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Effects of Response Cards on Math Performance for Students with Moderate Intellectual Disability

Lauren J. Boden

ACCEPTANCE

This dissertation, EFFECTS OF RESPONSE CARDS ON MATH PERFORMANCE FOR STUDENTS WITH MODERATE INTELLECTUAL DISABILITY, by LAUREN J BODEN, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

____
Paul A. Alberto, Ph.D.
Committee Chair

____
Laura D. Fredrick, Ph.D.
Committee Member

____
Kristine Jolivette, Ph.D.
Committee Member

____
Christopher A. Tullis, Ph.D.
Committee Member

____
Date

____
Laura D. Fredrick, Ph.D.
Chairperson, Department of Educational Psychology, Special Education, and Communication Disorders

____
Paul A. Alberto, Ph.D.
Dean
College of Education

AUTHOR'S STATEMENT

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Lauren J. Boden

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Lauren Jordan Boden
4190 Waterloo Circle
Tucker, GA 30084

The director of this dissertation is:

Paul A. Alberto
Department of Educational Psychology, Special Education, and Communication Disorders
College of Education
Georgia State University
Atlanta, GA 30303

CURRICULUM VITAE

Lauren J. Boden

ADDRESS: 4190 Waterloo Circle
Tucker, GA 30084

EDUCATION:

Ph.D.	2015	Georgia State University Education of Students with Exceptionalities
M.Ed.	2011	Georgia State University Multiple and Severe Disabilities
B.S.	2007	Clemson University Special Education

PROFESSIONAL EXPERIENCE:

2014-present	Limited Term Clinical Instructor Georgia State University
2012-2014	Project Coordinator, Implementing Positive Behavior Supports in Juvenile Correction Settings Georgia State University
2007-2012	Special Education Teacher Gwinnett County Public Schools, Snellville, GA

SELECTED PRESENTATIONS AND PUBLICATIONS:

Ennis, R. P., Jolivette, K., & Boden, L. J. (2013). STOP and DARE: Self-regulated strategy development for persuasive writing with elementary students with E/BD in a residential facility. *Education and Treatment of Children*, *36*, 81-99.

Swain-Bradway, J., Swoszowski, N. C., Jolivette, K., & Boden, L. J., Sprague, J. R. (2013). Voices from the field: Stakeholder perspectives on PBIS implementation in alternative educational settings. *Education and Treatment of Children, 36*, 31-46.

Boden, L. J., Ennis, R. P., & Jolivette, K. (2012). Implementing check-in check-out for students with intellectual disability in self-contained classrooms. *Teaching Exceptional Children, 45*, 32-41.

Boden, L. J., Jolivette, K., & Evanovich, L. L. (2014, October). Check-in Check-out for Students with Moderate Intellectual Disability. National PBIS Leadership Forum, Chicago, Illinois.

Sprague, J., Jolivette, K., & Boden, L. J. (2014, October). Implementing PBIS in secure care facilities: Adaptations for system, data, & practice changes. National PBIS Leadership Forum, Chicago, Illinois.

Jolivette, K., Boden, L. J., & Sprague, J. (2014, October). Youth voice on the implementation of facility-wide PBIS in their secure juvenile facility. National PBIS Leadership Forum, Chicago, Illinois.

Jolivette, K., Boden, L. J., & Sprague, J. (2014, October). Youth Perceptions of Facility-wide PBIS Implementation in Secure Juvenile Facilities. Teachers Educators for Children with Behavioral Disorders Conference, Tempe, Arizona.

Sprague, J., Jolivette, K., & Boden, L. J. (2014, October). Adoption and Implementation of the PBIS Framework in Secure Juvenile Facilities: Youth and Staff Outcomes. Teachers Educators for Children with Behavioral Disorders Conference, Tempe, Arizona.

Boden, L. J., & Waugh, R. (2014, April). Teaching students with moderate intellectual disability to calculate tax using an iPhone. Council for Exceptional Children Conference, Philadelphia, Pennsylvania.

Waugh, R., & Boden, L. J., Leontovich, M. (2014, April). Effects of error correction during assessment probes on the acquisition of sight words for sight words for students with moderate intellectual disability. Council for Exceptional Children Conference, Philadelphia, Pennsylvania.

Boden, L. J., & Alberto, P. A. (2014, January). Check-in/check-out for students with moderate intellectual disability. Council for Exceptional Children Division on Autism and Developmental Disabilities Conference, Clearwater Beach, Florida.

Boden, L. J., & Alberto, P. A. (2014, January). Teaching students with moderate intellectual disability to calculate tax on grocery items using an iPhone. Council for Exceptional Children Division on Autism and Developmental Disabilities Conference, Clearwater Beach, Florida.

EFFECTS OF RESPONSE CARDS ON MATH PERFORMANCE FOR STUDENTS WITH MODERATE INTELLECTUAL DISABILITY

by

Lauren J. Boden

Under the Direction of Paul A. Alberto

ABSTRACT

Response cards (RC) are signs or cards that allow students to hold up their answer and simultaneously respond to teacher prompts. Researchers have examined the use of RC in a variety of different settings with students with and without disabilities and have found an array of positive effects on behavioral and academic outcomes; however, there is a paucity of research on the use of RC for students with moderate intellectual disability (MoID). This study directly examined the effects of RC with students with MoID on academic engagement, active student responding, task accuracy, and total instructional time while teaching students to determine more/less than. A multiple-baseline across dyads design with an embedded reversal was employed to determine the effects of RC on the dependent variables. Direct observation data were collected via recorded video sessions for all dependent variables. Visual analysis assessed the following six features as recommended by Kratochwill et al. (2010): level, trend, variability, immediacy of the effect, overlap, and consistency of data patterns across similar phases. In addition, percent change across phases was calculated.

Results of the study were mixed; however, a functional relation was established for one of the five students for the dependent variables of academic engagement and active student responding. All five student participants reached mastery criteria for task accuracy. Both teacher participants were able to implement the intervention with high levels of fidelity. In addition, teachers and students found the intervention to be socially acceptable and all students preferred to complete their instruction using RC.

INDEX WORDS: Response cards, Moderate intellectual disability, Math instruction, Simultaneous prompting

EFFECTS OF RESPONSE CARDS ON MATH PERFORMANCE FOR STUDENTS WITH MODERATE INTELLECTUAL DISABILITY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ASR	Active Student Responding
ASD	Autism Spectrum Disorder
DI	Direct Instruction
DLT	Discriminant Learning Theory
IDEA	Individuals with Disabilities Education Act
IOA	Inter-observer Agreement
IRP-15	Intervention Rating Profile 15
MID	Mild Intellectual Disability
MoID	Moderate Intellectual Disability
PID	Profound Intellectual Disability
RC	Response Cards
SID	Severe Intellectual Disability

1 EFFECT OF RESPONSE CARDS ON ACADEMIC AND BEHAVIORAL OUTCOMES FOR STUDENTS WITH DISABILITIES

Students with significant cognitive disability have traditionally been described within academic literature by their level of intellectual functioning. Students with moderate intellectual disability (MoID) have intelligence quotients falling between 40-55, while students with severe intellectual disability (SID) have intelligence quotients falling between 25-40. Recently, students with MoID or SID have been referred to as students with moderate to severe disability (MSD). The term MSD allows for both students with MoID and SID to be included under one umbrella. Students with MSD display a variety of behavioral and learning characteristics which present challenges in the classroom. Students with MSD may display challenging behavior such as aggression or self-injury (Emerson et al., 2001) as well as a variety of inappropriate social behaviors (Guralnick, Conner, & Johnson, 2011; Leffert, Siperstein, & Millikan, 2000). In order to remediate these behaviors, students with MSD require systematic instruction in the area of social skills and the use of behavioral management strategies to shape their challenging behaviors into more appropriate behaviors. In addition to challenging behavior, students with MSD display significant deficits across academic areas.

One academic area in which there is limited research is the area of mathematics (Browder, Jimenez, & Trela, 2012). While researchers and practitioners often use the terms mathematics and arithmetic interchangeable, arithmetic is one branch of mathematics that deals with the properties and manipulation of numbers. While researchers working with students with more significant cognitive disability may use the term mathematics, most research with this group of students is focused on basic arithmetic skills. In a meta-analysis on teaching mathematics to students with MSD, Browder, Spooner, Ahlgrim-Delzell, Harris, and Wakeman

(2008) located a total of 68 studies over a span of 30 years (1975-2005), most of which focused on counting, number matching, calculation, and money skills. Given the limited number of empirical studies, much is to be learned in regards to effective instruction in arithmetic for students with MSD.

Students with MSD who have basic arithmetic skills can learn to apply those skills in functional activities such as shopping, managing time, and solving problems (Cihak & Foust, 2008). Over the last decade, the focus of education for students with MSD has shifted to include access to the general curriculum for all academic areas (Browder et al., 2008; Spooner, Dymond, Smith, & Kennedy, 2006). According to the reauthorization of the Individuals with Disabilities Education Act (IDEA, 2004) all students with disabilities, even the most severe disabilities, are required to participate in the general curriculum and take alternative assessments on grade level material in all academic areas. Students with MSD are now required to exhibit arithmetic skills in academic as well as functional settings.

Math Instruction for Students with ID

The vast majority of research in teaching arithmetic to students with intellectual disability focuses on students with mild intellectual disability (MID). The limited research that has been conducted for students with MoID has focused on teaching basic arithmetic skills such as counting, identifying numbers, and adding. These skills have been taught using direct instruction (DI) and Discriminant Learning Theory (DLT) (Young, Baker, & Martin, 1990), peer tutoring (Lacioni, 1982; Vacc & Cannon, 1991), calculators (Koller & Mulhern, 1977), “dot notation” or Touchmath (Fletcher, Boon, & Cihak, 2010; Kokasaka, 1975), reinforcement (Miller, 1976), and number lines (Fletcher et al., 2010). Recently, a shift has occurred away from sole instruction in basic arithmetic skills to include a focus on teaching grade-level math standards to all students Browder et al., 2008; Spooner et al., 2006).

The shift to teach grade-level standards to all students has led to a growing body of literature on teaching grade-level math standards to students with MSD. Researchers have examined the use of response prompting strategies such as time delay and simultaneous prompting to teach an array of standards to students with MSD. For example, Karl, Collins, Hager, and Ault (2013) embedded core content standards in reading, math, and science into a functional cooking activity for students with MoID. In a similar study, Browder, Jiminez, et al. (2012) taught students with MSD to perform mathematical skills pertaining to content standards from data analysis, algebra, and geometry. Browder, Trela, et al. (2012) taught algebra, geometry, measurement, and data analysis skills to middle school students with MoID. Although grade level standards are being addressed, this is occurring at the most basic skill level. That is, for a geometry standard in which students are to “specify locations and describe spatial relations using coordinate geometry,” students are simply locating pictures on a map and connecting points with a line. For the algebra standard “represent and analyze mathematical situations and structures using algebraic symbols,” students are simply sequencing on an equation prompt. Within the field of education for students with MSD, arguments exist both for and against teaching grade-aligned content in all academic areas (Ayers, Lowery, Douglas, & Sievers, 2011, 2012; Courtade, Spooner, Browder, & Jimenez, 2012).

When examining the body of mathematical literature for students with MSD including functional and standards-based instruction, there is a paucity of research with this population of students. Given the limited research, and the increased demand for students with MoID to demonstrate knowledge of both academic and functional arithmetic, researchers must determine evidence-based practices for this population. One area of arithmetic instruction that should be investigated for students with MoID is the ability to determine whether a number is more or less than another number. The ability to compare numbers in terms of more/less allows students to exhibit a range of arithmetic skills with functional applications. For example, a student with MoID who is able to determine more/less will be able to exhibit skills such as the ability to purchase on a budget.

Quantity comparison. There is a limited body of research on the concept of more/less. The existing literature focuses on the development of young children's ability to perform quantity comparisons. The term quantity comparison refers to a child's ability to determine what group has more or less members than another group and typically develops prior to school-age (Clements, 1984; Kraner, 1977).

In a study on training effects to develop logical operations (e.g., classification, serration, and number conservation) and number skills (e.g., counting), Clements (1984) found that 51% of four-year-old children were able to state which number was more when verbally presented with two numbers as well as identify which group had more when presented with two groups. Kraner (1977) examined the quantitative concepts of 273 children ages 3-6. The test on quantity comparisons revealed that the skill of being able to determine more than develops around age five-and-a-half, while the skill of being able to determine less than develops around age six-and-a-half. Kraner (1977) makes an important delineation in that the ability for children to identify one more than and one less than is a more advanced skill in that 80% of six-and-a-half year olds had not mastered this task.

Interventions with Students with MoID

As the ability to compare quantities is a basic number sense skill that develops prior to school-age for typically developing children (Kaufmann, Handl, & Thony, 2003), there is no research on systematically teaching quantity comparison to students without disabilities. In addition, there is no developmental research on the development of quantity comparison for students with MSD. Given that students with MSD learn skills at a slower rate than their nondisabled peers, they may require direct and systematic instruction in order to acquire this skill (Snell & Brown, 2011).

Manipulative/Number lines. There is some research to suggest that the use of manipulative materials may be one way to effectively and efficiently teach arithmetic skills to students with MoID (Fletcher et al., 2010). Manipulative materials offer a concrete representation of the skill students are learning. Teachers may use a variety of items as manipulative materials during arithmetic instruction (e.g., blocks, drawings, cubes, counter chips, or number lines). One obstacle in using manipulative materials to teach computation skills is the need to fade the use of the materials due to the difficulty they present when used outside of a classroom setting (Frank & Wacker, 1986). However, it may be difficult for students with MoID to perform arithmetic skills with accuracy without the continued use of manipulative materials. Therefore, these students need manipulative materials that are portable, discrete, and age-appropriate and can be used in a variety of settings.

Number lines may be one socially acceptable method to teach arithmetic skills to students with MSD. Number lines are easy to create and can be small enough to carry in a pocket. Number lines can be designed in a way that is age-appropriate for students with MSD making them socially acceptable for use in a range of settings. Number lines provide a visual representation of the order of numbers that may aid in the understanding of arithmetic concepts. Three studies have examined the use of a number line to teach arithmetic skills to students with developmental disabilities. One study examined the effect of a number line on purchasing skills (Frank & Wacker, 1986), and two studies examined the effect of a number line on addition (Cihak & Foust, 2008; Fletcher et al., 2010). To date, no studies have examined the effects of a number line on teaching more/less than for students with MoID.

