RESEARCH ARTICLE

The Use of Behavioral Skills Training to Teach Graph Analysis to Community Based Teachers

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Published online: 30 August 2017
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Abstract In this study, the experimenter trained three teachers to implement data decision rules to detect when instructional changes should be made during the visual analysis of discrete-trial percentage graphs. The experimenter used a concurrent, multiple-baseline design across participants. The experimenter trained the teachers to follow decision-making rules using instruction, modeling, rehearsal, and feedback. Following intervention, participants increased the percentage of correct data-based decisions and decreased the percentage of errors.

Keywords Graph analysis · Behavioral skills training · Discrete trial teaching

Discrete trial teaching (DTT) is an effective method to teach new behavioral responses to children with autism that consists of presenting a clear discriminative stimulus, prompting correct responding accordingly, reinforcing correct responses, allowing for an intertrial interval, and recording raw data. After conducting DTT, behavior analysts must graph data to enable them to make data-based decisions because inaccurate decisions may lead to slow skill acquisition and wasted instructional time

(Keohane & Greer, 2005). Therefore, it is important that supervisors teach staff to accurately analyze graphic data and make data-based decisions; however, there is limited research on effective methods of teaching graph analysis skills.

Several authors have used superimposed trend lines generated by split-middle (SM) and least-squares regression procedures as visual aids for improving accuracy in graph analysis (Baer & Parsonson, 1981; Kazdin, 1982; Parsonson & Baer, 1978; White & Haring, 1980). For example, Bailey (1984) increased the interrater agreement of 13 special education graduate students on the significance of the change in level and/or slope in arithmetic and semilogarithmic graphs by superimposing trend lines. Additionally, Hagopian et al. (1997) trained three predoctoral interns to use structured criteria written by a consortium of data analysis experts to analyze functional analysis graphs. The structured criteria included drawing criterion lines and following several rules to make decisions based on where data points fell in relationship to the criterion lines. Finally, Fisher, Kelley, and Lomas (2003) conducted three studies to increase the accuracy of visual inspection methods in detecting treatment effects in A–B design graphs. The first study used a computer-simulated Monte Carlo study to evaluate the dual-criteria (DC) method, a refinement of the SM method, which included adding a second criterion line superimposed on the treatment phase generated from the baseline mean. The DC method controlled Type I error rates better than the SM method did. In Study 2, five behavior therapists learned to use the DC method through brief verbal and written instructions with modeling. There were marked increases in the percentage of correct data interpretations. In Study 3, the experimenters incorporated the same training methods into a slide presentation to train 87 adults attending a workshop on behavior analysis in 15 min.

This Experiment was completed by the first author in partial fulfillment of the Ph.D. in Psychology (Behavior Analysis Training Area) degree at The Graduate Center, City University of New York.

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These studies all used visual aids to increase the accuracy of the visual analysis of graphs; however, professionals would find it difficult to draw trend or criterion lines on graphs that are continually updated. Thus, it is important to evaluate how visual analysis of graphs may be improved with other methods.

Keohane and Greer (2005) used weekly data check meetings between supervisors and center-based applied behavior analysis (ABA) teachers. Teachers learned to use rules regarding decision opportunities such as (a) three descending data paths indicated a problem with instruction where a phase change or new tactic was needed, (b) three data points at the criterion indicated that the student had met the criterion and that a change was needed, and (c) three data paths with no trend also indicated that a phase change or new tactic was needed. During intervention, the experimenters conducted weekly data check meetings during which supervisors asked teachers questions such as, “Why didn’t you initiate a phase change at this point?” in response to the graphic data display. Correct teacher responses required scientific rationale based on the rules, such as, “There was no trend and the data were variable.” Incorrect responses included statements unrelated to the rules, such as, “Maybe the student needed more time to achieve the objective.” The experimenters recorded correct teacher responses and gave correctional feedback for incorrect responses. Rules and corrective feedback were effective in increasing accurate, data-based decisions.

