic placement of condition lines,<sup>7</sup> condition labels, criterion lines, and scale

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<sup>6</sup> As basic features,  $y$ -axes may be converted from arithmetic to logarithmic, data paths may be connected or disconnected across non-contiguous sessions, and axis titles, minimums, maximums, and units may be customized; however, the default interfaces for these features may be difficult to navigate for some users and relying on the methods of these basic features would have interfered with advanced template features (e.g.,  $y$ -axis scale breaks).

<sup>7</sup> Vanselow and Bourret (2012) described a procedure for creating dynamic condition lines with error bars in Excel 2007 and 2011; however, this procedure did not permit individual formatting of condition lines and could not be extended to creating dynamic criterion lines. Dubuque (2014) described a procedure for creating dynamic condition lines with an embedded histogram in Excel 2013 and Excel for Mac 2011; however, in addition to the limitations above, it resulted in placement of data points between tick marks and thickness of condition lines resizing with the plot area.

break icons; automatically disconnecting data paths across condition lines, criterion changes, missing sessions, and scale breaks; adjusting axis minimums, maximums, and units automatically<sup>8</sup> or from custom user values inputted in cells; floating the y-axis without a static “sleight of hand” (cf. Carr & Burkholder, 1998); permitting zeros to display on a logarithmic scale; conversion via dropdown menus of the y-axis and data paths between the options listed above; automatic omission of a legend given only one active variable; reformatting selected condition lines as solid or dashed by typing Ctrl+Alt+L; and automatic repositioning of the graph into view when cells were selected farther up or down the spreadsheet.

**2.3.5 Graphing Task Analysis'.** The second graphing task analysis condition was identical to the first graphing task analysis condition except that students were presented with spreadsheets preloaded with half of each data set by the principal investigator, who strictly adhered to the task analysis. They were instructed to add the remaining data to the extant graphs, mimicking formative graphing. If this was a student’s final condition, on completion, the student was instructed to securely upload the screen recordings to the study website and to complete the participant satisfaction survey.

**2.3.6 Graphing Template'.** The second graphing template condition was identical to the first graphing template condition except that students were presented with graphing templates preloaded with half of each data set by me, who strictly adhered to the template reference sheet. They were instructed to add the remaining data to the extant graphs, mimicking formative graphing. If this was a student’s final condition, on completion, the student was instructed to

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<sup>8</sup> Automatic calculation of axis limits, a basic feature, was reprogrammed (e.g.,  $x$ -axis maximums were defined as the last session with data versus the next major  $x$ -axis unit greater than or equal to the last session with data).

securely upload the screen recordings to the study website and to complete the participant satisfaction survey.

#### **2.4 Participant Satisfaction**

The students completed a six-item survey (see Appendix D) that asked them to rate the ease of creating new graphs and of graphing formatively with the graphing templates versus the graphing task analysis as well as to rate their confidence in the accuracy their graphs.

### Chapter 3: Results

Individual graphing accuracies are displayed in Appendix E. Two students were excluded from all analyses: one not submit usable data (i.e., screen recordings were corrupted), and one did not use the correct materials in the correct conditions. On average, the included students more accurately created graphs with the graphing task analysis than without assistance. Only Janice more accurately created graphs without assistance than with the graphing task analysis. With the graphing template relative to the graphing task analysis, all students more accurately created graphs ( $MD = 18.58\%$ ) as well as added data to graphs ( $MD = 22.18\%$ ). More specifically, the students averaged 67.67% (61.19–78.53) accuracy for baseline, 76.12% (69.52–83.94) for graphing task analysis, 94.70% (89.07–98.56) for graphing template, 76.01% (74.15–78.50) for graphing task analysis', and 98.19% (97.11–98.58) for graphing template'. Interobserver reliability was 98.79%.

Across students, the highest accuracy for the graphing task analysis condition (83.94%) was lower than the lowest accuracy for the graphing template condition (89.07%), and the highest accuracy for the graphing task analysis condition' (78.50%) was lower than the lowest accuracy for the graphing template' condition (97.11%). This pattern held regardless of the group to which students were assigned. Across conditions, in general, the students most accurately graphed the “arithmetic” line graph/multielement design ( $M = 86.80\%$ ), followed by the cumulative record/reversal design ( $M = 80.48\%$ ) and the semi-logarithmic line graph/changing-criterion design ( $M = 80.34\%$ ).

Individual graphing durations are displayed in Appendix F. On average, the students spent approximately as long to create graphs without assistance as with the graphing task analysis: Janice and Heather spent less time creating graphs with the graphing task analysis while

Rose and Tara spent less time without assistance. With the graphing template relative to the graphing task analysis, all students took less time to create graphs ( $MD = 27.40$  min, 47.12%) as well as to add data to graphs ( $MD = 13.59$  min, 43.59%). More specifically, the students averaged 51.71 min (37.55–85.55) for completing baseline, 51.83 min (37.22–66.32) for graphing task analysis, 24.42 min (21.72–30.2) for graphing template, 24.05 min (16.32–31.10) for graphing task analysis', and 10.46 min (8.15–14.97) for graphing template' for a total of 102.46 min for all conditions. They averaged 31.83% (23.05–41.66) of total graphing time in baseline, 31.90% (26.50–38.05) in graphing task analysis, 15.03% (12.46–17.62) in graphing template, 14.80% (12.02–17.84) in graphing task analysis', and 6.44% (4.33–8.58) in graphing template'. Interobserver reliability was 99.87%.

Across students, the shortest duration for the graphing task analysis condition (37.22 min) was longer than the longest duration for the graphing template condition (30.02 min), and the shortest duration for the graphing task analysis condition' (16.23 min) was longer than the longest duration for the graphing template' condition (14.97 min). This pattern held regardless of the group to which students were assigned, although Heather, who was exposed to the graphing template prior to the graphing task analysis, created graphs from the task analysis most efficiently. Across conditions, in general, the students spent the longest time graphing the cumulative record/reversal design ( $M = 15.28$  min), followed by the semi-logarithmic line graph/changing-criterion design ( $M = 10.03$  min), followed by the “arithmetic” line graph/multielement design ( $M = 7.18$  min).