Frank and Wacker (1986) used a number line in conjunction with coin segments to teach four elementary-aged students with mild to moderate intellectual disability to make purchases using mixed change. The number line used contained coin segment strips with mixed change that corresponded with each number on the line. For example, the number 20 on the number line had a coin segment strip with 20 cents attached. The researchers found the use of a number line when combined with the visual prompt of coin segments to have a positive effect on purchasing skills for all students.

The efficacy of number lines to teach addition facts has been compared to the use of TouchMath for students with autism spectrum disorder (ASD) (Cihak & Foust, 2008; Fletcher et al., 2010), and MoID (Fletcher et al., 2010). In these studies, students showed progress using number lines and TouchMath; however, researchers found TouchMath to be more effective than the use of the number line for students with autism. Although TouchMath was found to be an effective strategy for teaching addition skills, TouchMath presents several possible challenges for students with MoID. First, TouchMath requires touchpoints to be faded over time. Second, TouchMath requires "double touches" (some dots are counted more than once on particular numbers) which may be an additional obstacle for students with MoID. Lastly, TouchMath is a math program that teachers must purchase for classroom use, whereas a classroom teacher can easily create a number line. Given these limitations, the use of a number line to teach arithmetic skills may be a more efficient and effective strategy for students who have MoID.

Simultaneous Prompting

Systematic instruction should include the use of specific prompt fading for students with significant cognitive disability (Browder et al., 2008). One direct and systematic instructional approach to facilitate learning is the use of near errorless learning. Errorless learning is an instructional approach in which the number of errors made by students is decreased in comparison to traditional trial and error approaches (Mueller, Palkovic, & Maynard, 2007). During near errorless learning, stimulus control is transferred from the controlling prompt to the natural stimulus. This transfer of control allows for greater independence of the individual when performing the skill. Within errorless learning, there are five instructional strategies: most-to-least prompts, least-to-most prompts, graduated guidance, simultaneous prompting, and time delay (Gibson & Schuster, 1992; Wolery & Gast, 1984). Although there is considerable evidence that errorless learning is an effective method of instruction for students with MoID, more research is warranted to further investigate the effectiveness of this strategy within arithmetic instruction.

Simultaneous prompting has been used to teach a variety of academic and functional skills to students with MSD over the last two decades (Waugh, Alberto, & Fredrick, 2011b). Targeted skills include instruction in literacy, math, communication, daily living skills, leisure, and vocational tasks. To date, there are over forty peer-reviewed articles that demonstrate the effectiveness of simultaneous prompting as an instructional strategy for students with a developmental disability.

During instruction in simultaneous prompting, the instructional cue and controlling prompt are presented simultaneously (Gibson & Schuster, 1992; Schuster, Griffin, & Wolery, 1992; Singleton, Schuster, & Ault, 1995). An instructional cue is a prompt presented to a student that cues the student to attend to stimuli. The controlling prompt is a prompt that elicits correct responding. For example, if teaching a student to identify the number three, a teacher would hold up a card with the number three to the student. The teacher would then say “What number” (the instructional cue) and then immediately say “Three” (the controlling prompt), thus delivering the two cues almost simultaneously. This simultaneous delivery of the two prompts reduces student errors to almost zero allowing for students to acquire new skills while minimal errors are made. Assessment probes are conducted prior to each instructional session to assess skill acquisition from the previous sessions. During assessment probes, the instructional cue is delivered followed by a five second delay before delivering the controlling prompt. The delay allows for independent responding in which students’ correct responses are reinforced and errors are corrected when necessary (Waugh, Alberto, & Fredrick, 2011a).

In the area of arithmetic, eight studies have employed simultaneous prompting procedures during instruction for students with developmental disability (Akmanoglu-Uludag & Batu, 2005; Birkan, 2005; Creech-Galloway, Collins, & Knight, 2013; Fickel, Schuster, & Collins, 1998; Gursel, Tekin-Iftar, & Bouzkurt, 2006; Karl et al., 2013; Rao & Kane, 2009; Rao & Mallow, 2009). These studies included students with a range of disability including mild intellectual disability (MID) (Birkan, 2005; Fickel et al., 1998; Gursel et al., 2006; Rao & Kane, 2009; Rao & Mallow, 2009), MoID (Birkan, 2005; Creech-Galloway et al., 2013; Fickel et al., 1998; Gursel et al., 2006; Karl et al., 2013; Rao & Mallow, 2009), and ASD (Akmanoglu-Uludag et al., 2005). Of these studies, simultaneous prompting has been used to teach discrete math skills (Akmanoglu & Batu, 2005; Birkan, 2005; Fickel et al., 1998; Gursel et al., 2006; Rao & Mallow, 2009) as well as chained math skills (Creech-Galloway et al., 2013; Karl et al., 2013; Rao & Kane, 2009). Researchers have shown that simultaneous prompting can be an effective method for teaching both academic and functional skills for students with MSD (Birkan, 2005; Creech-Galloway et al., 2013; Fickel et al., 1998; Gursel et al., 2006; Karl et al., 2013; Rao & Mallow, 2009).

Active Student Responding

The use of group instruction when teaching students with MoID produces a number of benefits that cannot be found when instructing in a 1:1 format. Group instruction is advantageous in that it maximizes teacher instructional time, allows for student to student interaction, and gives the opportunity for students to learn observationally from their peers (Collins, Gast, Ault, & Wolery, 1991). Despite the benefits or group instruction, it can sometimes be challenging to keep all students engaged (Heward et al., 1996). One way to increase student engagement in a group setting is through the use of strategies that increase active student responding (ASR).

ASR can be defined as a response to an antecedent that can be observed (Heward, 1994). The concept of ASR is rooted in behavioral theory. Behaviorism is the theory that all behavior is learned and can be shaped through reinforcement and punishment. Teachers arrange learning trials in which contingencies of reinforcement are available to students and as a result, learning is expedited (Skinner, 1968). Randolph (2007) argued that the fundamental behavior theory behind ASR is the premise that the learning trial, which consists of an antecedent, student behavior, and teacher consequence is the key component of instruction. Learning takes place during instruction when students' appropriate responses are reinforced following an antecedent. The amount of time that elapses between the antecedent, behavior, and consequence, and the amount of time between each instructional trial determines how many learning trials may be conducted in one instructional session. When more instructional trials are presented in a session, students are given more opportunities to actively participate and access reinforcement in a near errorless learning strategy.

ASR has been found to increase task engagement and decrease disruptive and off-task behavior as when students are more engaged in the task at hand, they are less likely to display inappropriate behaviors (Sutherland & Wehby, 2001). In addition, when students are engaged in high levels of ASR, they have higher levels of skill acquisition as they have more opportunities to practice and to have correct responses reinforced (Horn, Schuster, & Collins, 2006; Skibo, Mims, & Spooner, 2011). There are a variety of instructional strategies that increase levels of ASR. Strategies such as response cards, choral responding, and guided notes increase ASR by maximizing the number of learning trials that can be presented during group instruction (Randolph, 2007).

The traditional form of ASR within the classroom requires students to raise their hand in response to a teacher question. Hand raising presents a number of problems when used with students who have MSD and may not be an optimal way to increase ASR within the classroom (Horn, 2010). First, hand raising only allows the opportunity for one student to respond to a given stimulus. Second, students with MSD may have additional physical impairments that prevent them from being able to raise their hand. Response prompting strategies such as simultaneous prompting incorporate the use of choral responding as a way to increase ASR. When using choral responding, all students answer in unison when cued by the teacher (Kamps, Dugan, Lenoard, & Daoust, 1994). Although choral responding may result in desired benefits such as increased opportunities to respond or increased student engagement, it may not be an effective way of increasing ASR for all students with MSD as some students with MSD have secondary speech impairments that inhibit their ability to respond verbally.

Response Cards

Response cards (RC) are cards or signs that can be held up simultaneously by a group of students in response to a teacher question (Christle & Schuster, 2003; Heward et al., 1996). As a simultaneous response is required by all students, response cards actively engage all students in instruction. The simultaneous response required by RC is a form of choral responding in which students are responding in unison in a nonverbal way. RC are considered low-tech tools that can be created with little cost and are easy for teachers to implement (Horn, 2010; Wood, Mabry, Kretlow, Lo, & Galloway, 2009). RC can include boards on which students write their own responses or cards that have been preprinted to include an array of response choices (Berrong, Schuster, Collins, & Morse, 2007). RC can be complex, containing multiple answers on one card in which students are required to select an answer by marking with an item such as a marker or clothespin or simply contain a single answer choice in which a student selects a card from an array of two or more.

When using RC, a teacher poses a question to the class, provides wait time for students to answer, and then provides students with a cue to show their response (Duchaine, Green, & Jolivette, 2011). This allows for students to acquire skills while teachers monitor skill acquisition for all students within a group simultaneously. The simultaneous response allows the teacher to assess student learning and adjust instruction as needed based on student understanding (Kellum, Carr, & Dozier, 2001). The teacher is able to reinforce correct responses, provide error correction, and reteach concepts as needed.

The use of RC in instruction has been found to produce an array of educational benefits. RC have been found to increase ASR for students with and without disabilities, increase opportunities to respond, and allow for immediate feedback for incorrect responses (Armendaiz & Umbreit, 1999; Carkiroglu, 2014; Cavanaugh, Heward, & Donelson, 1996; Christle & Schuster, 2003; Gardner, Heward, & Grossi, 1994; George, 2010; Lambert, Cartledge, Heward, & Lo, 2006; Simonsen, Fairbanks, Briesch, Myers, & Sugai, 2008). In addition, students tend to engage in less disruptive behavior and spend more time on task when RC are used as students are not afforded instances in which they are not responding as is the case with sequential turns in group instruction (Berrong et al., 2007; Horn et al., 2006; Lambert et al., 2006; Stichter et al., 2009).

RC have been evaluated as an instructional tool in a variety of educational settings with students with disabilities (Berrong et al., 2007; Carkirglu, 2014; Cavanaugh et al., 1996; Davis & O'Neil, 2004; George, 2010; Horn et al., 2006; Skibo et al., 2011; Wood et al., 2009) and without disabilities (Armendariz & Umbreit, 1999; Cavanaugh et al., 1996; Christle & Schuster, 2003; Davis & O'Neil, 2004; Godfrey, Grisham-Brown, Schuster, & Hemmeter 2003; Narayan, Heward, Gardner, Courson, & Omness, 1990). Researchers have examined the use of RC with students as young as preschool through students of college-age (Randolph, 2007).

In a meta-analysis on the use of RC, Randolph (2007) compared the use of response cards to the traditional form of ASR, hand raising. Eighteen studies were analyzed for test achievement, class participation, and off-task behavior. The researcher found statistically significant effect sizes for achievement, participation, and reduction of off-task behavior when using response cards as compared to hand raising. The results of this meta-analysis suggest that RC may be a more effective means of engaging students in ASR.

Response cards with students with disabilities. Researchers have examined the use of RC with students diagnosed with a range of disabilities including students with learning disabilities (Cavanaugh et al., 1996; Davis & O'Neil, 2004; Wood et al., 2009), emotional/behavioral disorders (Cavanaugh et al., 1996; George, 2010), MID (Carkirglu, 2014), MoID (Berrong et al., 2007; Horn et al., 2006; Skibo et al., 2011), severe intellectual disability (SID) (Berrong et al., 2007), profound intellectual disability (PID) (Skibo et al., 2011), unspecified intellectual disability (Cavanaugh et al., 1996) and unspecified developmental delays (Wood et al., 2009).

Demographics. Of the eight studies conducted on the use of RC that included students with disabilities, four were conducted in elementary schools (Berrong et al., 2007; Cakiroglu, 2014; Skibo et al., 2011; Wood et al., 2009), three were conducted in middle schools (Davis & O'Neill, 2004; George, 2010; Horn et al., 2006), and one was conducted in a high school (Cavanaugh et al., 1996). Research has taken place in inclusion settings (Cavanaugh et al., 1996; Wood et al., 2009), resource settings (Davis & O'Neill, 2004), and self-contained classrooms (Berrong et al., 2007; Cakiroglu, 2014; George, 2010; Horn et al., 2006; Skibo et al., 2011). In all, 57 students with disabilities were included across the eight studies. Four were diagnosed with a learning disability (Wood et al., 2009); one was diagnosed with an unspecified developmental delay (Wood et al., 2009); one was diagnosed with a learning disability and speech language impairment (Wood et al., 2009); 29 were diagnosed with an emotional/behavioral disorder (George, 2010); four were diagnosed with a mild intellectual disability (Cakiroglu; 2014); 14 were diagnosed with a moderate, severe, or profound intellectual disability (Berrong et al., 2007; Horn et al., 2006; Skibo et al., 2011); and eight were not specified (Cavanaugh et al., 1996). Researchers have examined the use of RC during writing (Davis & O'Neill, 2004), calendar

(Berrong et al., 2007; Wood et al., 2009), social studies (Cakiroglu, 2014; George, 2010), science (Cavanaugh et al., 1996), and math instruction (Horn et al., 2006; Skibo et al., 2011).

Experimental designs. The majority of research conducted on the use of RC with students with disabilities has compared the use of RC to hand raising (Berrong et al., 2007; Cakiroglu, 2014; Davis & O'Neill, 2004; Horn et al., 2006; Wood et al., 2009). These studies compared the use of RC to hand raising using an ABAB design during group instruction. In another study, George (2010) compared the use of RC to traditional instruction using a within-subjects crossover design. The comparison made by George (2010) differs from studies comparing RC to hand raising in that during traditional instruction, students answered teacher questions without being required to raise their hands. Cavanaugh et al. (1996) used an alternating-treatments design to compare a passive review which consisted of the teacher reading key points while displaying the point on an overhead projector to RC review which consisted of the teacher reading key points in which each point contained a blank that was then filled in by students using their RC. Finally, Skibo et al. (2011) examined the use of RC on skill acquisition using a multiple-probe across participants design.