Keohane and Greer (2005) demonstrated that staff can learn to analyze percentage graphs using only a set of rules through comprehensive training within the context of a center-based program; however, it is also important for home- and community-based teachers to have access to training in graph analysis. Comprehensive training over time is difficult to provide to community- and home-based teachers who often only meet with supervisors on a monthly basis. Therefore, it is necessary to explore ways to increase the visual analysis skills of home- and community-based teachers that do not require weekly supervisor contact. The aim of the present study was to evaluate the effects of a behavioral skills training (BST) package on training home-based ABA teachers to implement data-based decision rules accurately during DTT.

Method

Participants, Setting, and Materials

Three state-certified special education teachers providing home-based ABA services to young children with autism participated. Participants 1, 2, and 3 had 3, 3, and 1 years of experience as home-based special education providers, respectively. They were not Board Certified Behavior Analysts (BCBAs) or Board Certified Assistant Behavior Analysts (BCaBAs), nor had they ever been enrolled in graduate-level

coursework on behavior analysis; however, all attended quarterly trainings provided by their employing agency related to ABA principles of specific teaching procedures throughout the calendar year. The experimenter selected teachers to participate when the inspection of continuous percentage graphs from their students’ program books indicated less than 80% of correct data-based decisions according to the data analysis rules. Three students also participated, in that their data were used to assess the accuracy of the instructors’ data-based decisions. The three student participants were all 3-year-old boys.

The experimenter conducted training at a community-based ABA agency office. Training took place in a classroom containing one table and two chairs. Only training materials were placed on the table. The room contained educational materials commonly found in early intervention settings (e.g., blocks).

Materials included (a) percentage graphs from each teacher’s program book reflecting actual students’ responding during DTT, (b) a typed list of data-based decision rules, and (c) experimenter-created sample percentage graphs containing a variety of graph conditions and decision opportunities. The experimenter selected teachers’ percentage graphs that (a) had at least 6 data points, (b) were not inherited from or shared with other therapists or supervisors, and (c) were from programs that participants were running prior to training. The experimenters adapted the rules from Greer (2002) and Keohane (1997) so that participants did not have to calculate or determine the trend within each condition and needed only to determine whether individual paths in a given condition were flat, ascending, or descending. Table 1 presents these rules.

The experimenter created and block randomized the sample graphs to include one, two, three, or four decision opportunities per graph. All sample graphs included 7 to 15 data points. The experimenter randomized the order of presentation of sample graphs during training, which was constrained so that each participant encountered each of the nine possible data conditions at least once during BST. During training, the experimenter provided the participants with a ruler and a pencil and used a timer to track the training duration, a clipboard for storing graphs, a pencil for recording participants’ progress, and a calculator.

Dependent Variables

Dependent variables were the percentage of correct data-based decisions during graph analysis and the percentage of error teaching sessions on a given graph. There were specific correct responses for each of the nine possible conditions that could have been encountered on a graph (see Table 2). In all conditions, the rules required participants to (a) indicate a decision to change the instructional program or tactic by inserting a dashed vertical line to initiate a phase change within 1 cm after the last data point in the condition and extending from the *x*-axis of the graph to at least 1 cm above the top of the *y*-axis or (b) indicate a decision to continue the instructional program by inserting a check mark

Table 1 Rules for making data-based decisions regarding discrete-trial percentage graphs