Participant satisfaction data is listed in Appendix D. All students reported task analysis conditions to be moderately difficult to difficult and template conditions to be easy. Two students reported to be unconfident in the accuracy of their graphs generated with the task

analysis, and two students reported to be somewhat confident; two students reported to be somewhat confident in the accuracy of their graphs generated with the template, and two students reported to be confident. Participant satisfaction data only reflected one measure of graphing accuracy or duration: Easiness of adding data to graphs with the task analysis reflected graphing duration for this condition (i.e., student responding “moderately” spent 16.23 min and 22.38 min and students responding “difficult” spent 26.48 and 31.10 min).

### Chapter 4: Discussion

The results indicated that an advanced graphing template embedded with dynamic chart elements substantially increased graphing ease, graphing efficiency, and insofar as graphing by behavior-analytic standards improves their usefulness, the usefulness of graphs compared to graphing from a traditional graphing task analysis (e.g., Carr & Burkholder, 1998; Dixon et al., 2009) or by preexisting methods in the repertoires of master's degree students studying applied behavior analysis. If practitioners graph formatively and their efficiency with an advanced graphing template proves fractionally comparable to these reported data (i.e., 13.59 min mean savings across one update of three complex graphs), tremendous savings in human resources could accrue across weeks, months, and years.

This study includes several limitations. First, four students did not complete the study. This limitation could be addressed by on-site running of participants; however, in the case of two participants, it nevertheless underscores a limitation of graphing templates: They require compatible software. Second, the experimental design controlled for practice effects but did not measure them. It is likely that efficiency of creating graphs from both the task analysis and the template would have improved across multiple sessions, which an A-B-C-B-C-B'-C' design, for example, may have demonstrated. Of particular interest would be whether the independent variables, on repeated exposure, differentially affected graphing efficiency. Third, students may have graphed more efficiently and accurately with a different task analysis than the revised version of Dixon et al.'s (2009) which was written originally for Microsoft Excel 2007, which directed students to construct charts that contained errors per the criteria in Appendix B, and for which improvements have been recommended (see Lo & Starling, 2009). Fourth, per the study directions and the template reference sheet, students emitted errors that could have been avoided.



These errors types might be avoided with clearer instructions for experimental conditions (e.g., one participant made no apparent attempt to switch a y-axis to logarithmic) as well as adding numbering to the template reference sheet to walk students through all relevant template features (cf. Appendix H). Fifth, students did not graph a multiple-baseline design, which may be the most common and complicated design students studying behavior analysis encounter (Lo & Konrad, 2007). A multiple-baseline design was excluded to decrease study duration and because its inclusion would not have directly addressed functionality of the evaluated graphing template<sup>9</sup>—it may suffice to note, as did Vanselow & Bourret (2012) which made a similar decision, that the graphed reversal designs could have been stitched together statically. Sixth, additional participant satisfaction data (i.e., how easy was it to graph with no support, how confident were they in their created with no support, and would the student use the graphing template post-study) would have elaborated on the participant satisfaction of the graphing template.

In addition to addressing the limitations discussed above, future research might analyze to what extent improvements in graphing accuracy improve clinical decisions. A component analysis on this subject could lead to weighting of graphing criteria by social validity (e.g., differentially penalizing inclusion of a chart border and connecting of data paths across *x*-axis scale breaks). The graphing template in this study permitted two-click conversion of chart characteristics like an “arithmetic” y-axis to a cumulative record; future research might evaluate whether this type of functionality encourages variation graphic display choices and, subsequently, also improves clinical decisions.

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<sup>9</sup> An updated graphing template that generates dynamic stacked graphs via radio buttons will be available at <http://observechange.org>.

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**Appendix A**

*Chart Element Glossary*

Term	Definition	Examples
Chart Element	Any object that is displayed with a graph, whether embedded in the graph or not	Chart border, axes, axis labels, data points, condition labels, criterion lines, scale-break marker, figure caption
Static	A type of chart element that does not automatically and appropriately size and position on modification of chart parameters	Condition lines inserted with drawing tools <sup>a</sup> , condition labels inserted with text boxes, omission of 0 on the y-axis scale by covering it with a drawing object
Dynamic	A type of chart element that automatically and appropriately sizes and positions on modification of chart parameters	Condition lines that automatically reposition on new data added to a graph, condition labels that automatically center within conditions
Basic	A charting procedure that is implemented solely from right-clicking on a chart (including its sub-options) or from the Charts Tools tab of the Microsoft Office Ribbon <sup>b</sup> (including its sub-options)  Note: Basic chart elements are dynamic	Inserting data points by right-clicking on a blank chart and left-clicking “Select Data,” inserting a chart title from the Charts Tools tab, modifying axes by right-clicking on the axes and left-clicking on “Format Axis”
Ad-hoc	A charting procedure that produces static chart elements  Note: Ad-hoc chart elements are typically drawing objects <sup>a</sup> or text boxes	Inserting condition lines with drawing tools, inserting condition labels with text boxes, covering the 0 on the y-axis with a drawing object
Advanced	A non-basic charting procedure that produces dynamic chart elements  Note: Advanced chart elements are created with formulas or macros <sup>c</sup>	Inserting condition lines with data paths controlled by formulas and macros, inserting condition labels with data labels controlled by formulas, omitting the 0 on the y-axis with formulas

*Note.* Notes embedded in the table describe non-essential features of terms.

<sup>a</sup>Microsoft Excel includes rudimentary graphic design tools, or drawing tools, that produce “drawing objects” (e.g., lines, shapes). <sup>b</sup>The Chart Tools tab displays in the Microsoft Office Ribbon at the top of Microsoft Excel whenever a chart is select. <sup>c</sup>Macros are programming code written with Microsoft Visual Basic for Applications.