Dependent variables. Dependent variables examined during RC studies with students with disabilities have included academic responding (Berrong et al., 2007; Cakiroglu, 2014; Davis & O'Neill, 2004; George, 2010; Horn et al., 2006; Wood et al., 2009), opportunities to respond (Cakiroglu, 2014), correct responding (Cakiroglu, 2014; Davis & O'Neill, 2004; George, 2010; Horn et al., 2006; Skibo et al., 2011), off-task behavior (Davis & O'Neill, 2004; Wood et al., 2009), on-task behavior (Berrong et al., 2007; George, 2010; Horn et al., 2006), inappropriate behavior (Berrong et al., 2007; Horn et al., 2006), quiz/test scores (Cavanaugh et al., 1996; Davis & O'Neill, 2004; George, 2010), and student satisfaction surveys (George, 2010). Researchers have found RC to have a positive effect on academic responding (Berrong et al., 2007; Cakiroglu, 2014; Davis & O'Neill, 2004; George, 2010; Horn et al., 2006; Wood et al., 2009), opportunities to respond (Cakiroglu, 2014), correct responding (Cakiroglu, 2014; Davis & O'Neill, 2004; George, 2010; Skibo et al., 2011), off-task behavior (Wood et al., 2009), on-task behavior (Berrong et al., 2007; Horn et al., 2006), reduction of inappropriate behaviors (Berrong et al., 2007; Horn et al., 2006), and quiz/test scores (Cavanaugh et al., 1996; Davis & O'Neill, 2004; George, 2010) for students with disabilities. While the research on RC with students with disabilities has yielded many positive results, not all students responded to the intervention in a positive way. In Davis and O'Neill's (2004) study, results for off-task behavior were mixed across student participants. In addition, George (2010) found minimal differences in on-task behavior across conditions when comparing RC to traditional classroom instruction with students with emotional/behavioral disorders. Horn et al. (2006) found that RC yielded a higher percentage of correct responses for only two of three participants when comparing RC to hand raising.

Response card types. Researchers who have examined the use of RC with students with disabilities have examined a variety of different RC types including write on (Cavanaugh et al., 1996; Davis & O'Neill, 2004; George, 2010;), preprinted (Cakiroglu, 2014; Skibo et al., 2011; Wood et al., 2009), Velcro (Berrong et al., 2007), and flipboard (Horn et al., 2006) RC. The most common form of RC, write on, consisted of students using a dry-erase marker to write their answer on a small white board when prompted by the teacher. Pre printed RC were used in several different ways. Cakiroglu (2014) used pre printed RC in which answers were displayed in a multiple-choice format. Students used a dry erase marker to circle their answer prior to holding up the card. Skibo et al. (2011) also used pre printed RC. In this study, students were presented with an array of three RC with single-digit numbers printed on each. Students selected one of the cards to choose their answer. In another study, Wood et al. (2009) examined the effects of preprinted RC in which the preprinted RC included the following three categories; days/months, seasons, and weather. Students used the cards and a clothespin to mark their answers to teacher questions. Berrong et al. (2007) used Velcro boards as RC. Students were presented with a minimum of four responses from which to choose. Students selected their answer, stuck it on their board, and showed their response to the teacher. Finally, Horn et al. (2006) used laminated flip boards that resembled a digital clock as RC. Students used their flip board to match the time to a time shown on an analog clock by the instructor.

Response cards with students with moderate to severe disability. RC may be particularly advantageous for students with MSD as they may be used by students who are nonverbal or have significant speech limitations (Berrong et al., 2007). While hand raising may be a sufficient means in which to actively engage typical learners in instruction, this may not be effective for students with speech limitations or physical disabilities (Horn, 2010). Research on the use of RC for students with MSD is sparse; however, the research that has been conducted shows positive effects for these students. To date, there are three studies that have examined the use of RC with students with MSD.

Horn et al. (2006) examined the use of RC with middle school students with MoID. Specifically, this study included three students ranging from 12 to 15 years with IQs measured in the MoID range. Dependent variables included active responding, on-task behavior, occurrence of inappropriate behavior, and task accuracy. Using an ABAB design, the researchers compared the use of RC to hand raising while teaching the students to tell time using a digital clock. The mean level of active responding across all three students during the first and second hand-raising conditions was 54% (range, 37-80%) and 64.5% (range, 47-80%) as compared to 100% during the response-card conditions. In regards to on-task behavior, the mean level was 69.6% (range, 50-100%) and 88.08% (range, 50.0-100%) in the first and second hand-raising conditions, respectively. On-task behavior during RC conditions was 97.6% (range, 91.6-100%) and 100% during the first and second phases, respectively. Inappropriate behavior was measured as a rate per minute across all three students. During the first and second hand-raising phases, the rate of inappropriate behavior was 0.96 (range, 0.3-1.5) and 0.82 (range, 0-1.75) while the rate of inappropriate behavior per minute during the first and second RC phases was 0.24 (range, 0-0.4) and 0.19 (range, 0-0.42). Skill acquisition was examined using a pre- and post-measure for each phase of the study. Prior to the beginning of each intervention phase, the mean percent of correct responses across the group was 0%. The post-measures of skill acquisition are as follows: first hand-raising condition, 60%; second hand-raising condition, 56.6%; first RC condition, 90%; second response card condition, 90%.

The results of this study are an initial indication that RC may be an effective intervention for students with MoID. Students were engaged in higher levels of active responding and on-task behavior during phases in which RC were used as opposed to hand-raising phases. Across all three participants, RC produced a positive effect. In addition, students engaged in inappropriate behaviors less frequently when using RC. For two of the three student participants, RC yielded a higher percentage of correct responses.

Berrong et al. (2007) used RC with elementary-aged students with MSD and evaluated the effect on active responding and social behavior. Participants in the study included eight students with intellectual functioning within the MoID to SID range whose ages ranged from 10-12. An ABAB design was used in which the use of RC was compared to hand raising during calendar group instruction. Data were collected on active responding, on-task behavior, and inappropriate behavior. Across baseline and intervention conditions, the instructor presented the students with questions pertaining to the class calendar time, and data were collected for the first 20 minutes of each session or until the instructor had asked all questions. During each session, students had the opportunity to respond to nine individual questions.

In regards to active responding, the mean percent across all three participants for the first and second hand-raising conditions was 21.7% (range, 14.8-30%) and 28.7% (range, 25-33%) respectively, compared to 58.8% (range, 54-65%) and 56.3% (range, 49-63%), respectively during RC conditions. Mean percent of on-task behavior across all three participants was 35.7% (range, 28-45.7%) and 36.9% (range, 22.5-54%) for the first and second hand-raising conditions respectively, while the mean percent of on-task behavior across all three participants during the first and second RC conditions was 79.4% (range, 66.6-93%) and 71.5 (65.7-77.7%). Data on inappropriate behavior was recorded as a rate per minute. The mean rate for the group was 0.77 (range, 0.5-1.2) and 0.89 (range, 0.76-1.14) during the first and second hand-raising conditions respectively and 0.40 (range, 0.2-0.43) and 0.27 (range, 0.17-0.4) during the first and second RC conditions.

The results of this study indicate that the use of RC was effective in increasing active responding, increasing on-task behavior, and decreasing inappropriate behaviors for elementary aged students with MSD. This study also demonstrates an effective use of RC during an academically focused small group activity for students with MSD. A limitation noted by the authors was that the effect of RC on academic achievement was not examined. Although the data are positive and reveal an increase in active responding and on-task behavior, there is no evidence that the use of RC increased learning of the academic task. As a result, more research is needed to assess the effect of RC on academic achievement for students with MSD.

Skibo et al. (2011) used RC in conjunction with a system of least prompts to teach number identification to students with MSD. Participants in the study included three students in elementary school whose ages ranged from 7-10. The students had a range of intellectual functioning with one student functioning within the MoID range (IQ 44) and two students within the severe to profound intellectual disability range (IQs of less than 20). The dependent variable for the study was number of correct responses when identifying numerals 1-5. Student participants were given an array of three numeral choices and were then prompted by the teacher to "show me number X (e.g., 1)." Using the system of least prompts, students were then prompted to hold up the correct number. Only independent responses were counted towards mastery criteria.

A multiple-probe across participants design was used to examine the effect of RC on skill acquisition. All three student participants increased their correct responding from baseline to intervention; however, no mastery criterion was noted by the researchers. During baseline, the average number of correct responses out of 15 for all three students was 4.25 (range, 1-6). During the intervention phase, the average number of correct responses out of 15 for all three students was 9.35 (range, 4-14). A maintenance phase was conducted in which each student maintained intervention levels of correct responding with averages of 11.5, 12, and 11 correct out of 15. When examining the graph on student accuracy, the data are variable for each student. Given that students were responding via holding up a number when given an array of three, it is possible that students answered correctly without actually knowing the number. Despite this limitation, an increase in skill acquisition was noted for all three students and indicates that learning did occur. This study shows that RC may be an effective instructional tool when teaching arithmetic to students with MSD. The authors indicate that future research is needed on the use of RC to teach other arithmetic skills such as greater than, less than.

Future Directions

The literature on the use of RC indicates a positive effect on an array of educational and behavioral outcomes for students with disabilities. Researchers examining the use of RC have found that RC can increase levels of academic responding (Berrong et al., 2007; Cakiroglu, 2014; Davis & O'Neill, 2004; George, 2010; Horn et al., 2006; Wood et al., 2009), increase correct responding (Davis & O'Neill, 2004; Cakiroglu, 2014; Cavanaugh et al., 1996; George, 2010; Horn et al., 2006; Skibo et al., 2011), increase opportunities to respond (Cakiroglu, 2014), increase on-task behavior (Berrong et al., 2007; Horn et al., 2006), decrease off-task behavior (Wood et al., 2009), and decrease inappropriate behaviors (Horn et al., 2006). While there is a growing body of literature on the use of RC with students with disabilities, only three studies have examined the use of RC with students with MSD.

In all, the three research studies on the use of RC for students with MSD included a total of 14 participants. In addition to this paucity of research on the use of RC, there is only a small, though encouraging, body of literature on arithmetic with this population of students. Researchers have suggested that more research is needed on the use of RC during arithmetic instruction (Skibo et al., 2011). Further investigations should be conducted on the use of RC to teach a range of arithmetic skills such as more/less than to students with MSD.

Previous researchers have suggested that more investigation is needed to determine if RC are an effective strategy for increasing skill acquisition for students with MSD (Berrong et al., 2007). Out of the eight studies conducted on the use of RC with students with disabilities, six of these studies examined the effect on skill acquisition (Davis & O'Neill, 2004; Cakiroglu, 2014; Cavanaugh et al., 1996; George, 2010; Horn et al., 2006; Skibo et al., 2011). Given that only two of the three studies on the use of RC with students with MSD examined the effect on skill acquisition, more research is needed.

A large portion of the body of research on RC compares RC to hand raising. Although hand raising is a method of responding commonly used in general education classrooms, teachers of students with severe disabilities may be more likely to use alternative methods of responding, which may be advantageous given the physical limitations of some students with severe disabilities. It has been noted that additional research is needed to compare the use of RC to alternative response methods such as choral responding (Davis and O'Neill, 204). Choral responding is commonly used among teachers of students with MSD as it is a key component of response prompting strategies such as simultaneous prompting.

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2 EFFECTS OF RESPONSE CARDS IN THE TEACHING OF MORE AND LESS THAN WITH STUDENTS WITH MODERATE INTELLECTUAL DISABILITY

Instruction in arithmetic is a key component in the education of all students. Over the last decade, the focus of education for students with moderate intellectual disabilities (MoID) has shifted to include access to the general curriculum for all academic areas (Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008; Spooner, Dymond, Smith, & Kennedy, 2006). According to the reauthorization of the Individuals with Disabilities Education Act (IDEA, 2004), all students with disabilities, even the most severe disabilities, are required to participate in the general curriculum and take alternative assessments on grade level material in all academic areas. Students with MoID are now required to exhibit arithmetic skills in academic as well as functional contexts.

The majority of research in teaching arithmetic to students with intellectual disability focuses on students with mild intellectual disability (MID). The limited research that has been conducted for students with MoID has focused on teaching basic skills such as counting, identifying numbers, and adding. Researchers have examined the effectiveness of direct instruction (DI) and Discriminant Learning Theory (DLT) (Young, Baker, & Martin, 1990), peer tutoring (Lacioni, 1982; Vacc & Cannon, 1991), calculators (Koller & Mulhern, 1977), "dot notation" or Touchmath (Fletcher, Boon, & Cihak, 2010; Kokaska, 1975), reinforcement (Miller, 1976), and number lines (Fletcher et al., 2010) to teach these skills.

Given the academic and behavioral needs of this population of students, researchers have examined a variety of antecedent-based strategies to improve student outcomes. Three of these strategies include response cards (RC), manipulative materials, and simultaneous prompting.

Although these strategies have been investigated by researchers, the research is limited. Three research investigations have examined the use of RC with students with moderate to severe disability (MSD) (Berrong, Schuster, Collins, & Morse, 2007; Horn, Schuster, & Collins, 2006; Skibo, Mims, & Spooner, 2011). While a common classroom practice of many teachers is to use a variety of items as manipulative materials during arithmetic instruction (e.g., blocks, drawings, cubes, counter chips, or number lines), there is limited research on the use of these items for students with MSD. For example, only three studies have examined the use of a number line for students with MoID and autism spectrum disorders (ASD) (Cihak & Foust, 2008; Fletcher, Boon, & Cihak, 2010; Frank & Wacker, 1986). Although simultaneous prompting is an evidence-based practice for students with MSD, only eight studies have been conducted on it's use during arithmetic instruction for students with developmental disability (Akmanoglu-Uludag & Batu, 2005; Birkan, 2005; Creech-Galloway, Collins, & Knight, 2013; Fickel, Schuster, & Collins, 1998; Gursel, Tekin-Iftar, & Bouzkurt, 2006; Karl, Collins, Hager, & Ault, 2013; Rao & Kane, 2009; Rao & Mallow, 2009). Given this and the increased demand for students with MoID to demonstrate knowledge of arithmetic in academic as well as functional contexts, researchers need to determine evidence-based practices for this population.

Response Cards

One way to help students with MoID with academic and behavioral challenges is to increase active student responding (ASR). When students display ASR, they are actively engaged in a lesson by responding to teacher questions at a high rate. Rooted in the theory of behaviorism, when students engage in high levels of ASR, they are allowed more opportunities for reinforcement hence a greater opportunity for learning is present. ASR allows students to practice skills while the teacher is able to monitor student progress especially during group instruction (Horn, 2010). Within the classroom setting, a commonly observed form of ASR requires students to raise their hand and respond verbally to the teacher. Teachers of students with MSD often use response prompting strategies such as simultaneous prompting, which incorporates the use of choral responding. During choral responding, the teacher prompts all students to answer in unison (Kamps, Dugan, Lenoard, & Daoust, 1994). Although choral responding may increase opportunities to respond and student engagement, it may not be an effective way of increasing ASR for all students with MSD as choral responding traditionally requires a verbal response. Another way students can engage in ASR is through the use of RC. Cavanaugh, Heward, and Donelson (1996) define RC as cards or signs that students hold up simultaneously in response to a teacher question. The simultaneous response is a form of choral responding in which students are responding to a teacher question in unison in a nonverbal way. RC allow for students to acquire skills while teachers monitor skill acquisition for all students within a group simultaneously.