<p>1. After three consecutive ascending data paths, a decision should be made to continue the instructional tactic or program. Show a decision to continue by inserting a check mark within 1 cm below the <i>x</i>-axis and within 1 cm to the right of the date or session number corresponding with the last data point in the three-path sequence.</p> <p>2. After three descending data paths, a decision should be made to change the instructional tactic or program. Add a phase change line—a dashed vertical line inserted between the last data point of the descending three-path sequence and before any additional data points extending from the <i>x</i>-axis of the graph to at least 1 cm above the top of the <i>y</i>-axis—to make a change in the instructional program. Note: Flat paths in this condition should be treated the same as descending paths. For example, if two paths are flat and one is descending, a decision to change should be made.</p> <p>3. After three flat data paths, a decision should be made to change the instructional tactic or program. Add a phase change line—a dashed vertical line inserted between the last data point of the flat three-path sequence and before any additional data points extending from the <i>x</i>-axis of the graph to at least 1 cm above the top of the <i>y</i>-axis—to make a change in the instructional program.</p> <p>4. Decisions can also be made after four data paths. For example, if the first data path is ascending and the next three are descending, a decision should be made to change the instructional tactic or program after the fourth data path.</p> <p>If none of these conditions have occurred over a three- or four-path series, continue programming and expand your analysis to include five paths.</p> <p>When there are five paths</p> <p>5. If three out of the five data paths in a sequence are ascending, a decision should be made to continue the instructional tactic or program. Show a decision to continue by inserting a check mark within 1 cm below the <i>x</i>-axis and within 1 cm to the right of the date or session number corresponding with the last data point in the five-path sequence.</p> <p>6. If three out of the five data paths in a sequence are descending, a decision should be made to change the instructional tactic or program. Add a phase change line—a dashed vertical line inserted between the last data point of the five-path sequence and before any additional data points extending from the <i>x</i>-axis of the graph to at least 1 cm above the top of the <i>y</i>-axis—to make a change in the instructional program. Note: Flat paths in this condition should be treated the same as descending paths. For example, if three out of five paths are flat or descending, then a decision to change should be made.</p> <p>7. If the criterion for mastery of a program or prompt level is met, a decision should be made to change the instructional program or prompt level. Add a phase change line—a dashed vertical line inserted between the last data point of the sequence (e.g., three data points at 80% or better) and the next data point extending from the <i>x</i>-axis of the graph to at least 1 cm above the top of the <i>y</i>-axis—to update the program. Note: Criterion for mastery for each graph would be determined by the criterion identified in the specific learner's program. For the sample graphs that you will analyze, criterion for mastery will be displayed on the graph itself.</p> <p>8. After a data analysis decision has been made, begin the entire analysis process again with any additional data following your decision notation (check mark or phase change).</p> <p>Important indications</p> <p>1. A decision to continue an instructional tactic or program indicates that the student is making progress toward mastering the skill and that instruction should continue unchanged.</p> <p>2. A decision to change an instructional tactic or program indicates that the student is not making progress toward mastering the skill and that an instructional change is necessary (e.g., change to a more intrusive prompt level, change to a different type of prompt, provide instructional materials, reinforce, teach prerequisite skill).</p> <p>3. A decision to change when criterion for mastery is met indicates that the student has learned the short-term objective and that a new objective should be taught.</p>

within 1 cm below the *x*-axis and within 1 cm after the date or session number that corresponded with the last data point in the condition. After a decision was made on any given graph, correct participant behavior was to treat the next data path as the first of a new condition to be analyzed. Error sessions were any teaching sessions conducted after an incorrect data-based decision and until the participant made his or her next correct decision following the incorrect decision.

Data Collection

Data collection took place during baseline; after instructions; after modeling, rehearsal, and feedback; and during follow-up. For each graph, the experimenter scored the percentage of correct decisions and the percentage of error teaching sessions.

After instructions; after the modeling, rehearsal, and feedback package; and during follow-up, the experimenter scored a correct decision if (a) a check mark was inserted where a program should have continued according to the rules or (b) a phase change was inserted where a program should have been changed according to the rules by inserting the letter *C* directly on the data path where the teacher made a correct decision. The experimenter marked decisions as errors if (a) the teacher inserted a check mark where a change should have been made according to the rules, (b) inserted a phase change where a check mark should have been according to the rules, or (c) inserted neither a check mark nor phase change where a decision opportunity occurred. The experimenter marked error decisions on each graph by inserting the letter *E* directly on the data path where the teacher should have made a correct

Table 2 Nine possible graph conditions and correct participant decisions

Condition	Number of paths	Direction	Correct decision	Correct notation
1	Three	Ascending	Continue	Check mark
2	Three	Descending	Change tactic	Phase line
3	Three	Flat	Change tactic	Phase line
4	Three	Combination of flat and descending	Change tactic	Phase line
5	Four	First path descending, next three ascending	Continue	Check mark
6	Four	First path ascending, next three either flat or descending	Change tactic	Phase line
7	Five	Three or more paths either flat or descending	Change tactic	Phase line
8	Five	Three or more paths ascending	Continue	Check mark
9	One or two depending on student criterion for mastery	NA: Criterion was determined by the individual student's program criterion for mastery during analysis of student graphs. The experimenter decided on varying criteria for mastery for sample graphs. These criteria were noted on each individual sample graph (e.g., three consecutive sessions above 80%).	Change program	Phase line

NA = not applicable

decision. The experimenter marked error teaching sessions by circling the data point immediately following a decision error and placing the letters *ET* directly above each circle. The experimenter scored every sequential data point in the same manner until the teacher made a correct decision.