## Appendix B

### *Graphing Criteria*

#	Criteria	Citations
<i>x</i> -axis		
1	Thin, black, consistent with <i>y</i> -axis	Publication Manual (2010)
2	External tick marks thin, black, detailed without crowding	Preparation of Manuscripts (2012)
3	Tick-mark labels accurate, separated by at least 1 character width	Lo & Starling (2009)
4	Scale breaks indicated	Cooper et al. (2010)
5	Right boundary ends at last session number	Manuscript Preparation (2000)
<i>y</i> -axis		
6	Thin, black, consistent with <i>x</i> -axis	Publication Manual (2010)
7	External tick marks thin, black, detailed without crowding	Preparation of Manuscripts (2012)
8	Tick-mark labels accurate, separated by at least 1 character height	Lo & Starling (2009)
9	Tick-mark labels correctly scaled (i.e., arithmetic versus logarithmic)	--
10	Floated	Manuscript Preparation (2000)
11	Upper boundary accommodates all data	--
<i>x</i> -axis label		
12	Descriptive, concise	Publication Manual (2010)
13	Parallel to <i>x</i> -axis	Preparation of Manuscripts (2012)
14	Horizontally centered within chart, appropriately below <i>x</i> -axis tick-mark labels	--
<i>y</i> -axis label		
15	Descriptive, concise	Publication Manual (2010)
16	Rotated 90 degrees counterclockwise	Lo & Starling (2009)
17	Vertically centered within chart, appropriately left of <i>y</i> -axis tick-mark labels	--
Data points		
18	Consistently sized to approximately match a lower-case "o"	--
19	Easy to differentiate	Publication Manual (2010)
20	Aligned with tick marks	Lo & Starling (2009)
21	Plotted without systematic errors	Lo & Starling (2009)
Data paths		

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22	Thin, black, consistent with other data paths	Preparation of Manuscripts (2012)
23	Connected by default	Lo & Starling (2009)
24	Disconnected at condition change lines	Manuscript Preparation (2000)
25	Disconnected at criterion changes	Cooper et al. (2010)
26	Disconnected for missing data (unless multielement)	Lo & Starling (2009)
27	Disconnected at scale breaks	Cooper et al. (2010)
Condition change lines		
28	Thin, black, consistent with other condition change lines	--
29	Precisely parallel with y-axis	--
30	Precisely positioned midway between data points at correct <i>x</i> -axis loci	Cooper et al. (2010)
31	Precisely originated at <i>x</i> -axis, terminated at y-axis maximum	Cooper et al. (2010)
Condition labels		
32	Descriptive, concise	--
33	Parallel to <i>x</i> -axis if space permits	Cooper et al. (2010)
34	Horizontally centered within condition, appropriately above y-axis, vertically aligned with other labels	Manuscript Preparation (2000)
35	Fitted within condition	--
Criterion change lines		
36	Thin, black, solid, consistent with other criterion change lines	--
37	Precisely parallel with <i>x</i> -axis	--
38	Precisely positioned at correct y-axis loci	Cooper et al. (2010)
39	Precisely originated/terminated midway between data points prior to/after criterion start/end	Cooper et al. (2010)
Chart title or figure caption		
40	Descriptive, concise chart title <i>or</i> figure caption	--
41	For chart titles, consistent with other fonts but sized 0–4 points larger	Publication Manual (2010)
42	Parallel to <i>x</i> -axis	--
43	For chart titles, centered within chart, appropriately above other elements; for figure captions, left-justified across chart, appropriately below other elements	Publication Manual (2010)
Legend		
44	Descriptive, concise labeling of all variables <i>if</i> more than 2 variables	Lo & Starling (2009)

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45	Other chart elements not obscured	Publication Manual (2010)
	Chart and plot areas	
46	White or blank	Lo & Starling (2009)
47	No border	Lo & Starling (2009)
48	Generally 2:3 height–width ratio but proportioned so all elements discernible	Cooper et al. (2010); Publication Manual (2010)
	Other	
49	All elements grayscale, maximum of 3 grades	Publication Manual (2010)
50	All text a consistent, black sans-serif font sized 8–14 points except chart title	Publication Manual (2010)
51	No superfluous elements	Lo & Starling (2009)
52	All elements embedded in chart	Manuscript Preparation (2000)

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*Note.* All criteria were assessed from video-recording screenshots except 52, which was necessarily assessed directly from video recordings.

Appendix C

*Participant Characteristics Survey*

Question	Response Options				Participant Responses			
	A	B	C		Janice	Rose	Tara	Heather
1. What is your gender?					Female	Female	Female	Female
2. What is your age?					29	31	22	23
3. What is your ethnicity?					White	White	White	White
4. What is your major?					ABA	ABA	ABA	ABA
5. What is your year in college?					First	First	First	First
6. How many times have you graphed data?	1-10	11-50	>50		11-50	11-50	11-50	11-50
7. How many times have you used software to graph data?	1-10	11-50	>50		11-50	11-50	1-10 <sup>a</sup>	11-50
8. How many times have you used Microsoft Excel to graph data?	1-10	11-50	>50		11-50	11-50	11-50	11-50
9. How familiar are you with behavior-analytic graphing standards?	Unfamiliar	Somewhat	Familiar		Somewhat	Familiar	Somewhat	Somewhat
	Unfamiliar	Somewhat	Familiar		Unfamiliar	Unfamiliar	Unfamiliar	Unfamiliar