RC have been evaluated in a variety of educational settings with students with and without disabilities (Armendariz & Umbreit, 1999; Cavanaugh et al., 1996; Christle & Schuster, 2003; Davis & O'Neil, 2004; Godfrey, Grisham-Brown, & Schuster, 2003; Narayan, Heward, Gardner, Courson, & Omness, 1990). Researchers have examined the use of RC with students as young as preschool through college-aged (Randolph, 2007). Several research groups have investigated the use of RC with students diagnosed with MSD (Berrong, Schuster, Collins, & Morse, 2007; Horn, Schuster, & Collins, 2006; Skibo, Mims, & Spooner, 2011). In addition to increasing active responding, RC have a variety of other positive affects on learning. Researchers have examined RC with MSD on skill acquisition (Horn et al., 2006; Skibo et al., 2011), the reduction of inappropriate behaviors (Berrong et al., 2007; Horn et al., 2006), and ASR (Horn et al., 2006) with promising results.

Berrong et al. (2007) evaluated the effects of RC on the task engagement of eight elementary-aged students with MSD using an ABAB design. Researchers compared the difference between hand raising and the use of RC during a calendar activity on active responding, on-task behavior, and the occurrence of inappropriate behavior. RC increased active responding for six of the eight students and on-task behavior for all eight students. Horn et al. (2006) evaluated the effectiveness of RC for three students with MSD in middle school while teaching students to tell time. The researchers collected data on active responding, on-task behavior, occurrence of inappropriate behavior, and task accuracy. Students had higher levels of active responding and on-task behavior when using RC. In addition, inappropriate behaviors occurred less frequently during RC phases and a positive effect on skill acquisition was noted. Skibo et al. (2011) evaluated the effects of RC in conjunction with system of least prompts during math instruction for students diagnosed with severe intellectual disability (SID). Specifically, students were taught the skill of number identification. A multiple probe across participants design was used to evaluate the effects of the intervention on the dependent variables and results of the study were positive. All three student participants learned number identification through the use of RC.

Although the initial research on the use of RC with students with MSD is promising, the breadth of this research is limited. Of the three studies conducted on the use of RC with this population of students, only 14 students were included in total (Berrong et al., 2007; Horn et al., 2006; Skibo et al., 2011). Researchers have found RC to have a positive effect on skill acquisition (Horn et al., 2006; Skibo et al., 2011), the reduction of inappropriate behaviors

(Berrong et al., 2007; Horn et al., 2006), and ASR (Horn et al., 2006) for students with MSD. More research is warranted to expand the research base on the use of RC with students with MSD particularly in academic areas such as arithmetic.

Quantity Comparison

There is sparse research focusing on the concept of more/less for students with or without disabilities. Existing literature on the concept refers to the term quantity comparison and examines the development of the skill. Researchers have noted that the ability to determine quantity comparison develops prior to school-age without instruction for typically developing children (Kaufmann, Handl, & Thony, 2003). Because children develop the ability to compare quantities on their own, there is no research on systematically teaching students to demonstrate quantity comparison. Given that students with MSD typically require more time than their typically developing peers to learn skills and the use of direct and systematic instruction, the ability to determine more/less may not develop without intervention for this group of students.

Number lines

Manipulative materials are commonly used to teach basic arithmetic skills as they offer concrete representation of the skill being taught. Examples of manipulative materials include blocks, cubes, and number lines. Though the research is limited, number lines may be one effective way to teach arithmetic skills to students with MSD. The visual representation of the order of numbers provided by a number line may aid in the acquisition of a variety of arithmetic concepts. To date, three studies have examined the use of a number line to teach arithmetic skills to students with developmental disabilities (Cihak & Foust, 2008; Fletcher et al., 2010; Frank & Wacker, 1986).

Frank and Wacker (1986) examined the use of a number line in conjunction with coin segments to teach purchasing skills to four elementary-aged students with mild to moderate intellectual disability. Specifically, students were taught to use the number line, which contained coin segment strips with mixed change that corresponded with each number on the line, to purchase an item. For example, if a student was prompted to purchase an item that cost $0.25, the number 25 on the number line had a coin segment strip with 25 cents attached. The student then used the coin segment to determine which coins were needed to make the purchase. All three students responded positively to the intervention.

Two studies have examined the efficacy of number lines as compared to TouchMath to teach addition facts for students with ASD (Cihak & Foust, 2008; Fletcher et al., 2010), and MoID (Fletcher et al., 2010). Using an alternating treatments design, students were taught addition facts using both strategies. In both studies, TouchMath was found to be more effective; however, some students also showed progress using number lines. More research is warranted to determine if number lines are an effective manipulative material for students with MoID during arithmetic instruction.

Simultaneous Prompting

Simultaneous prompting is a near errorless response prompting strategy that pairs the instructional cue with the controlling prompt. Assessment probes are conducted prior to instruction to assess skill acquisition (Gibson & Schuster, 1992). Simultaneous prompting has been used to teach discrete and chained tasks to students ranging from typically developing to students with SID (Waugh, Alberto, & Fredrick, 2011). Simultaneous prompting has been used to teach a variety of skills including literacy, arithmetic, communication, vocational, and leisure. In the area of arithmetic, simultaneous prompting has been used to teach number identification

(Akmanoglu & Batu, 2005; Birkan, 2005), symbol identification (Gursel, Tekin-Iftar, & Bozkurt, 2006), telling time (Brikan, 2005), math facts (Rao & Mallow, 2009; Fickel et al., 1998), and computation (Rao & Kane, 2009).

Purpose

The research conducted on the use of a number line and RC with individuals with MoID has shown an array of positive effects for these students. Despite this, more research needs to be conducted to determine the most effective ways to implement these instructional aids with this population of students. In addition, the limited scope of research in the area of arithmetic for students with MoID calls for further research. Research needs to be conducted to determine the effectiveness of number lines and RC for students with MoID during math instruction.

The purpose of this study was to extend the line of research on the use of RC with students with MoID. Specifically, RC were used in conjunction with simultaneous prompting and a number line to teach the concept of more/less than. This study addressed the following research questions: (1) What is the effect of a number line and a number line in conjunction with RC on task engagement of students with MoID during arithmetic instruction? (2) What is the effect of a number line and a number line in conjunction with RC on active responding during arithmetic instruction for students with MoID? (3) What is the effect of a number line and a number line in conjunction with RC on skill acquisition of more/less than during arithmetic instruction for students with MoID? (4) What is the effect of a number line and a number line in conjunction with RC on total daily instructional time during arithmetic instruction for students with MoID? (5) What are the student and teacher perceptions of the use of a number line in conjunction with RC during arithmetic instruction? And (6) can a classroom teacher implement a number line in conjunction with RC during arithmetic instruction with fidelity?

Method

Setting

Student and teacher participants were selected from an urban public middle school in the southeast. The school selected served a range of students including students with and at-risk for disabilities in general education and special education classrooms as well as those with more significant intellectual disability receiving services in self-contained classrooms. The intervention was implemented in two self-contained classrooms for students diagnosed as functioning within the ranges of MID, MoID, and ASD. All intervention procedures took place during math class. Lessons occurred for approximately 10 minutes per day for ten weeks and included a daily assessment probe and a group instructional session.

Participants

Student participants. Participants included six students receiving special education services under the eligibility category of MoID (See Table 1). Students were included in the study if they: (a) had a diagnosis of MoID (IQ 40-55) based on school psychological reports, (b) were between 10-15 years of age, (c) were unable to determine more/less than when presented with two numerals that are less than ten, (d) were able to identify numbers 0-10, (e) provided verbal assent, (f) and had parental permission. Students were excluded from the study if they: (a) had a physical disability which prevented the use of manipulating materials; (b) had an additional sensory disability; or (c) were unable to sit, interact, or attend to relevant stimuli for an instructional session of twenty minutes per teacher report.

Teacher participants. The teacher participants were included if she: (a) was a highly-qualified special education teacher certified to teach students with MoID, (b) provided consent, (c) provided special education services in a self-contained classroom, (d) could implement simultaneous prompting and RC with a high degree of fidelity (greater than 90% during training), and (e) agreed to serve as the interventionist for the duration of the study.

Materials

Lesson materials. Lesson materials were provided by the researcher. Lesson materials included: RC note cards, number lines, lesson plans, and trial sets. RC containing the words "more" and "less" were printed in black ink on 5 x 7 inch cardstock for each student (See Appendix A). Teacher participants had an identical set of RC; however, these were printed on 8.5 x 11 cardstock. RC were laminated for durability purposes. In addition, each student had a number line containing numerals 0-10 (See Appendix B). Number lines measured 2 x 10 inches and were printed on white cardstock with black ink. Teacher participants had an identical number line that measured 6 x 24 inches. Teacher participants were provided with a lesson plan to be used each session which included instructions for the assessment probe and instructional session (See Appendices C and D). The lesson plans provided the teacher with guidelines for numbers to be included during instruction, number of trials to be presented to each individual student, and number of trials to be presented to the whole group.

Assessment materials. The teacher participants conducted assessment probes each day immediately prior to instruction. Assessment probes were conducted on a one-to-one basis during all conditions. During assessment probes, the students were presented with each math problem three times. Assessment probe materials included all student materials from intervention: RC and a number line. In addition, a researcher-created data sheet was used to record student responses to determine skill acquisition. In addition to daily assessment probes, a variety of data were collected via recorded daily instructional sessions.

Video materials. The teacher participants were provided with a handheld video camera and tripod to record daily math instruction and assessment probes. The researcher was responsible for all video storage. Videos were stored on a researcher computer that was password and firewall protected.

Training

Teacher training. Teacher participants were trained to implement all intervention procedures prior to the first session. The researcher met with the teachers to explain all assessment and instruction procedures and to assess fidelity of instruction. The researcher provided the teachers with an overview of all intervention procedures and materials, and she modeled each step of the intervention. The researcher reviewed the components of simultaneous prompting, number line usage, and RC; and ensured that the teachers were able to implement the strategy with fidelity. The teachers participated in mock assessment probe and instructional sessions until all procedures were implemented with at least 90% fidelity for two consecutive sessions. In addition to lesson plans containing detailed procedures for assessment probes and instructional sessions (See Appendices C and D), the teachers were given a fidelity checklist containing all essential components of the instructional sessions (See Appendix E). The teachers used the checklist to monitor their own fidelity during instruction. The researcher used the same checklist to monitor fidelity throughout the duration of the study.

Data collector training. The teachers were trained by the researcher to collect data during daily assessment probes. The teachers collected dichotomous data on whether or not each student correctly answered each math problem. The researcher collected interobserver agreement (IOA) data on daily assessment probes. The researcher served as the primary data collector for all other dependent variables. All assessment probes and instructional sessions were recorded via a handheld video camera. A second observer was trained by the researcher to collect IOA data on task engagement, active responding, fidelity of implementation, and total instructional time via recorded instructional sessions. The second observer was trained to criterion by the researcher. Point-by-point data comparison (Kennedy, 2005) was used on all dependent variables with the exception of total instructional time and training was conducted until 90% agreement was reached across two consecutive sessions.

Dependent Variables

A list of all dependent variables with a schedule for data collection is listed in Table 2. Data on the following six dependent variables were collected: academic engagement, active student responding, skill acquisition, total instructional time, social validity, and treatment fidelity. Researchers collected direct observation data on all dependent variables with the exception of social validity via recorded instructional sessions during baseline and intervention sessions.

Academic engagement. Prior to the beginning of the study, academic engagement was operationally defined by the researcher and included the following behaviors: looking at the teacher or materials, using the number line to determine an answer, responding verbally or via RC, or responding to prompts. Nonexamples included the following behaviors: talking to peers, making off-task comments, getting out of seat, covering face with hands, and using instructional materials in an inappropriate manner (i.e., spinning materials, hitting self, peers, or desk with materials; waving materials in the air). Ten second whole-interval recording was used to determine academic engagement. Interobserver agreement (IOA) was calculated by point-by-point agreement. Percentages were calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying by 100% (Kennedy, 2005). IOA was completed for 36.36% of baseline sessions and 34.62% of intervention sessions for dyad one. Average IOA was 90.84% (range, 84.00-100.00%) during baseline sessions and 93.46% (range, 83.35-100.00%) during intervention sessions. IOA was completed for 40% of baseline sessions and 35.71% of intervention sessions for dyad two. Average IOA was 86.73% (range, 80.00-100.00%) during baseline sessions and 91.33% (range, 80.00-100.00%) during intervention sessions. IOA was completed for 38.46% of baseline sessions and 33.33% of intervention sessions for Vanessa. Average IOA was 90.88% (range, 80.95-100.00%) during baseline sessions and 87.24% (range, 85.00-89.47%) during intervention sessions.

Active student responding. Researchers collected direct observation data on the percentage of responses given opportunities to respond via recorded baseline and instructional sessions. Data were collected during probe and instructional sessions. ASR was defined as any instance in which students responded to a teacher prompt to answer a math problem. The teacher provided 15 opportunities to respond to a math problem during assessment probes and 15 opportunities to respond during instruction. Each opportunity given was recorded and coded based on an individual or group opportunity in addition to whether or not the student responded to the prompt. Students were given 5 seconds to respond to each prompt. If students did not respond, the controlling prompt was delivered and a no was recorded for ASR. IOA was conducted for a minimum of 33% of sessions across all phases of the intervention and across student participants (Kennedy, 2005). IOA was calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying by 100% (Kennedy, 2005). IOA was completed for 36.36% of baseline sessions and 34.62% of intervention sessions for dyad one. Average IOA was 92.92% (range, 83.33-100.00%) during baseline sessions and 100% during intervention sessions. IOA was completed for 40% of baseline sessions and 35.71% of intervention sessions for dyad two. Average IOA was 99.52% (range, 96.67-100.00%) during baseline sessions and100% during intervention sessions. IOA was completed for 38.46% of baseline sessions and 33.33% of intervention sessions for Vanessa. Average IOA was 100% across baseline and intervention sessions.

Skill acquisition. Skill acquisition was measured for each student participant during daily assessment probes. Skill acquisition was defined as the number of correct responses during assessment probes and was presented as a total out of a possible 15 responses. During each assessment probe, students were presented with five math problems three times each for a total of 15 opportunities. IOA was calculated by point-by-point agreement. Percentages were calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying by 100% (Kennedy, 2005). IOA was calculated for 100% of baseline and intervention assessment probes for each participant. IOA was 100% for all participants.

Total instructional time. All instructional sessions and assessment probes were recorded and timed. Total time across both conditions was evaluated to determine if one condition was more efficient in terms of time saved during daily instruction. The total time for both conditions was recorded and averaged by number of sessions until each dyad reached mastery criteria. IOA was calculated using a total agreement approach in which the smaller total is divided by the larger total and multiplied by 100% (Kennedy, 2005). IOA was completed for 36.36% of baseline sessions and 34.62% of intervention sessions for dyad one, 40% of baseline sessions and 35.71% of intervention sessions for dyad two, and 38.46% of baseline sessions and 33.33% of intervention sessions for Vanessa. Average IOA was 100% across all sessions for all tiers.