During baseline, decisions to continue did not require the check-mark notation in order to be scored as correct. The experimenter scored decisions to continue during baseline as correct if the instructor continued the program as indicated by continuous data plotted after a given decision opportunity. The check mark is not a commonly used notation in percentage graph analyses. Therefore, to score baseline decisions to continue instruction as incorrect because the participants did not include a check-mark notation would have unfairly skewed baseline performance in the opposite direction of training. Because the experimenter introduced the check-mark notation during the instructions component of training, all graphs scored after instructions, training, and follow-up required the check-mark notation.

The experimenter calculated the percentage of correct decisions by dividing the number of correct decisions by the total number of decision opportunities on a graph and multiplying by 100. The experimenter calculated the percentage of error teaching sessions by dividing the number of error teaching sessions by the total number of teaching sessions on a graph and multiplying by 100.

Interobserver Agreement (IOA)

Two observers independently scored participant data in order to evaluate IOA. The experimenter used a number generator to randomly select 30% of each participant's graphs across all phases of the experiment for scoring. An agreement was defined as any instance where both observers had inserted *C*, *E*,

or *ET* in the same place on a given graph. A disagreement was defined as any instance where the observers did not insert the same scoring notation in the same place. The experimenter calculated the percentage of IOA by dividing the total number of agreements by the total number of agreements plus disagreements multiplied by 100. The overall mean IOA was 98.4% (range of 89–100%). IOA was 100%, 95.2% (range of 89–100%), and 100% for Participants 1, 2, and 3, respectively. For Participant 2, there were two disagreements on the number of error instructional sessions between incorrect and correct decisions. This was due to disagreements on the criteria for mastery of short-term objectives for the student instructed by Participant 2 (e.g., two sessions at 90% accuracy or better vs. three sessions at 80% accuracy or better).

Procedure

Baseline For each participant, the experimenter selected graphs from the student program books by removing them from the book, turning them over blank side up, shuffling them, and spreading them out on a flat surface. The experimenter then picked up and scored each student graph until the participant data indicated stable baseline performance (3 for Participant 1, 6 for Participant 2, and 5 for Participant 3). The experimenter then gave the participants additional experimenter-created sample graphs and said, "Please analyze these graphs to the best of your ability." Baseline data included accuracy of analyses on student and experimenter-created graphs in order to control for any differences in responding to the different types of graphs and in order to control for any improvements in graph analysis according to the data decision rules that may have occurred simply as a result of exposure to multiple sample graphs over time.

BST The experimenter implemented BST in three phases: (a) instructions; (b) modeling, rehearsal, and feedback; and (c) repetition of rehearsal and feedback (if necessary). Before the instructions phase, the experimenter gave a nine-item quiz to each teacher to evaluate her prerequisite skills to identify (a) a data point; (b) a data path; (c) the x - and y -axes; (d) specific data points plotted at specific values (e.g., 80%); and (e) lines that were ascending, descending, flat, or vertical. If the participant scored 100%, the experimenter immediately provided the participant with the rules and said, “Read these rules.” If the participant did not score 100%, the experimenter directed her to circle the correct answers. The participants had access to the quiz with the correct answers for the rest of the training. The experimenter then provided the participant with the written rules and said, “Read these rules.” After a participant read the rules, the experimenter provided her with three experimenter-created graphs and said, “Analyze these graphs according to the data decision rules.” All of the participants read the rules silently or quietly to themselves and looked to the experimenter to indicate that they had finished.

During Phase 2, the experimenter modeled accurate implementation of data decision rules by stating and pointing to the specific rule and inserting the check mark or phase changes on a graph that contained each of the nine possible graph conditions outlined in the data decision rules. The experimenter then provided the participant with a graph and said, “Analyze the graph according to the data decision rules.” After the participant analyzed the graph, the experimenter provided feedback regarding accuracy. For example, if the participant made a correct decision to change a program or instructional tactic, the experimenter said,

Here, there are five data paths where three are either flat or descending, and you have correctly inserted a phase change here. This phase change indicates that the student is not making progress toward meeting criterion for the program and that a change in the instructional tactic or program is necessary.