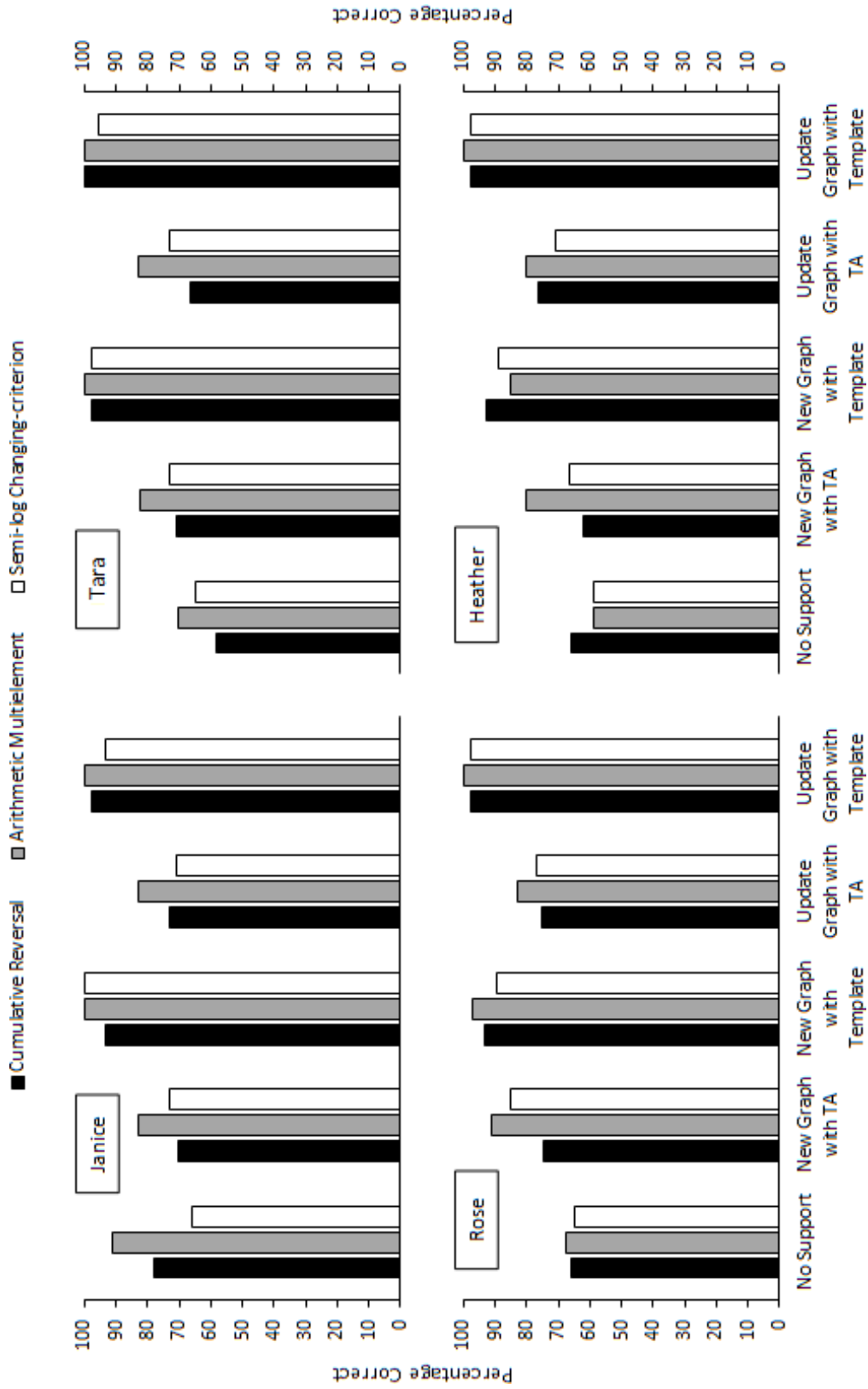
<sup>a</sup>This response should be 11-50 or greater, if this range describes the reported frequency of graphing with Microsoft Excel.

**Appendix D**

*Participant Satisfaction Survey*

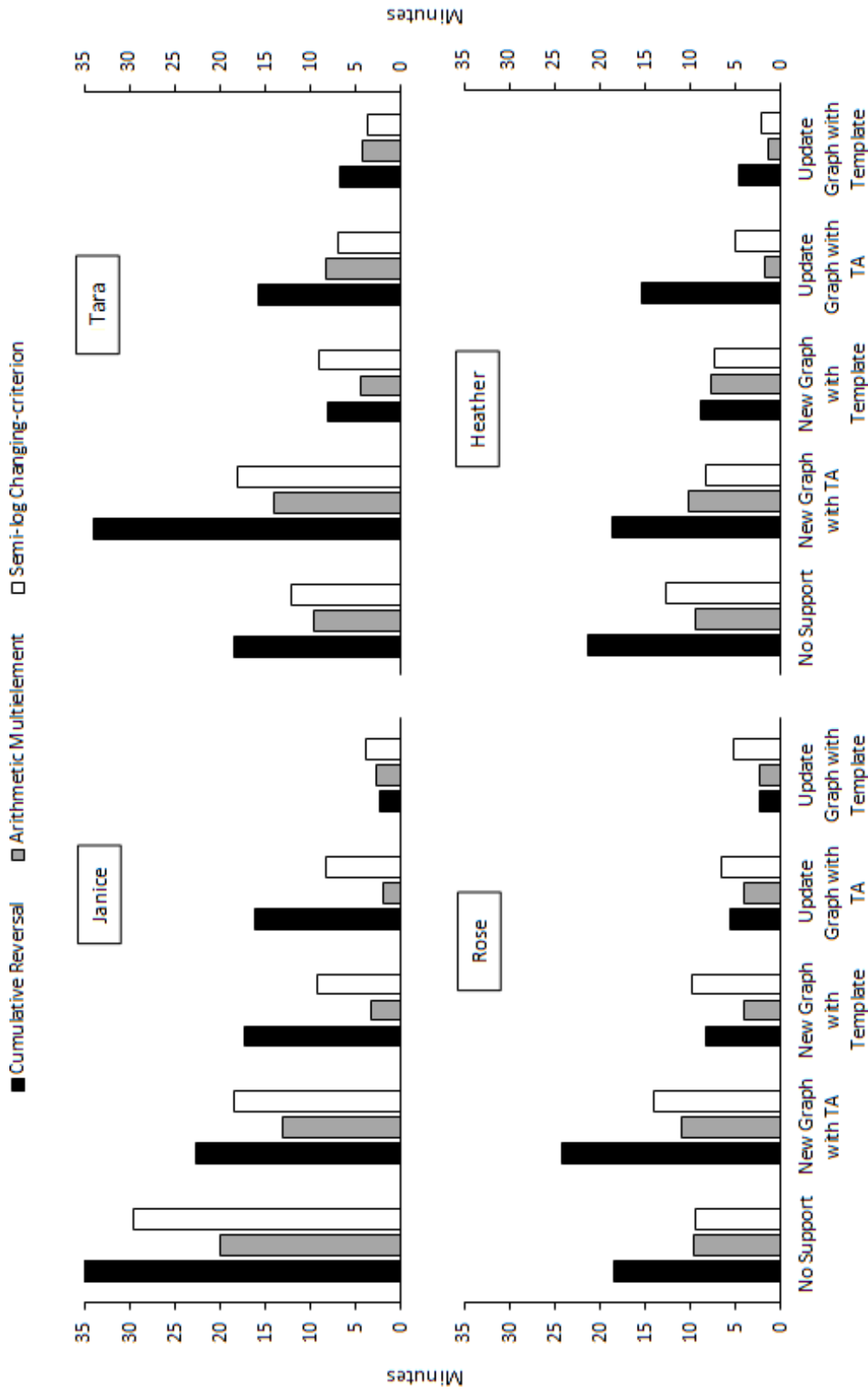
Question	Response Options				Participant Responses			
	A	B	C		Janice	Rose	Tara	Heather
1. Using the templates, how easy was it to create a new graph?	Easy	Moderately	Difficult		Easy	Easy	Easy	Easy
2. Using the task analyses, how easy was it to create a new graph?	Easy	Moderately	Difficult		Moderately	Difficult	Difficult	Moderately
3. Using the templates, how easy was it to add new data to an existing graph?	Easy	Moderately	Difficult		Easy	Easy	Easy	Easy
4. Using the task analyses, how easy was it to add new data to an existing graph?	Easy	Moderately	Difficult		Difficult	Moderately	Difficult	Moderately
5. Using the templates, how confident were you in the consistency of your graphs with behavior-analytic graphing standards?	Confident	Somewhat	Unconfident		Confident	Confident	Somewhat	Somewhat
				t				
	Confident	Somewhat	Unconfident		Somewhat	Unconfident	Unconfident	Somewhat
				t		t	t	t