Social validity. To assess social validity pre- and post-intervention, the Intervention Rating Profile (IRP-15; Witt & Elliott, 1985) was administered by the researcher to the teacher participants (See Appendix F). The IRP-15 contains 15 items on a 6-point Likert scale (1=strongly disagree to 6=strongly agree) yielding a score from 15-90. In addition, social validity from the student participants was assessed by asking each student which condition they preferred. Prior to conducting the maintenance probe for each student, the classroom teacher asked each student whether he or she liked using the RC to answer or if they preferred answering without the response cards. The maintenance probe was conducted using the student's identified preference.

Treatment fidelity. Treatment fidelity was assessed by the researcher during baseline and intervention using a researcher-created checklist for 100% of sessions across all phases of intervention (Kennedy, 2005; See Appendix E). Treatment fidelity was conducted during baseline sessions as a controlled baseline was implemented. Treatment fidelity was calculated by dividing the number of observed behaviors by the number of planned behaviors and multiplying by 100%. A second trained observer conducted IOA of treatment fidelity for a minimum of 33% of sessions. IOA was calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying by 100% (Kennedy, 2005). IOA was completed for 36.36% of baseline sessions and 34.62% of intervention sessions for dyad one. Average IOA was 99.73% (range, 98.9-100.00%) during baseline sessions and 100% during intervention sessions. IOA was completed for 40% of baseline sessions and 35.71% of intervention sessions for dyad two. Average IOA was 99.45% (range, 98.9-100.00%) during baseline sessions and 99.31% (range, 97.8-100.00%) during intervention sessions. IOA was completed for 38.46% of baseline sessions and 33.33% of intervention sessions for Vanessa.

Average IOA was 99.63% (range, 98.9-100.00%) across baseline sessions 100% across intervention sessions.

Experimental Design and Analysis

A yoked multiple-baseline across dyads design with an embedded reversal was used to evaluate the effectiveness of the intervention on the dependent variables (Kazdin, 2011). A controlled baseline was implemented in which instruction took place during baseline phases. A yoked design facilitated instruction to take place in dyads. The multiple baseline design allowed for a functional relation to be noted as intervention effects are replicated across phases and groups of students. The embedded reversal allowed the researcher to determine the effect of adding RC on the dependent variables. Visual analysis of the data was used to answer research questions one through three. Visual analysis assessed the following six features as recommended by Kratochwill et al. (2010): level, trend, variability, immediacy of the effect, overlap, and consistency of data patterns across similar phases. In addition, percent change across phases was calculated**.**

Prior to all phase changes, stability of the data was assessed. Data were considered stable if all data points fell within 50% of the mean (Alberto & Troutman, 2009). Phase change decisions were based on an average of 20% change in task engagement across each dyad of participants. Once the data were stable, a 20% change in task engagement across a pair of students was noted, and a minimum of five data points had been collected, a phase change occurred.

Procedures

Verbal assent and consent procedures. Parental permission was provided by a parent or legal guardian of each participant. Parental permission forms were sent home via the student backpack for all students in the classrooms who's IQ fell within the MoID range. Consent forms were received from eight students across the two classrooms. The researcher made herself available to meet with any parent or legal guardian to further explain the study procedures; however, this was not needed. As student participants in this study had significant cognitive disabilities and were unable to provide consent to participate, verbal assent was obtained from each student participant prior to instruction each day. The classroom teacher asked each student whether or not he/she would like to work on math. Informed consent was also obtained from the teacher participants. The researcher met with the teachers to explain all study procedures. The teachers were provided with an opportunity to ask questions about the study. Both teacher participants expressed interest in participating in the study, therefore consent forms were presented.

Prerequisite skills. To be included in the study, student participants had to meet the following prerequisite skills: were unable to determine more/less than when presented with two numerals that are less than ten and were able to identify numbers 0-10. After obtaining parental consent, the teacher participants assessed each of the eight students on the above skills. Two students were unable to identify numbers 0-10; therefore, they were excluded from the study.

Response card training. Prior to the use of RC in instruction, training occurred to teach students how to respond with RC. During RC training, students were instructed to use the RC during number identification. This skill was used as it is a prerequisite for inclusion within the study; therefore, all students had mastered the skill. Skill mastery allowed training to focus on teaching students to respond via RC. Data on the dependent variables were not collected during the training session. The training sessions continued until all students were able to accurately hold up a RC in response to a teacher question for 90% of trials in one instructional session.

Group instruction. Prior to the beginning of the study, student participants were to be placed in groups of two students. Students were assigned groups based on the order in which they completed the above prerequisite skills assessments and training sessions. Group instruction took place during all phases of instruction. Teachers used choral responding throughout instruction. During baseline conditions, students responded verbally and in unison to teacher prompts. During intervention conditions, students responded via RC in unison to teacher prompts. Students were allowed to respond verbally in addition to holding up their RC during intervention conditions, but a verbal response was not required during this condition. A total of 15 instructional trials were presented during each instructional session in which the teachers prompted students to respond in unison. Teachers provided individual prompts to students as needed if a student did not respond with his or her partner, or responded incorrectly. During response card sessions, students responded via RC. Verbal reinforcement was delivered on a fixed rate for correct responding. In addition, appropriate behavior was reinforced on a variable rate. That is, the teacher delivered reinforcement for appropriate behavior such as staying in seat, responding to teacher prompts, and using manipulative materials correctly throughout assessment probes and instructional sessions.

More/less than training. Once placed in instructional groups, each dyad of students was trained on the vocabulary of more/less than prior to beginning the study. The researcher provided the teacher participants with five different groups of common objects. Each group of objects was split into a small (3-5 objects) and a large (15-20 objects) group and placed in a clear Ziploc bag. Using simultaneous prompting, the teacher taught the vocabulary of more/less than to each dyad. During instruction, the teacher presented the students with the small and large group of items and gave the antecedent of “Which group has more?” This antecedent was immediately followed by the prompt of pointing to the group with more and stating "This group has more, because it is bigger." During instruction, the teacher randomly rotated between stating which group had more and which group had less for a total of seven trials of one group and eight trials of the other during each session.

Assessment probes were conducted prior to instruction to assess student learning. For the last dyad of students, more/less than training had to be further broken down. Vanessa and her partner were instructed only on the vocabulary of more until they reached criterion of 80% correct for two consecutive sessions. Once criterion was met for more, they were instructed on the vocabulary of less. Once both students mastered more and less independently, they were required to reach criterion with both terms when presented together. Vanessa was able to master both terms after being trained on more and less independently; however, her partner was unable to master the vocabulary of more/less than. As a result, he was excluded from the study.

Simultaneous prompting and number line. During the controlled baseline phases, the teachers instructed students to use a number line to determine more/less than. The teachers used simultaneous prompting to instruct students in each step of the procedure (See Table 3). During instruction, the teachers verbally presented five math problems three times each for a total of fifteen total instructional trials. Students responded verbally using choral responding to all instructional cues.

After the first baseline and intervention phases with dyad one, it was determined that students were unsure which number they were being asked about. That is, when asked "is six more or less than one," students did not know if the number in question was six or one. An instructional change was made to add a step to prompt students to "look at" the number in questions. For the above problem, "is six more or less than one," students were then prompted to “look at six” prior to giving the prompt “six is bigger, so six is more than one.” This instructional change was made at session thirteen for all participants.

Simultaneous prompting, number line, and response cards. During the simultaneous prompting, number line, and RC condition instructional procedures were identical to the simultaneous prompting and number line condition with the exception of student responses. Students responded to teacher prompts by simultaneously holding up their RC. In addition to holding up their RC, some students continued to respond verbally to teacher prompts.

Assessment probes. Assessment probes were conducted prior to instruction to assess skill acquisition (Gibson & Schuster, 1992). Assessment probes consisted of five questions presented three times each. During assessment probes the teacher presented the instructional cue and waited five seconds for the student to respond (See Table 4). If the student did not respond, the teacher prompted the student through the steps to correctly answer the problem. If the student made an error, the teacher provided the student with error correction and prompted the student through the remaining steps. In both cases, the teacher recorded an error on the data sheet. The teacher provided reinforcement for correct responding. During the simultaneous prompting and number line condition, the teacher conducted assessment probes using a one-to-one format. During the simultaneous prompting, number line, and RC condition, an attempt was made to conduct assessment probes with both students simultaneously. If assessment probes could be conducted simultaneously, teacher time would be saved as students are able to independently respond using RC. After the first three sessions with the first dyad of students, it was clear that student participants would not answer independently (i.e., without looking at their partner’s response and adjusting their own answer). As data obtained from simultaneous assessment probes was deemed to not be a true measure of skill acquisition, all remaining assessment probes were conducted on a one-to-one basis. The data collected during these three sessions (7-9) were still included and are represented on the graph for dyad one (See Figure 3).

Error correction. Error correction procedures were conducted across all phases during assessment probes and instructional sessions. The teacher watched the students complete each step to solve the problem. If an error was made, the teacher delivered the controlling prompt, modeled the step, and had the student complete the step correctly.

Results

Task Engagement

All five student participants had higher levels of task engagement when using RC as compared to baseline conditions (See Figure 1 and Table 5). Results for the first yoked tier of Darius and Jake are as follows. Darius averaged a mean percentage of academic engagement of 52.43% (range, 30.19-95.24%) during the first baseline phase, 63.05% (range, 58.33-69.44%) during the first intervention phase, 53.86% (range, 35.71-80.77%) during the return to baseline, and 82.45% (range, 72.73-96.00%) during the second intervention phase. This was an increase of 20.26% and 53.08% in intervention one and two, respectively. Darius's task engagement during the maintenance probe was 55%. Jake averaged a mean percentage of academic engagement of 27.57% (range, 13.21-42.86%) during the first baseline phase, 62.19% (range, 38.71-80.00%) during the first intervention phase, 41.07% (range, 27.05-52.00%) during the return to baseline, and 68.93% (range, 62.50-76.00%) during the second intervention phase. This was an increase of 125.37% and 67.84% in intervention one and two, respectively. Jake's task engagement during the maintenance probe was 60%.

Visual analysis of the data for the first yoked tier reveals a number of important details. First, for Darius, a high level of task engagement was noted during session five; however, task engagement dropped back down during session six. While a functional relation can not be noted for Darius between the intervention and task engagement, Darius's task engagement was much more variable during baseline phases as compared to intervention phases. Jake displayed higher levels of task engagement during response card phases as compared to baseline phases. Jake's percentage of nonoverlapping data points across all phases was 100% and a strong immediacy of effect was noted across all conditions. In addition, Jake's pattern of engagement across both baseline phases and both intervention phases was consistent; as a result, a functional relation was found between RC and Jake's task engagement.

Data for the second yoked tier of Kelsey and Zoe is as follows. Kelsey averaged a mean percentage of academic engagement of 29.04% (range, 18.18-36.84%) during the first baseline phase, 48.28% (range, 19.05-74.19%) during the first intervention phase, 45.55% (range, 15.00-64.29%) during the return to baseline, and 61.87% (range, 20.00-81.25%) during the second intervention phase. This was an increase of 66.25% and 35.83% in intervention one and two, respectively. Kelsey's task engagement during the maintenance probe was 72.22%. During the first baseline phase, Zoe's mean percentage of task engagement was 53.31% (range, 36.36-61.70%). During the first intervention condition, Zoe's mean percentage of task engagement was 83.88% (range, 57.14-87.10%). Zoe's percent change from the first baseline phase to the first intervention phase was 51.65%.

Visual analysis of data for the second yoked tier did not reveal a functional relation between the intervention and task engagement for either student. Kelsey's data were highly variable across all conditions. Her data display a high level of overlapping data, no immediacy of effect, and lack of consistency within phases. Zoe's data were analyzed based on the first baseline and intervention conditions only. Zoe's percentage of nonoverlapping data points from baseline to intervention was 90.91%. Zoe demonstrated a strong immediacy of effect from baseline to intervention and her data were stable within both conditions. As data are not present for the second baseline and intervention phases for Zoe, a functional relation could not be noted.

For the third tier, Vanessa averaged a mean percentage of academic engagement of 53.19% (range, 30.77-68.75%) during the first baseline phase, 82.77% (range, 64.71-94.74%) during the first intervention phase, and 73.36%. (range, 50.00-90.91%) during the return to baseline. Percent change from the first baseline phase to the first intervention phase was 49.97%. Intervention stopped after the second baseline phase as there was no decrease in engagement when the intervention was withdrawn. Vanessa's task engagement during the maintenance probe was 90.91%.

When comparing the first baseline and intervention phases, Vanessa's percentage of nonoverlapping data was 80%. Vanessa's data display a weak immediacy of effect from baseline to intervention. When comparing the first intervention phase to the second baseline phase, minimal change is noted in task engagement. As a result, a functional relation was not found between the intervention and task engagement for Vanessa.

While all five students showed higher levels of task engagement during RC conditions, a functional relation between the intervention and task engagement was only found for Jake. While Zoe and Darius's data were promising, a functional relation could not be noted. The use of RC had appeared to have minimal effect for Kelsey and Vanessa.

Active Student Responding

In terms of ASR, two of the five students (Darius and Vanessa) displayed high levels of ASR across all conditions (See Figure 2 and Table 6). The remaining three students (Jake, Kelsey, and Zoe) displayed higher levels of ASR in RC conditions as compared to baseline conditions. Data for the first yoked tier of Darius and Jake is as follows. Darius averaged a mean percentage of ASR of 90.56% (range, 83.33-100.00%) during the first baseline phase, 95.33% (80.00-100.00) during the first intervention phase, 93.33% (range, 80.00-100.00%) during the return to baseline, and 99.52% (range, 96.67-100.00%) during the second intervention phase. Darius's ASR during the maintenance probe was 100%. Jake averaged a mean percentage of ASR of 80.56% (range, 50.00-96.67%) during the first baseline phase, 98.67% (range, 96.67-100.00%) during the first intervention phase, 74.08% (range, 63.33-80.00%) during the return to baseline, and 98.57% (range, 96.67-100.00%) during the second intervention phase. Jake's ASR during the maintenance probe was 100%.