Each participant received feedback on the analysis of three graphs. The experimenter then gave each participant three additional experimenter-generated graphs to analyze without feedback.

During Phase 3, the experimenter repeated rehearsal and feedback if the participant did not meet the criterion. Mastery criterion was 100% correct data-based decisions over analyses of three consecutive graphs. If the participant did not meet the criterion after the initial rehearsal and feedback component completed in Phase 2, the experimenter repeated the component by providing feedback on three additional graph analyses and by providing three additional graphs for the participant to analyze without feedback. Participants 1 and 2 required a repetition of rehearsal and feedback to meet the criterion.

Generalization and Maintenance Upon meeting mastery criterion, the experimenter gave each participant two student graphs to analyze in order to assess generalization. The experimenter selected the student graphs in the same fashion as she did during baseline. After the participant analyzed the student graphs, the experimenter reviewed the accuracy of the analysis with the participant as she had during the rehearsal and feedback component and then dismissed the participant. To assess maintenance, the experimenter collected follow-up data as soon as each participant had collected 3 to 4 weeks of student data points after training. Maintenance checks were then conducted weekly until the study ended. As a result, the graph analysis skills of Participants 1, 2, and 3 were assessed for maintenance for about six, three, and one months, respectively. The experimenter conducted maintenance identically to baseline. The experimenter conducted two additional repetitions of the rehearsal and feedback component (“booster” sessions) with Participant 1 after her 12th and 18th follow-up graphs indicated decreases in the overall accuracy of correct data-based decisions. Booster sessions lasted about 15 min. After the second booster session, Participant 1’s accuracy stabilized at a mean of 100%.

Social Validity

Seven BCBA’s and the three research participants completed a social validity questionnaire. They rated the importance, helpfulness, efficiency, and efficacy of the training package in improving accuracy of graph analyses for the three participants according to a Likert scale of 1 (*not at all important*) to 5 (*extremely important*).

Results

Figure 1 shows the percentage of correct data-based decisions and the percentage of error teaching sessions for each participant during the experiment. Mean scores for correct data-based decisions for Participants 1, 2, and 3 were 11%, 33%, and 30% during baseline, respectively. Mean scores after the instructions component were 11%, 0%, and 39%, respectively. After BST, the percentage of participants’ correct decisions increased in level ($M = 67\%$, 89% , and 100% for Participants 1, 2, and 3, respectively). Participants 1 and 2 showed a decrease in accuracy on the third graph analyzed after modeling, rehearsal, and feedback; however, both achieved mean scores of 100% on graphs analyzed following the repetition of rehearsal and feedback. After termination of BST, Participants 1, 2, and 3 maintained accurate decision-making skills at mean levels of 81%, 100%, and 100%, respectively. Error teaching sessions decreased for all participants after BST. The percentages of error teaching sessions for Participants 1, 2, and 3 during baseline were 48%, 28%,

Fig. 1 The graph displays the percentage of correct data decisions (closed symbols) and the percentage of error teaching sessions (open symbols) for Participants 1, 2, and 3 during baseline; instructions (Inst); modeling, rehearsal, and feedback (Mod + Reh + FB); and follow-up. Circle data points represent sessions where participants analyzed student

data, and triangle data points represent sessions where participants analyzed experimenter-created data. $R + F$ with an arrow indicates the first session after a repetition of the rehearsal and feedback component, and B with an arrow indicates the first session after a booster rehearsal and feedback training session during follow-up

and 33%, respectively. Mean scores after instructions alone were 44%, 61%, and 34%, respectively. After BST, the percentages of error teaching sessions were 2%, 1%, and 0%,

respectively, and were maintained at levels of 6%, 0%, and 0%, respectively, during follow-up. Training times were 43.4, 52.8, and 66.2 min for Participants 1, 2, and 3, respectively.