Appendix E



Graphing accuracy. Janice, Rose, and Tara completed graphs in left-to-right order; Heather completed graphs in the following order: No support, new graph with template, new graph with task analysis (TA), update graph with template, and update graph with TA.

**Appendix F**



Graphing duration. Janice, Rose, and Tara completed graphs in left-to-right order; Heather completed graphs in the following order: No support, new graph with template, new graph with task analysis (TA), update graph with template, and update graph with TA.

## Appendix G

### Task Analyses

The task analyses that follow will describe how to construct reversal, multielement (often used to evaluate functional analysis data), and changing-criterion designs.

#### Reversal Designs

##### Creating a Reversal Design Graph

1. Enter the text "Session #" in Cell A1 and enter the text "Data" in Cell B1.
2. Enter the session numbers or dates in the first column below the text "Session #". You may wish to color code the condition types for ease of visual discrimination.
3. Underneath the text "Data," enter the values that correspond to the session numbers. Following our example, enter the data and dates from your data packet as shown in Figure 1.
4. With the mouse, highlight the cells that contain both the text (i.e., Cells A1 and B1) and the data as shown in Figure 1.
5. With the data and the text highlighted, select the menu option INSERT from the option bar at the top of the screen. When you are done you will see a variety of icons positioned across the top of the screen. This is the new graphical interface for the various types of objects that can be inserted into a spreadsheet. Note the center panel titled CHARTS. In this panel select the first option in the second row, INSERT LINE CHART. In the INSERT LINE CHART submenu, select the first option in the second row under the 2-D LINE options, which is called LINE WITH MARKERS. A graph should immediately appear.

##### Editing the Default Graph

1. The first step is to remove the unnecessary data path that displays your session numbers. Right click on a blank area of the chart. From the available options choose SELECT DATA.
2. In the SELECT DATA SOURCE window, under the Legend Entries (Series) box, select SESSION NUMBER so it is highlighted. Next, click on the REMOVE button.
3. Remain in the SELECT DATA SOURCE window. Under the Horizontal (Category) Axis Labels box click on EDIT.
4. In the resulting AXIS LABELS dialogue box, highlight Cells A2 through A16, which you will use for the values contained on the x axis. Once done click OK. To close the SELECT DATA SOURCE window, click OK.
5. The next step is to remove the lines connecting data points between different conditions. In our example, baseline data were collected on Sessions 1 through 4 and 9 through 11, with the remaining session numbers corresponding to intervention conditions. To remove the data series line between Data Points 4 and 5, position the mouse on the data series. Click the left button once to highlight the series. Position your mouse pointer directly on Data Point 5 and keep it there.
6. Click the left button once. The highlighted series should disappear, leaving only Data Point 5 highlighted. Right click and select the last option entitled FORMAT DATA POINT. From the FORMAT DATA POINT sidebar, select the paint bucket icon. Select the suboption NO LINE from the list under LINE and close.

## Task Analyses

7. At this time you will notice the legend has changed considerably. For now ignore these changes and proceed to disconnect the data series line between Data Points 8 and 9. To do this, select Data Point 9 as described above and press the F4 key. This shortcut repeats the last step Excel 2007 performed. Do this again between Data Points 11 and 12.
8. Remove the unnecessary legend by selecting it once with the left mouse button and pressing the delete key. At this point your graph should be completed and ready for customization, which may include the addition of condition-change lines, axis labels, and condition labels.