Visual analysis of the data for the first yoked tier reveals a functional relation for one of the two students. Darius displayed high levels of ASR across all phases of the study. As Darius already displayed high levels of ASR during baseline phases, a functional relation was not found between the intervention and ASR for Darius. Jake's percentage of nonoverlapping data across condition was as follows: 60% from the first baseline phase to the first intervention phase, 100% from the first intervention phase to the second baseline phase, and 100% from the second baseline phase to first intervention phase. A strong immediacy of effect between the intervention and ASR was found across all phases. Jake's data are consistent within phases and indicate a functional relationship between the use of RC and ASR.

For the second yoked tier, a functional relation was not found for either student. Kelsey averaged a mean percentage of ASR of 60.00% (range, 36.67-73.33%) during the first baseline phase, 95.33% (range, 73.33-100.00) during the first intervention phase, 81.85% (range, 66.67-100.00%) during the return to baseline, and 100.00% during the second intervention phase. Kelsey's ASR during the maintenance probe was 100%. Zoe's mean percentage of ASR during the first baseline phase was 58.67% (range, 36.67-70.00%). Zoe’s mean percentage of ASR during the first intervention phase was 99.00% (range, 93.33-100.00%).

Kelsey's percentage of nonoverlapping data from baseline to intervention was 90%. A strong immediacy of effect is noted from the first baseline phase to the first intervention phase as well as from the first intervention phase to the second baseline phase; however, Kelsey displayed high levels of ASR at the end of the second baseline phase. As a result, a functional relation was not found between the intervention and ASR for Kelsey. Zoe’s percentage of nonoverlapping data from baseline to intervention was 100%. A strong immediacy of effect was noted from the first baseline phase to the first intervention phase; however, an ascending trend is noted in the first baseline phase for Zoe. In addition, Zoe’s data are incomplete; therefore, a functional relation was not found between the intervention and ASR for Zoe.

Vanessa’s mean percentage of ASR was 100% across all phases of the study. As Vanessa’s ASR was 100% during baseline phases, the intervention had no affect on her ASR. A functional relation was not found between the intervention and ASR for Vanessa.

Skill Acquisition

All five students demonstrated gains in skill acquisition across both conditions (See Figure 3 and Table 7) Four of the five met mastery criteria of 80% correct for two consecutive sessions during the duration of the study. Darius met criteria during sessions 23 and 24 in the second intervention phase, Jake met criteria during sessions 15 and 16 during the return to baseline, Kelsey met criteria during sessions 40 and 41 during the second intervention phase, and Vanessa met criteria during session 28 and 29 during the first baseline phase. The results on skill acquisition for the first dyad of Jake and Darius are as follows. Darius averaged a mean of 18.89% correct (range, 0.00-26.67%) during the first baseline phase, 23.34% correct (range, 67-

40.00%) during the first intervention phase, 50.00% correct (range, 26.67-66.67%) during the return to baseline, and 71.40% correct (46.47-100.00%) during the second intervention phase. Darius scored 100% correct on the maintenance probe. Jake averaged a mean of 4.45% correct (0.00-13.33) during the first baseline phase, 16.67% (range, 0.00-46.67%) during the first intervention phase, 77.78% correct (range, 20.00-100.00%) during the return to baseline, and 93.33% correct (range, 73.33-100.00%) during the second intervention phase. Jake scored 93.33% correct on the maintenance probe.

Visual analysis of Darius's and Jake's data reveals a low percentage of nonoverlapping data for all phases, no immediacy of effect across any phases of the study, and a lack of consistency within phases for both students.

The results on skill acquisition for the second dyad of Kelsey and Zoe are as follows. Kelsey averaged a mean of 16.67% correct (range, 0.00-40.00%) during the first baseline phase, 46.67% correct (range, 6.67-66.67%) during the first intervention phase, 29.63% correct (range, 13.33-46.67%) during the return to baseline, and 60.95% correct (range, 46.67-100.00%) during the second intervention phase. Kelsey scored 100% correct on the maintenance probe. During the first baseline condition, Zoe averaged a mean of 10% correct (range, 0.00-20.00%). During the first intervention condition, Zoe averaged a mean of 41.33% correct (range, 20.00-66.67%).

Visual analysis of Kelsey's data shows a strong immediacy of effect from the first intervention phase to the second baseline phase. Kelsey's data are highly variable during the first intervention phase and there is a low percentage of nonoverlapping data across all phases. Data are not consistent within phases. Visual analysis of Zoe's data reveals a strong immediacy of effect from the first baseline phase to the first intervention phase; however, Zoe's data during the first intervention phase are highly variable. A functional relation was not found between the intervention and skill acquisition for either student.

The results for Vanessa are as follows. Vanessa averaged a mean of 62.67% correct (range, 33.33-86.67%) during the first baseline phase, 83.33% correct (range, 73.33-93.33%) during the first intervention phase, and 88.57% correct (range, 80.00-93.33%) during the return to baseline. Vanessa scored 93.33% correct on the maintenance probe. Visual analysis of Vanessa's data reveals that learning took place during the first baseline phase. No immediacy of effect is found across any phases of the study. In addition, an upward trend is noted during the first baseline phase.

Total Time

Four of the five student participants averaged a shorter duration of probe and instructional time when participating in response card sessions (See Table 8). There were 11 baseline sessions and 12 intervention sessions for dyad one. Jake averaged a total time of 12 minutes and 11 seconds during baseline sessions and 11 minutes and 27 seconds during intervention sessions. Darius averaged a total time of 10 minutes and 5 seconds during baseline sessions and 9 minutes and 41 seconds during intervention sessions. Both student participants in the first dyad demonstrated slightly shorter durations during intervention sessions as compared to baseline sessions. For the second dyad, Kelsey and Zoe, results were similar. Kelsey received instruction in 14 baseline sessions and 17 intervention sessions. Kelsey averaged a total time of 6 minutes and 32 seconds during baseline sessions and 6 minutes and 8 seconds during intervention sessions. Zoe received instruction in 6 baseline session and 10 intervention sessions. Zoe averaged a total time of 7 minutes and 5 seconds during baseline sessions and 6 minutes and 5 seconds during intervention sessions. Vanessa's results varied in regards to total time as compared to the other four participants. Vanessa received instruction in 12 baseline sessions and six intervention sessions. Vanessa's total time averaged 5 minutes and 54 seconds during baseline sessions and 6 minutes and 39 sessions during intervention sessions.

Social Validity

Teacher perceptions of the intervention were measured using the IRP-15. Teacher's completed the IRP-15 pre- and post-intervention. Pre-intervention, both teacher participants completed the IRP-15 and highly agreed with all questionnaire items for a score of 90/90. Post-intervention results were the same with both teachers strongly agreeing with each item for a score of 90/90 as well. In addition, one teacher participant stated that she had begun using RC with other students in her classroom to increase their academic engagement.

Student perceptions of the intervention were measured by asking each student which condition they preferred. All five students stated that they preferred using RC when answering teacher questions. All five students used RC during their maintenance probe. Anecdotal records taken by the researcher show that two of the five students requested to use RC during the second baseline condition when response cards were withdrawn.

Treatment Fidelity

Both teacher participants delivered baseline and intervention procedures with high levels of fidelity throughout the duration of the study. Treatment fidelity was assessed during baseline in addition to intervention sessions as a controlled baseline was implemented. For dyad one, Whitney's mean percentage of treatment fidelity was 99.15% (range, 97.37-100%) during baseline conditions and 98.51% (range, 95.6-100%) during intervention conditions. For Vanessa, Whitney's mean percentage of treatment fidelity was 100% across all conditions. Shannon's mean percentage of treatment fidelity for dyad two was 99.84% (range, 97.8-100%) during baseline conditions and 99.94% (98.9-100) during intervention conditions.

Discussion

Research conducted on the use of RC has shown an array of academic and behavioral benefits for students both with (Berrong et al., 2007; Carkirglu, 2014; Cavanaugh et al., 1996; Davis & O'Neil, 2004; George, 2010; Horn et al., 2006; Skibo et al., 2011; Wood, Mabry, Kretlow, Lo, & Galloway, 2009) and without disabilities (Armendariz & Umbreit, 1999; Cavanaugh et al., 1996; Christle & Schuster, 2003; Davis & O'Neil, 2004; Godfrey, Grisham-Brown, Schuster, & Hemmeter 2003; Narayan, Heward, Gardner, Courson, & Omness, 1990). The results of this study did not yield a demonstration of effect between the intervention and the dependent variables; however, positive results were present. First, the data were mixed across participants for task engagement. When examining the data on task engagement, the intervention had the highest impact on task engagement for Jake. Jake showed higher levels of task engagement during intervention conditions, demonstrated high percentages of nonoverlapping data, showed a strong immediacy of effect across conditions, and displayed consistency within phases. As a result, a functional relation was noted for Jake between the use of RC and task engagement. Anecdotal records taken by the researcher through observations and teacher report indicate that Jake responded to teacher prompts with a shorter latency when using RC and displayed less avoidance behavior. RC may have provided Jake with an easier response method to teacher instruction as a result increasing his task engagement. Although Darius' mean percentage of task engagement was higher overall during RC conditions, his data were highly variable during baseline conditions with over-lapping data between phases. Visual analysis of the data did reveal that when using RC, Darius' level of academic engagement was more consistent within the phase. This indicates that while a functional relation was not demonstrated for Darius between RC and his task engagement, the data displayed a more consistent pattern of responding during RC conditions.

Kelsey displayed a variety of off-task behaviors across all phases of the study. An increase in engagement was observed when RC were first introduced, but Kelsey began to display a new set of off-task behaviors in which she used the RC inappropriately or made noises in addition to holding up her RC. Jake and Darius also demonstrated new off-task behaviors when RC were introduced, but they did not display these behaviors for the duration of the study. Kelsey may have needed further training on the use of RC in relation to appropriate and inappropriate use of RC. Zoe withdrew from the study prior to its completion. Visual analysis of Zoe's first baseline and intervention phases reveal a positive effect between the intervention and task engagement. As more data were not collected, a demonstration of effect can not be noted.

When examining Vanessa's academic engagement data, a substantial decrease in engagement was not observed when RC were removed. This may be a result of Vanessa reaching mastery criterion in terms of skill acquisition. As learning had already taken place, Vanessa demonstrated higher levels of task engagement. After seven sessions in the withdrawal condition, it was determined that the intervention was no longer beneficial for Vanessa as she had already mastered the skill and maintained high levels of task engagement.

In regards to skill acquisition, all student participants' demonstrated learning and four of the five reached mastery criterion during the study. A demonstration of effect was not found as learning occurred across both baseline and intervention conditions. This result was anticipated as researchers have shown that the use of simultaneous prompting alone increases skill acquisition for students with MoID (Waugh et al., 2011). In addition, if learning has truly taken place, a decrease should not be observed when removing a portion of the intervention.

Another factor in the variability of the data was that students had a 50% chance of selecting the correct answer, based on the nature of the RC. During baseline conditions, students were asked to verbally state whether the number was more or less. During intervention conditions, students were asked to hold up the RC that said more or less. In some instances, students stated a number as opposed to more or less or simply did not respond at all. After the first baseline condition, all students learned that the appropriate response was more or less and responded verbally with those terms or with their RC; hence, having a 50% chance of answering correctly. Vanessa reached mastery criteria during the first baseline condition after only five sessions. Vanessa required additional training during the more/less than training phases, in which she was trained on the word less and then trained on the word more in separate phases. This additional training may have affected how quickly she acquired the skill. In addition, Vanessa is the only student who completed the entire study in a 1:1 teaching arrangement. This change from group to individual instruction also may have had an effect on her skill acquisition as the teacher was only focused on her during assessment probes and instructional sessions.

In terms of ASR, three of the five students displayed higher levels of ASR when using RC. RC did not have an effect on ASR for Darius or Vanessa, both of whom responded at high levels across all conditions. A demonstration of effect between the intervention and ASR was found for Jake when visually analyzing his data indicating that the use of RC allowed Jake to respond more frequently to teacher prompts. Consistent with his findings on task engagement, RC may have provided Jake with an easier response method, increasing the likelihood that he would answer teacher questions. Kelsey averaged a higher level of ASR in RC conditions as compared to baseline conditions. Anecdotal records reveal that Kelsey often did not respond during probe sessions when unsure of the answer. Kelsey may have responded more frequently to a teacher question when using RC despite being unsure of the answer as she knew one of the two answer cards was the correct answer. Kelsey began to show high levels of ASR at the end of the withdrawal condition. Around this time, prior to the beginning of an intervention session, Kelsey's teacher stated "Kelsey and I want to do better so that we can use the cards again." This desire to be able to use RC again may have affected Kelsey's responding.

Total instructional time was slightly less during RC conditions for four of the five student participants. One benefit to the use of RC is the ability to assess student learning simultaneously. An attempt was made to conduct probe sessions simultaneously to assess student learning from the previous day. Students struggled with group probes and were unable to provide independent responses; therefore, group probes were discontinued after the first intervention condition for dyad one. If group probes were successful, total time may be reduced even greater as the teacher would not be required to complete individual probe sessions for each student. Despite discontinuing group probes, RC revealed less total instructional time than baseline conditions. This may mean that students are able to respond quicker to teacher prompts when using response cards.

A positive finding of the study was that teachers were able to implement the use of RC with students with MoID during math instruction with high levels of fidelity. In addition, both teachers and students found the intervention to be socially acceptable. As all five student participants stated that they preferred using RC to answer questions, this may be an effective strategy to help prompt students with MoID to participate in small group instruction.

Although a functional relation was only found for one student on two of the dependent variables, some aspects of student performance were positive. Four of the five students met mastery criterion on skill acquisition and were able to accurately identify more/less than; however, Jake and Vanessa did so during baseline conditions. A functional relation was found for Jake between RC and task engagement and ASR. A functional relation was not found between task engagement and ASR for the other four participants; however, all students increased their task engagement using RC and Kelsey and Zoe increased their ASR using RC. Teacher's were able to implement intervention procedures with high levels of fidelity and both teacher and student participants found RC to be a socially acceptable intervention.

Limitations and Future Directions

A number of limitations can be noted when examining the results of the study. First, a true baseline was not established. As a result, learning began to occur during the first baseline condition for some participants. A true baseline in which no instruction occurred, would have allowed for a lack of skill knowledge to be established. Once the intervention was in place, if skill acquisition increased, a functional relation may have been noted between the intervention and skill mastery. In addition, learning can not be reversed; therefore, a decrease in accuracy did not occur when the intervention was removed. This decrease would however be expected for the non-academic variables of task engagement and ASR. Future researchers should investigate the use of RC for students with MSD using alternative single-case designs such as an alternating treatments design to address this limitation

Second, the use of simultaneous prompting as an instructional strategy may have had an effect on task engagement and ASR. Simultaneous prompting incorporates the use of choral responding. Choral responding requires students to repeat the correct response after the teacher, naturally increasing students' task engagement as well as ASR. As RC is a form of choral responding itself, the strategies may have not been different enough to observe a difference in responding. Future researchers should examine the use of RC in conjunction with other response prompting strategies such as system of least prompts in which choral responding is not required.