BCBAs' responses to the social validity questionnaire rated the importance of the accuracy of visual graph analysis in the provision of DTT at a mean of 5, according to a Likert scale of 1 (*not at all important*) to 5 (*extremely important*). These respondents rated the helpfulness, efficiency, and efficacy of the training package in improving graph analyses at means of 4, 4, and 4 out of 5, respectively. Individual comments from BCBAs suggested the inclusion of indications regarding the trend in the data analysis rules and adjustment of the training to accommodate more than one participant at a time. The research participants' responses also rated the importance of the accuracy of visual graph analysis in the provision of DTT at a mean of 5 and rated the efficiency and efficacy of the training package in improving graph analyses at means of 4 and 4, respectively. The participants, however, rated the helpfulness of the training package at a mean of 4.6. The participants did not make individual comments or suggestions regarding the training package.

Discussion

BST systematically improved data-based decision making and reduced error teaching sessions for all three of the participants. This extended the findings of Bailey (1984), Hagopian et al. (1997), and Fisher et al. (2003) by demonstrating that teachers can acquire decision-making skills without criterion or trend lines. The rules alone did not improve participant performance without BST. The experiment in this study involved one BST meeting with each participant (with two additional meetings for Participant 1). The experiment conducted by Keohane and Greer (2005) involved a minimum of six supervisor meetings per participant and a maximum of 23 meetings during training. Accuracy of data-based decisions was also maintained in the absence of weekly supervision. Only one participant required any training during the maintenance phase, and these trainings were short and infrequent (occurring about monthly). Therefore, the current experiment extended that of Keohane and Greer (2005) because the participants acquired graph analysis skills without extensive, ongoing training.

There were several limitations to this experiment. First, the participants may not have been representative of the full range of home-based ABA providers because all were master's-level, state-certified special educators. Therefore, the external validity of this study may be limited to more highly educated home-based ABA providers. In addition, participant performance after BST varied. For example, Participant 1 showed greater variability in her percentage of correct decisions after exposure to BST than the other two participants. Participant 1 also required retraining during follow-up, whereas the other two participants did not. The reasons for this difference were undetermined; however, there were two differences between this participant and the others that may be noteworthy. First, Participant 1 was the most experienced ABA provider of the three participants. It

is possible that a learning history that conflicted with the correct application of the data analysis rules affected her performance. Second, Participant 1 was exposed to the shortest duration of BST. Future studies may examine the relationship of total training time to skill acquisition to determine the ideal duration of BST required to adequately train and ensure the maintenance of this type of skill. Another limitation is that BST did not mimic the typical circumstances under which decision making occurs, as participants did not plot student data during training. Also, teachers do not typically insert check marks indicating decisions to continue instructional tactics, so the external validity of this aspect of the training may be limited. In addition, the experimenter did not train teachers to identify specific instructional tactics to change. Future research might teach the use of decision-making rules that efficiently sample effective changes in instructional strategies. Keohane and Greer (2005) reported training teachers to make specific changes to instructional programs but did not report which types of changes were most effective. In this study, the experimenter also did not analyze which components of training were necessary and sufficient to improve participant performance. Future research might conduct a component analysis to identify the effective components of this training package and develop maximally efficient forms of staff training (Ward-Horner & Sturmey, 2010). The final shortcoming was that there was no evaluation of the extent to which correct teacher application of the data analysis rules affected student performance. Because the ultimate goal of staff training in applied behavior analysis is to improve outcomes for clients, the lack of any data demonstrating this improvement points to a necessary next step in this line of research.

Compliance with Ethical Standards

Conflict of Interest Lindsay Maffei-Almodovar, Gina Feliciano, and Daniel M. Fienup declare no conflicts of interest related to this article. Peter Sturmey receives consultancy and training fees and royalties related to staff training and consultation.

Human Participants and Animal Studies The procedures performed in this study involving human participants were in accordance with the ethical standards of the City University of New York (CUNY) Human Research Protection Program (HRPP) and in accordance with the 1964 Declaration of Helsinki and its later amendments. This article does not contain any studies with animals performed by any of the authors. This study was completed by Lindsay Maffei-Almodovar in partial fulfillment of a PhD in psychology (behavior analysis training area) at The Graduate Center, City University of New York.

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