## Customizing Your Graph

1. An exciting new feature introduced with Excel 2007 that was not available on earlier versions of the software is the graphical interface for quick customization of your chart. This interface, named "Chart Tools," provides you with a means to customize your chart very quickly; this saves time from the laborious steps necessary in earlier versions of Excel. Figure 2 displays the new chart designs with the various layout options of the Chart Tools in the new graphical interface expanded. Select the ADD CHART ELEMENTS button and add axis titles to your graph by selecting second option AXIS TITLES from the dropdown menu. Select PRIMARY HORIZONTAL.
2. In the resulting text box below the x axis, enter the text you wish to use for your x-axis label. Do this by clicking in the text box and highlighting the default text already there (i.e., Axis Title). Replace the default text and type in your text. Enter an appropriate title based on the information in your data packet.
3. Repeat the previous two steps for the y-axis title by selecting PRIMARY VERTICAL. Enter an appropriate title based on the information in your data packet.
4. To edit the chart title, click once on the chart title. Highlight it with the mouse and enter the chart title. Title the chart based on the information in your data packet.
5. To add tick marks to the x-axis, click once on the x-axis numbers. From the FORMAT AXIS sidebar, find MAJOR TYPE under the TICK MARKS submenu.
6. Repeat the previous step for the y-axis tick marks by clicking on the y-axis numbers.
7. To add a vertical axis line, click once on the y-axis numbers. From the FORMAT AXIS sidebar, select the paint bucket icon. Select the submenu COLOR from the list under LINE and choose black.
8. Repeat the previous step to change the x-axis line to black by clicking on the x-axis numbers.
9. Now remove the horizontal gridlines displayed on the graph. Return to the ADD CHART ELEMENTS button under chart tools. Select the seventh icon GRIDLINES and select the first option PRIMARY HORIZONTAL GRIDLINES.
10. To insert condition-change lines, first make sure you have clicked your mouse on the graph to highlight it and not the spreadsheet. If you have the spreadsheet highlighted instead of the graph, your condition-change line will end up in the spreadsheet area and not on the desired graph. After clicking once on the graph to select it, choose the SHAPES icon within the INSERT panel (i.e., the second panel). At this point, a large menu will appear that includes lines, arrows, rectangles, and various other shapes.
11. Select the first line option, which is depicted by a small diagonal line, by clicking on it once. Position the mouse pointer on the x axis between Sessions 4 and 5. Click once to initiate the line, and while holding down the mouse button, drag the pointer straight up the graph so that it is

## Task Analyses

- parallel with the entire y axis. You can ensure that the line will be perfectly vertical (or horizontal) if you hold down the shift key while drawing the line.
12. At this point, you will notice the top menu has changed to DRAWING TOOLS. Remain here because you need to change the color of line from blue to black. To do this, locate the second panel SHAPE STYLES and select the black line.
  13. To add the next two condition-change lines, with your newly dashed line highlighted, right-click on the line and select the option COPY, and then right-click again outside the data plot area (i.e., around the chart title) and select the option PASTE. You will now notice that the newly added line is to the bottom right of the original line. Select the new line by clicking on it and position it between Data Points 8 and 9. Once your second line has been positioned correctly, right-click anywhere outside the data plot area (e.g., around the chart title) and select the PASTE option to add the final condition-change line. Position this final line between Data Points 11 and 12.
  14. The next step is to add condition labels to the chart. Select the TEXT BOX icon from the INSERT panel, position the mouse pointer in the top portion of the first baseline condition, and proceed to insert a small rectangle within which you will enter the text "Baseline." Repeat the above steps for the remaining condition labels, adding the appropriate text for each condition. Alternatively, you can highlight the textbox that you had just created on your graph and right-click on it. From the submenu that appears, select the COPY option and then right-click again and select the PASTE option. A copy of the condition label should appear, and you can position it above the appropriate condition in the graph. Do this as many times as necessary.
  15. The final steps for formatting the graph involve steps to ensure that the graph will not look out of place when pasted or transferred to another program such as Microsoft Word or Microsoft PowerPoint. What this involves is removing border colors from the chart area (i.e., the area with the boundaries of the chart surrounding the graph where the axis labels and chart title can be found). Left-click on any spot in the chart area. From the resulting sidebar select NO LINE under the submenu BORDER. Your final graph should look similar to the one displayed in Figure 3.



## Task Analyses

**Multielement Designs**

## Creating a Multielement Design Graph

One of the most common applications of multielement designs is for evaluating the results of an experimental functional analysis. Thus, the following instructions for creating a multielement design are presented in the context of creating a graph to depict functional analysis data. To begin, enter the session headings, session numbers, and data values from your data packet as depicted in Figure 4.

1. Repeat the previously described steps from the reversal design instructions to create the chart. The graph will look similar to the type created for the reversal design.
2. Repeat the previously described steps from the reversal design instructions to delete the unnecessary session number data series and edit the x-axis labels. You can also add black axes lines and tick marks and remove the horizontal grid lines at this time.
3. In contrast to the reversal design graph, the use of empty cells in your data has resulted in an absence of connecting lines between the data points within each series. To connect the data points for each functional analysis condition, it will require Excel 2013 to ignore the empty cells between actual data points.
4. To configure Excel 2013 to do this, highlight the graph, right-click on it, and select the option SELECT DATA. With the SELECT DATA SOURCE window open, select the HIDDEN AND EMPTY CELLS button in the bottom left corner of the window. A small window will appear titled HIDDEN AND EMPTY CELL SETTINGS.
5. Choose the third option, SHOW EMPTY CELLS AS, and choose CONNECT DATA POINTS WITH LINE. Click the OK button, which will return you to the SELECT DATA SOURCE window. Click the OK button within the SELECT DATA SOURCE window to return to the graph. At this point, the data points should be properly connected on the graph.
6. In addition to editing the chart titles, axis labels, and condition labels, you can edit the data series markers, lines, and colors by simply selecting the data series you wish to edit, right-clicking on it while the series is highlighted, and selecting the last option, FORMAT DATA SERIES. The FORMAT DATA SERIES window will appear and give you various options with which you can edit the markers, lines, and colors in multiple ways. Your completed graph should look similar to the one depicted in Figure 5.