Third, students were required to meet a number of prerequisite skills and complete several training phases prior to beginning the study. As a result, several students were unable to be included. Vanessa's partner never completed the more/less than training; therefore, Vanessa received all sessions in a 1:1 setting. In addition, Zoe withdrew from the study prior to completion and Kelsey completed the remainder of sessions in a 1:1 setting. It is possible that the 1:1 teaching arrangement as opposed to group instruction had an effect on all dependent variables for these two students. Future research should be conducted on the use of RC with students with MoID in a group setting with a larger number of participants.

Fourth, students were not assessed on one to one correspondence prior to the study. The student's ability to demonstrate one to one correspondence may have affected the rate at which they acquired the skill of more/less than. Future researchers should assess students on this skill prior to intervention to determine if there may be an effect on skill acquisition.

Last, students may have benefited from additional training on the use of RC. Anecdotal records taken by the researcher indicate that several students began to exhibit new inappropriate behaviors when RC were introduced. Inappropriate behaviors included flapping the cards in the air, hitting self in face with cards, or making off-task comments or noises while simultaneously responding with the card. Kelsey displayed high levels of inappropriate behaviors while using RC throughout the duration of the study, causing her data to be highly variable. Future researchers should include criterion for appropriate RC use when training students with severe disability to use RC.

In conclusion, while the results of this study do not reveal a functional relation between the intervention and the dependent variables for all students, positive results were found. It is possible that RC may enable students with MoID to be more engaged during small group instruction as well as increase ASR. Future researchers should examine the use of RC on the academic as well as behavioral effects for students with MoID.

Table 1.

Participant Demographics

Student	Age	IQ Instrument	Eligibility	Grade	Ethnicity/Race	Gender
Jake	11	40 RIAS	MoID	6	African American	Male
Darius	15	40 KBIT	MoID	8	African American	Male
Kelsey	15	55 WASI	MoID	8	Caucasian	Female
Zoe	13	Unavailable	MoID	7	African American	Female
Vanessa	13	48 KBIT	MoID	7	African American	Female

Teacher Demographics

Name	Age	Level of Education	Years in Position	Years Teaching	Ethnicity/Race	Gender
Whitney	44	Specialist	15	17	Caucasian	Female
Shannon	42	M.Ed.	21	21	Caucasian	Female

Note: 1: RIAS=Reynolds Intellectual Assessment Scales; 2: KBIT=Kaufmann Brief Intelligence Test; 3: WASI=Wechsler Abbreviated Scale of Intelligence; 4: M.Ed.=Master of Education

Table 2. *Dependent Variables Data Collection Schedule*

Variable	Dates Collected	IOA/Reliability
Direct observations of academic engagement	Daily during all conditions	33% of sessions
Direct observations of ASR	Daily during all conditions	33% of sessions
Direct observations of problems correct	Daily during assessment probes for all conditions	33% of sessions
Total Time (Instruction and assessment)	Daily during all conditions	33% of sessions
Lesson treatment fidelity – researcher completed	Daily during all conditions	33% of sessions
IRP-15	Week before baseline, week following IV conclusion	
Student Social Validity	Week following IV conclusion	

Note: 1: IRP-15=Intervention Rating Profile-15, 2: ASR=Active student responding; 3: IV=Intervention; 4: IOA=inter-observer agreement.

Table 3.

Example of Instructional Trial

	Instructional Cue	Delay	Controlling Prompt	Behavior	Consequence
Intervention	"Is six more or less than one?"	O sec	"Touch one on your number line" + Model	Students touch one	Teacher reinforces correct response. Provides error correction if needed
	"Touch six on your number line"	O sec	IC + Model	Students touch six	Teacher reinforces correct response. Provides error correction if needed
	"Look at six"	O sec	IC + Model	Students look at six	Teacher reinforces correct response. Provides error correction if needed
	"Six is bigger, so six is more than one. Is six more or less than one?"	O sec	IC + Model	Students respond "more." In RC condition, students hold up more RC	Teacher reinforces correct response. Provides error correction if needed

Note: IC=Instructional cue

Table 4.

Example of Assessment Probe Trial

	Instructional Cue	Delay	Controlling Prompt	Behavior	Consequence
Assessment Probe	"Is six more or less than one?"	5 sec	"Touch one on your number line" + Model	Students touch one	Teacher reinforces correct response. Provides error correction if needed
	"Touch six on your number line"	5 sec	IC + Model	Students touch six	Teacher reinforces correct response. Provides error correction if needed
	"Look at six"	5 sec	IC + Model	Students look at six	Teacher reinforces correct response. Provides error correction if needed
	"Six is bigger so six is more than one. "Is six more or less than one?"	5 sec	IC + Model	Students respond "more." In RC condition, students hold up more RC	Teacher reinforces correct response. Provides error correction if needed

Note: IC=Instructional cue

Table 5.

Task Engagement Results by Student

Student	Percent Occurrence of Task Engagement				Percent Change		
	Baseline 1 M (R)	Intervention 1 M (R)	Baseline 2 M (R)	Intervention 2 M (R)	B 1 to IV1 % Change	IV 1 to B2 % Change	B2 to IV 2 % Change
Darius	52.43 (30.19-95.24)	63.05 (58.33-69.44)	53.86 (35.71-80.77)	82.45 (72.73-96.00)	20.26%	-14.58%	53.08%
Jake	27.57 (13.21-42.86)	62.19 (38.71-80.00)	41.07 (27.05-52.00)	68.93 (62.50-76.00)	125.37%	-33.96%	67.84%
Kelsey	29.04 (18.18-36.84)	48.28 (19.05-74.19)	45.55 (15.00-64.29)	61.87 (20.00-81.25)	66.25%	-5.65%	35.83%
Zoe	53.31 (36.36-61.70)	83.88 (57.14-87.10)			51.65%		
Vanessa	53.19 (30.77-68.75)	82.77 (64.71-94.74)	73.36 (50.00-90.91)		49.97%	-11.37%	

Note: 1: M=Mean, 2: R=Range; 3: B=Baseline; 4, IV=Intervention; 5, - = decrease

Table 6.

Active Student Responding Results by Student

Student	Percent Occurrence of Active Student Responding			
	Baseline 1 M (R)	Intervention 1 M (R)	Baseline 2 M (R)	Intervention 2 M (R)
Darius	90.56 (83.33-100.00)	95.33 (80.00-100.00)	93.33 (80.00-100.00)	99.52 (96.67-100.00)
Jake	80.56 (50.00-96.67)	98.67 (96.67-100.00)	74.00 (63.33-80.00)	98.57 (96.67-100.00)
Kelsey	60.00 (36.67-73.33)	95.33 (73.33-100.00)	81.85 (66.67-100.00)	100.00
Zoe	58.67 (36.67-70.00)	99.00 (93.33-100.00)		
Vanessa	100.00	100.00	100.00	

Note: 1: M=Mean, 2: R=Range

Table 7.

Skill Acquisition Results by Student

Student	Percent Correct			
	Baseline 1 M (R)	Intervention 1 M (R)	Baseline 2 M (R)	Intervention 2 M (R)
Darius	18,89 (0.00-26.67)	23.34 (6.67-40.00)	50.00 (26.67-66.67)	71.40 (46.47-100.00)
Jake	4.45 (0.00-13.33)	16.67 (0.00-46.67)	77.78 (20.00-100.00)	93.33 (73.33-100.00)
Kelsey	16.67 (0.00-40.00)	46.67 (6.67-66.67)	29.63 (13.33-46.67)	60.95 (46.67-100.00)
Zoe	10.00 (0.00-20.00)	41.33 (20.00-66.67)		
Vanessa	62.67 (33.33-86.67)	83.33 (73.33-93.33)	88.57 (80.00-93.33)	

Note: 1,: M=Mean, 2: R=Range

Table 8.

Total Time

		Total Time	
Group	Student	Baseline M	Intervention M
1	Jake	12 min 11 s	11 min 27 s
	Darius	10 min 5 s	9 min 41 s
2	Kelsey	6 min 32 s	6 min 8 s
	Zoe	7 min 5 s	6 min 5 s
3	Vanessa	5 min 54 s	6 min 39 s