## Task Analyses

**Changing-Criterion Designs**

## Creating a Changing-Criterion Design Graph

1. Repeat the previously described steps from the reversal design instructions to create the chart. The graph will look similar to the type created for the reversal design.
2. Repeat the previously described steps from the reversal design instructions to delete the unnecessary session number data series and edit the x-axis labels. You can also add black axes lines and tick marks and remove the horizontal grid lines at this time.
3. Repeat the previously described steps from the reversal design instructions to add condition-change lines.
4. To add criterion lines, repeat the steps for adding condition-change lines except drag the pointer across the graph so that it is parallel with the x axis. Criterion lines should span only the data points that were exposed to that criterion level.
5. Repeat the previously described steps from the reversal design instructions to disconnect the data series line between condition lines and changes in criteria.
6. In addition to removing border and fill colors and editing the chart titles, axis labels, and condition labels, you can edit the data series markers, lines, and colors by simply selecting the data series you wish to edit, right-clicking on it while the series is highlighted, and selecting the last option, FORMAT DATA SERIES. The FORMAT DATA SERIES window will appear and give you various options with which you can edit the markers, lines, and colors in multiple ways. Your completed graph should look similar to the one depicted in Figure 6.

Task Analyses

Figure 1

The screenshot shows the Microsoft Excel interface with the 'Home' tab selected. The ribbon includes 'Clipboard', 'Font', and 'Alignment' groups. The active cell is A1, and the formula bar shows 'Session #'. The spreadsheet grid displays the following data:

	A	B	C	D	E	F
1	Session #	Data				
2		1	2			
3		2	4			
4		3	3			
5		4	2			
6		5	12			
7		6	14			
8		7	9			
9		8	10			
10		9	3			
11		10	2			
12		11	4			
13		12	12			
14		13	15			
15		14	16			
16		15	10			
17						
18						
19						
20						

Sample data entered into a spreadsheet for a reversal design graph.

Task Analyses

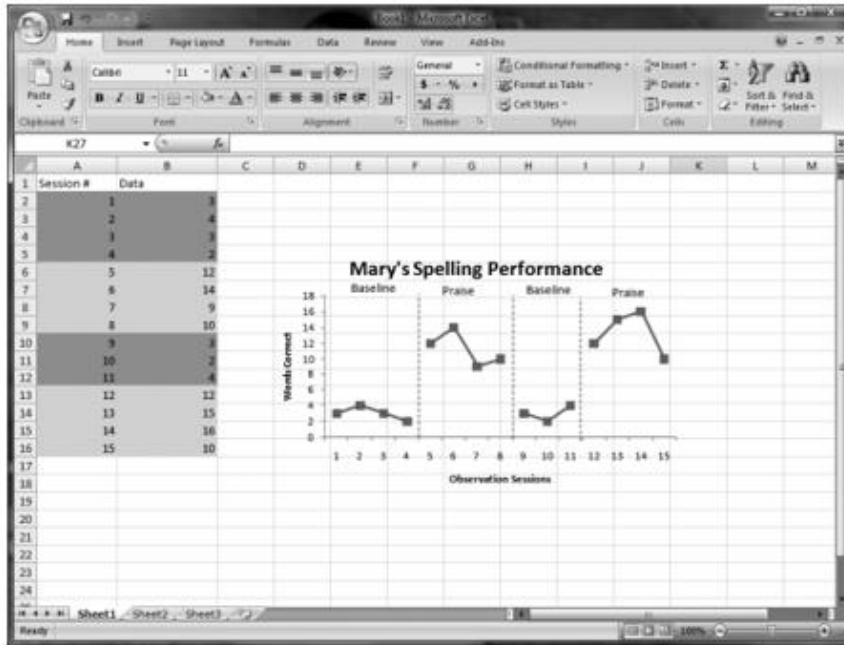
Figure 2



New design and layout options in Microsoft Excel 2013.

Task Analyses

Figure 3



The completed reversal design graph.

Task Analyses

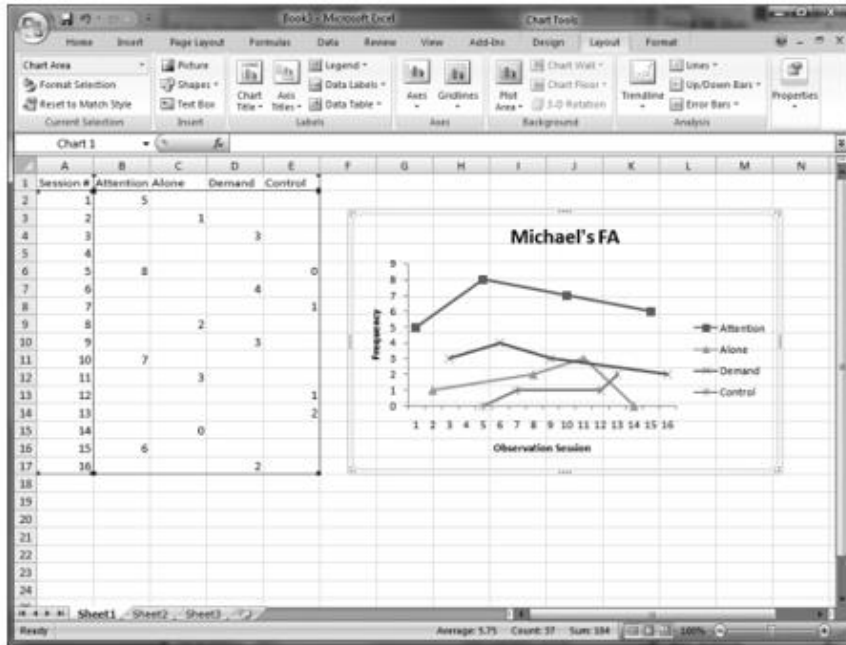
Figure 4

	A	B	C	D	E	F
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			
13	12				1	
14	13				2	
15	14		0			
16	15	6				
17	16			2		
18						

Sample data entered into a spreadsheet for a multielement design graph.