Note: 1: M=Mean

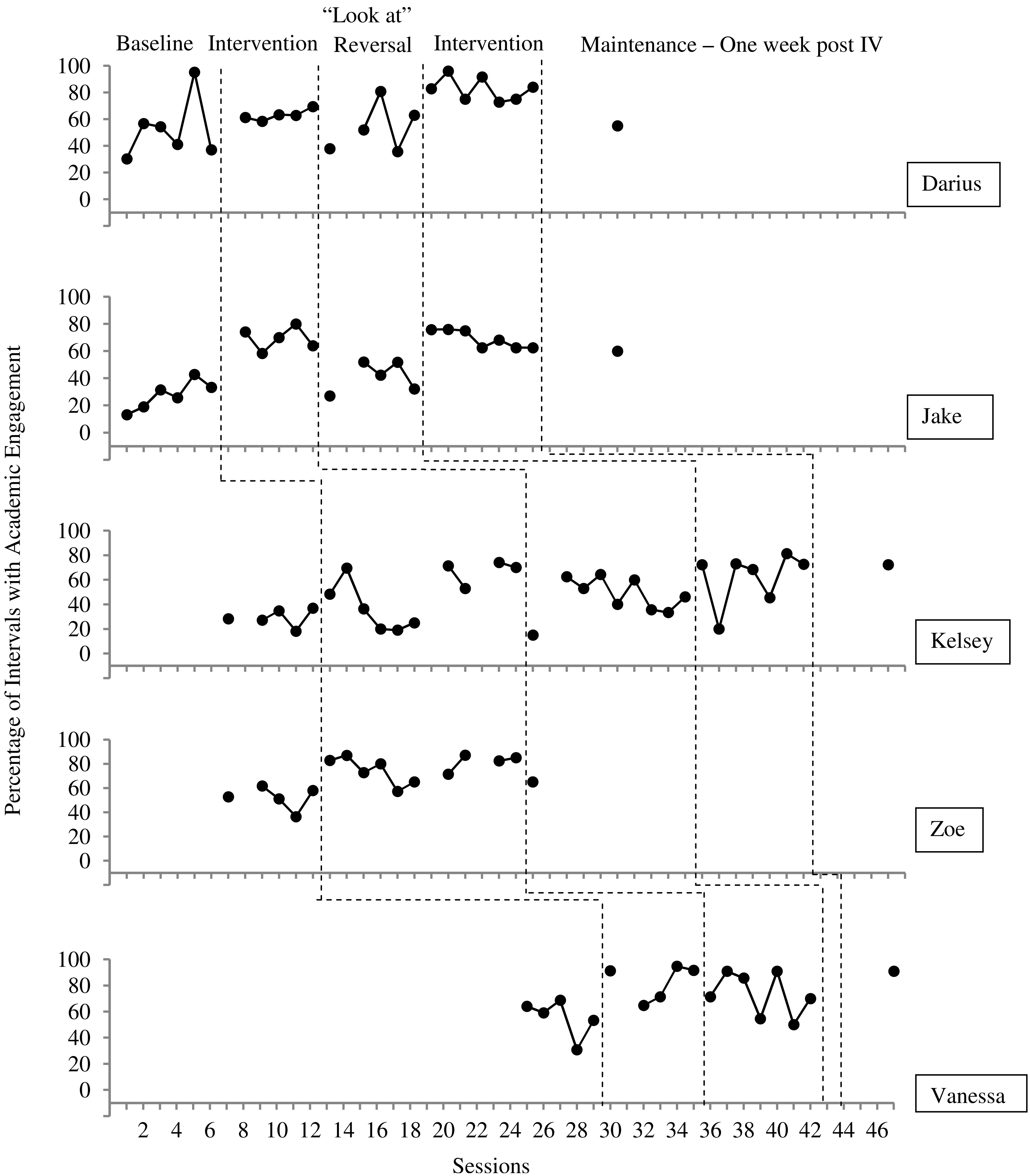

Figure 1. *Percentage of intervals with academic engagement*

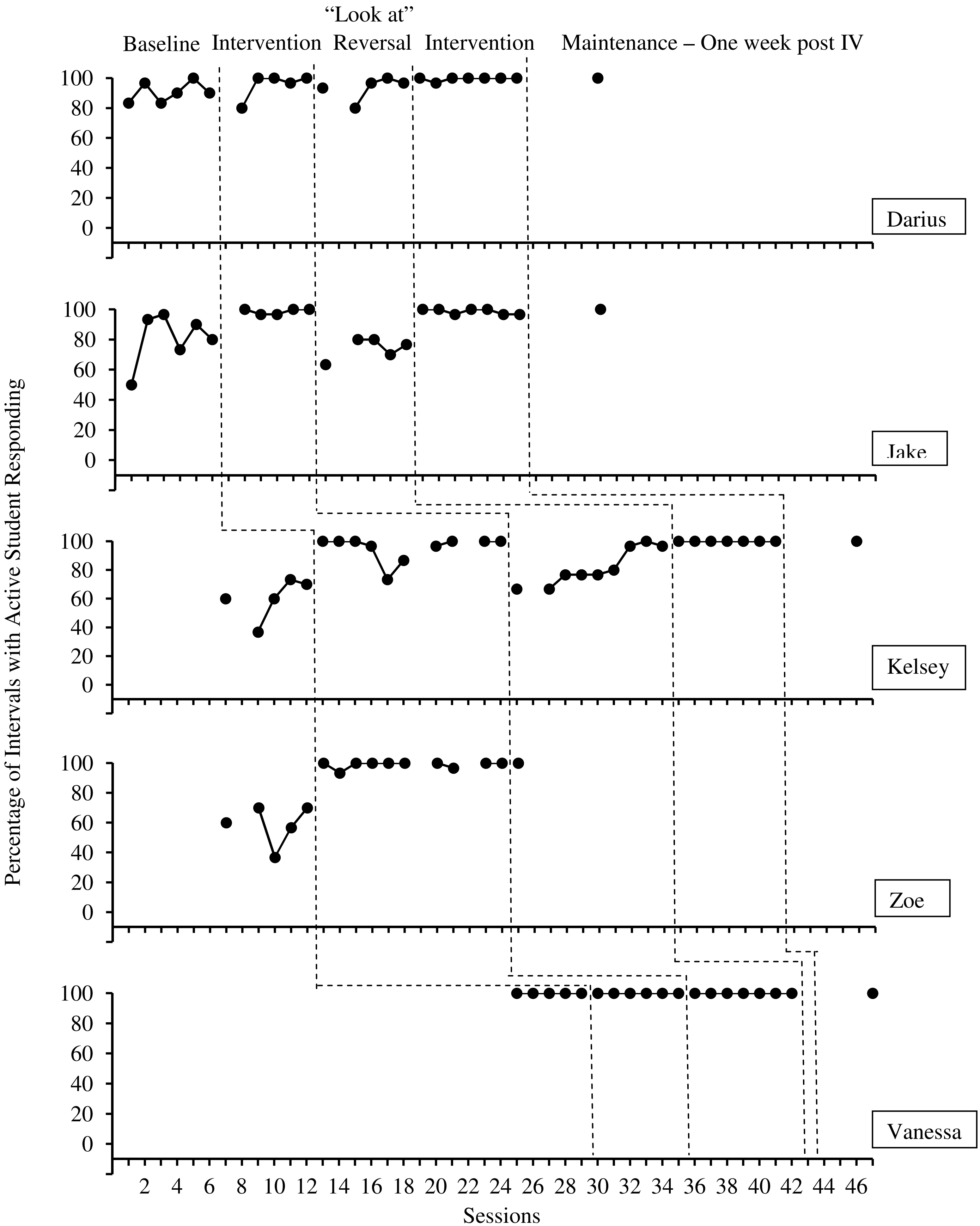

Figure 2. *Percentage of Active Student Responding*

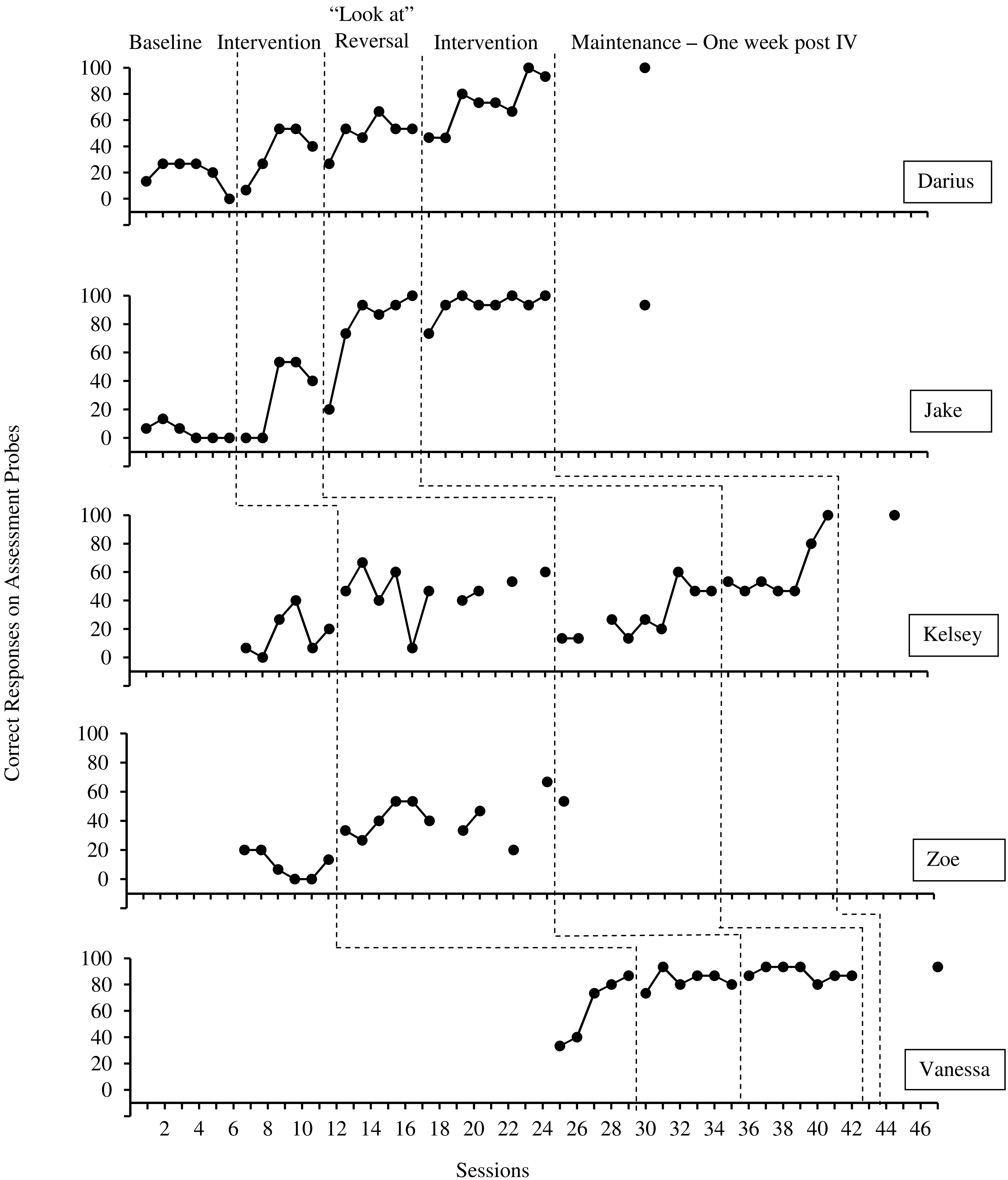

Figure 3. *Correct responses on assessment probes*

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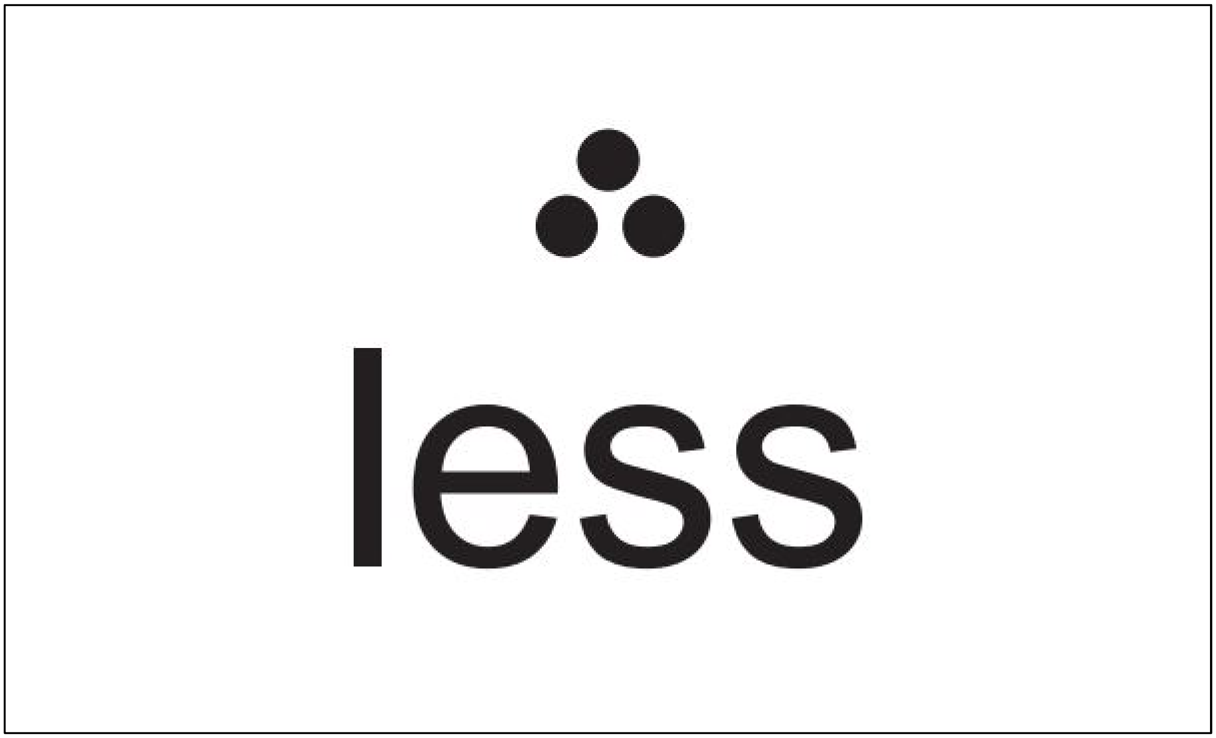
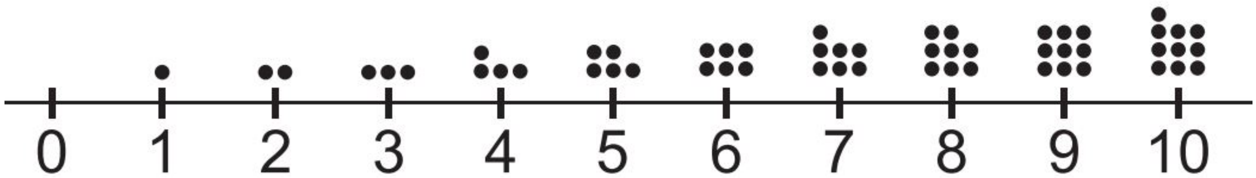
Appendix A. *Response Cards*



Appendix B. *Number line*



Appendix C. *Lesson Plan for Number Line and Simultaneous Prompting Condition*

Number Line and Simultaneous Prompting Lesson Plan

Problems to be presented:

1. Six vs. One
2. Nine vs. Seven
3. Five vs. Four
4. Ten vs. Two
5. Eight vs. Three

Assessment Probe

Format: One on one
Student materials: Number line
Present each problem using the following format:

Instructional Cue	Delay	Behavior	Consequence	Data
"Is six more or less than one?"	5 sec	a) Student responds "more"	a) Provide reinforcement	a) Record correct response
		b) Student responds "less"	b) Provide error correction	b) Record incorrect response
		c) No response	c) Provide error correction	c) Record incorrect response

*If student begins to make an error on any step, immediately provide error correction and record an incorrect

Instructional Session

Format: Group
Student Materials: Number line

Present each problem three times for a total of fifteen instructional trials.

Present each problem using the following format:

Instructional Cue	Delay	Controlling Prompt	Behavior	Consequence
"Is six more or less than one?"	O sec	"Touch one on your number line"+ Model	Students touch one	Reinforce correct response. Provide error correction if needed

"Touch six on your number line"	O sec	IC + Model	Students touch six	Reinforce correct response. Provide error correction if needed
"Look at six"	O sec	IC + Model	Students look at six	Reinforce correct response. Provide error correction if needed
"Six is bigger, than one so six is more" "Is six more or less than one?"	O sec	"More"	Students respond "more."	Reinforce correct response. Provide error correction if needed

Appendix D. *Lesson plan for Number Line, Simultaneous Prompting, and Response Card Condition*

Number Line, Simultaneous Prompting, and Response Cards Lesson Plan

Problems to be presented:

1. Six vs. One
2. Nine vs. Seven
3. Five vs. Four
4. Ten vs. Two
5. Eight vs. Three

Assessment Probe

Format: One on one
Student materials: Number line, response cards

Present each problem three times for a total of fifteen instructional trials. All students respond simultaneously to each trial

Present each problem using the following format:

Instructional Cue	Delay	Behavior	Consequence	Data
"Is six more or less than one?"	5 sec	a) Student holds up more	a) Provide reinforcement	a) Record correct response
		b) Student holds up less	b) Provide error correction	b) Record incorrect response
		c) No response	c) Provide error correction	c) Record incorrect response

*If student begins to make an error on any step, immediately provide error correction and record an incorrect

Instructional Session

Format: Group
Student Materials: Number line, overlay, and response cards

Present each problem using the following format

Instructional Cue	Delay	Controlling Prompt	Behavior	Consequence
"Is six more or	O sec	"Touch one	Students touch	Reinforce correct response.

less than one?”		on your number line” + Model	one	Provide error correction if needed
“Touch six on your number line”	O sec	IC + Model	Students touch six	Reinforce correct response. Provide error correction if needed
“Look at six”	O sec	IC + Model	Students look at six	Reinforce correct response. Provide error correction if needed
“Six is bigger than one, so six is more” “Is six more or less than one?”	O sec	“More” + hold up RC	All Students hold up more	Reinforce correct response. Provide error correction if needed

Appendix E. *Treatment Fidelity Checklist*

Teacher Behavior Checklist

Date: ______________ **Student Participants**: ________________________________

Condition: NL/SP NL/SP/RC **Observer**:________________________

Behavior	1	2	3	4	5	6	7	8	9	10	1	12	13	14	15
Verbal Assent															
Gains Student Attention															
Presents IC															
"Find # on your number line"															
"Find # on your number line"															
"Look at #"															
"# is bigger/smaller, so # is more/less than #"															
Provides reinforcement															
Provides error correction if needed															

Note: Teacher states and models each step of the instructional trial

Score # of observed behaviors ____________ / # of planned behaviors __________ X 100% = __
____

IOA yes / no

Second observer _________________

# of agreements ____________ / # of agreements + disagreements ________ X 100% = _________

Appenix F. *Intervention Rating Profile*

Form 4.2

Intervention Rating Profile—15

The purpose of this questionnaire is to obtain information that will aid in the selection of classroom interventions. These interventions will be used by teachers of children with behavior problems. Please circle the number which best describes your agreement or disagreement with each statement.

	Strongly Disagree	*Disagree*	*Slightly Disagree*	*Slightly Agree*	*Agree*	*Strongly Agree*
1. This would be an acceptable intervention for the child's problem behavior.	1	2	3	4	5	6
2. Most teachers would find this intervention appropriate for behavior problems in addition to the one described.	1	2	3	4	5	6
3. This intervention should prove effective in changing the child's problem behavior.	1	2	3	4	5	6
4. I would suggest the use of this intervention to other teachers.	1	2	3	4	5	6
5. The child's behavior problem is severe enough to warrant use of this intervention.	1	2	3	4	5	6
6. Most teachers would find this intervention suitable for the behavior problem described.	1	2	3	4	5	6
7. I would be willing to use this intervention in the classroom setting.	1	2	3	4	5	6
8. This intervention would *not* result in negative side effects for the child.	1	2	3	4	5	6
9. This intervention would be appropriate for a variety of children.	1	2	3	4	5	6
10. This intervention is consistent with those I have used in classroom settings.	1	2	3	4	5	6
11. The intervention was a fair way to handle the child's problem behavior.	1	2	3	4	5	6
12. This intervention is reasonable for the behavior problem described.	1	2	3	4	5	6
13. I liked the procedures used in this intervention.	1	2	3	4	5	6
14. This intervention was a good way to handle this child's behavior problem.	1	2	3	4	5	6
15. Overall, this intervention would be beneficial for the child.	1	2	3	4	5	6