Task Analyses

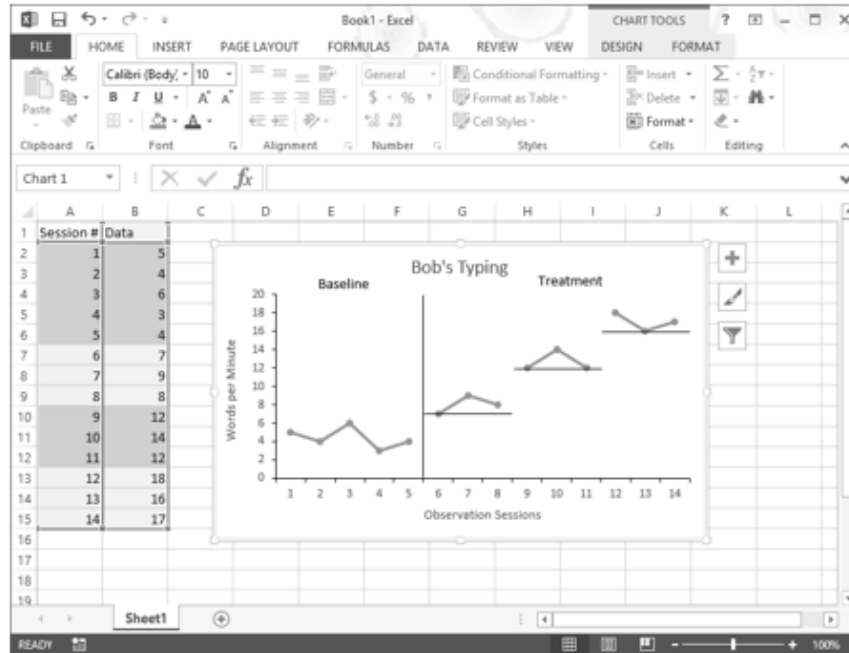
Figure 5



The completed multielement design graph.

Task Analyses

Figure 6



The completed changing-criterion design with an A-B design graph.



Appendix H

## Cheatsheet for Spreadsheet Templates

This page will help you navigate the spreadsheet templates. Pop-ups with additional information will appear when you click most cells in the spreadsheet.

CHART ELEMENTS		CONDITIONS	CRITERION LINES	Sessions	PC	Mac	Linux	
Titles	Chart	Baseline	5	1		10	5	
	x-Axis	Sessions	5	10	2	16	4	
			8	12	3	11	6	
	y-Axis	Words per Minute	8	12	4			3
12			12	5			4	
X-Axis	Minimum (1)	Treatment		6			7	
	Maximum (23)	Standard		7	12	5	8	
				8	17	5	12	
	Data Path Type	Standard			9	15	2	14
					14	5	12	
					16	7	18	
					17	5	16	
	Minimum (0)				11	21	6	17
Scale Break	Start			12	19	9	5	
Major Unit (3)				12	1	5		
Minor Unit (1)								
Scale Type	Arithmetic							
Show/Hide	PC	<input checked="" type="checkbox"/>						
	Mac	<input checked="" type="checkbox"/>						
	Linux	<input checked="" type="checkbox"/>						
	Variable 4	<input type="checkbox"/>						
	Variable 5	<input type="checkbox"/>						
Conditions	<input checked="" type="checkbox"/>							
Criteria	<input checked="" type="checkbox"/>							

**Enter chart titles here—there is no need to change them from within the chart**

**In white cells, enter condition labels**

**In shaded cells, enter the location of condition lines**

**Switch to "Multielement" as needed**

**Most of the cells in this column require no user input—the default values will be appropriate**

**In white cells, enter criteria (i.e., criterion line height)**

**In shaded cells, enter start and end (e.g., 8 and 11) of the nested criteria (e.g., 12)**

**Enter variable labels here—there is no need to change them from within the chart**

**Only chart elements (left column) update automatically. Changes to conditions, criterion lines, and data appear in the chart only after pressing this green button or F9**

Click to Update Conditions, Criterion Lines, and Data (F9)
?

**Use the drop-down menu to switch between Arithmetic, Cumulative, and Logarithmic scales**

**Uncheck all unused variables to omit them from the legend**

Appendix I

## Data J1

**Experimental Design | Reversal**

**y-axis | Cumulative**

**Other Features | x-axis scale break after session 4**

**Sample Graph**

Your specific data will differ

Session	Widgets Built	Breaks Taken	Condition
1	3	4	Baseline
2	5	2	
3	2	3	
4	9	1	Bonuses
5	7	2	
6	10	0	
7	7	0	Baseline
8	9	1	
9	6	4	
10	5	3	Bonuses
11	2	6	
12	1	4	
13	2	5	Baseline
14	8	1	
15	11	2	
16	12	1	Bonuses
17	8	0	
18	9	1	

## Data J2

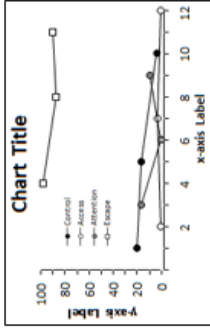
**Experimental Design** | Multielement

**y-axis** | Arithmetic

**Other Features** | None

**Sample Graph**

Your specific data will differ



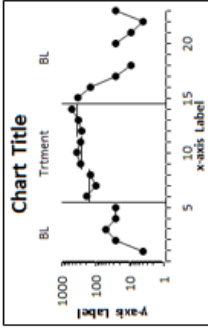
Session	Percentage of Time Singing Aloud		
	Control	Automatic	Attention
1	75		Escape
2		0	
3			56
4			30
5	66		
6			72
7		3	
8			19
9			89
10	92		
11			8
12		0	
13			0
14			94
15		0	
16	85		

## Data J3

**Experimental Design** | Changing-criterion

**y-axis** | Semi-logarithmic

**Other Features** | Data is missing for session 5



**Sample Graph**  
Your specific data will differ

Session	Steps per Day	Condition	Criterion
1	19	Baseline	N/A
2	7		
3	7		
4	32		
5			
6	11	Lottery	250
7	20		
8	266		
9	317		
10	252	Lottery	500
11	442		
12	518		
13	510		
14	1104	Lottery	1000
15	1021		
16	1120		
17	33		
18	21	Baseline	N/A
19	17		
20	39		