THE EFFECTS OF FLUENCY-BASED INSTRUCTION ON THE IDENTIFICATION OF COMPONENT READING SKILLS

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This study examined the effects of fluency-based instruction on the identification of six component-composite relations for early reading skills. Five participants (ages 5-8) who struggled with reading participated. A multiple probe design was used to assess the effects of frequency building on prerequisite skills on the emergence of composite reading skills. The results show that the prerequisite skills taught did not have an effect on the composite skill probes but did have an effect on the assessment scores. The data expand the research pertaining to Precision Teaching, fluency-based instruction, and component-composite relations. These data suggest that additional skills may be needed to be taught in order to effects on the composite skills. In addition, these authors identify the need for the identification of the component skills necessary to teach rapid autonomic naming.

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INTRODUCTION

Behavior analysis has been involved in education for over 50 years. Beginning with Skinner's (1968) *The Technology of Teaching* and Keller's (1968) "Goodbye Teacher," a new era was established once the collaboration between behavior analysis and education formed. Since then, this collaboration has produced a multitude of studies on a variety of different topics integrating the two disciplines (Becker, 1971; Bijou & Ruiz, 1981; Brigham, Hawkins, Scott, & Mclaughlin, 1976; Crandall & Sloane, 1997; Gardner et al., 1994; Heward, Heron, Hill, & Trap-Porter, 1984; Heward et al., 2005; Neef, Iwata, et al., 2004). Behavior analysis has offered solutions to many of the problems affecting public schools today including designing effective curricula (McTiernan, Holloway, Healy, & Hogan, 2015), improving classroom management (Alberto & Troutman, 2006; Carnine, 1976; Greenwood, Hops, Delquadri, & Guild, 1974; Madsen, Becker, & Thomas, 1968), promoting attendance (Alexander, Corbett, & Smigel, 1976), and increasing academic performance (Ayllon & Roberts, 1974; Cavanaugh, Heward, & Donelson, 1996; Houten, Hill, & Parsons, 1975).

A specific integration of behavior analysis and education occurred with Ogden Lindsley's development of precision teaching (PT). Lindsley (1990) promoted the use of frequency as the measure for academic performance. He noted that the frequency of responding was "10 to 100 times more sensitive than percentage correct," (Lindsley, 1990, p. 10). Even though his initial research regarding response rate focused on the effects of drugs and different reinforcers on the behavior of children with psychosis or those children who were typically developing, he immediately saw the implications for education. Namely, Lindsley (1990) suggested that using only percent correct as a measure of mastery ignores the speed of performance and often produces learners who may be accurate but who may also be very slow. Consider two learners who both achieve the same score with a percent correct measure but one learner takes one hour to complete the exercise and the other takes only 10 min. As percent correct is often the only measure used within education (ignoring rate entirely), Lindsley (1990) tried to disseminate his findings to educators, training teachers on the use of PT in the classroom.

Lindsley (1997) defined PT as "a system of tactics and strategies for the self-monitoring of learning" (p. 537). PT includes graphing and decision making using the Standard Celeration Chart (SCC) and incorporates frequency building. The SCC is a measurement tool used to make instructional decisions by looking at learning rates over time (count over time over time or celerations; Calkin, 2005). Frequency building focuses on teaching a skill until a fluid combination of accuracy and speed that characterize competent performance (or fluency) emerges (Binder, 1996). Precision teachers will test to see if the skill has become fluent after frequency building through the use of retention, endurance, stability, and application (RESA) checks (Johnson & Layng, 1992) or maintenance, endurance, stability, application, and generativity (MESsAGe; Johnson & Street, 2012)[1]. RESA checks test to see if the learner is able to engage in the skill within the suggested frequency range in situations that are different than the teaching situation (cf., Berens, Boyce, Berens, Doney, & Kenzer, 2003). Retention (R) assesses the frequency of responding after a period of time without practice. Endurance (E) tests to see if the learner can engage in the skill at similar frequencies for longer periods of time than those used in teaching. Stability (S) is achieved if the learner can maintain the frequency of responding. Lastly, application (A) is tested under conditions in which the learner uses the skills taught when presented with untaught examples. If all the conditions of RESA are met, it can be

[1] In this study, experimenters used RESA to determine if the component skills were fluent even though MESsAGe is a more recent contribution to the PT literature. Fewer studies have supported the use of MESsAGe and specific assessments are less developed to date.

said that a skill is fluent.

Frequency building has been applied across a variety of settings, populations, and behaviors including businesses (Binder & Bloom, 1989; Binder & Sweeney, 2002), adult literacy (Johnson & Layng, 1992), building motor skills (Eastridge & Mozzoni, 2005; Twarek, Cihon, & Eshleman, 2010), establishing verbal behavior (Cihon, White, Zimmerman, Stordahl, Gesick, & Eshleman, accepted for publication; Emmick, Cihon, & Eshleman, 2010), golf (McDowell, McIntyre, Bones, & Keenan, 2002), and classroom instruction (Beck & Clement, 1991; Berens et al., 2003; Johnson & Layng, 1992; McDowell & Kennan, 2001). Frequency building has also been used to teach a variety of different academic skills including mathematics (Chiesa & Robertson, 2000; Lin & Kubina, 2005; Singer-Dudek & Greer, 2005), spelling (Noland, McLaughlin, & Sweeney, 1994; Shirley & Pennypacker, 1994; Kubina, Young, & Kilwein, 2004), rapid automatic naming (RAN [Milyko, Berens, & Ghezzi, 2012]), reading (Blackwell, Stookey, & McLaughlin, 1996; Downs & Morin, 1990; Hughes, Beverly, & Whitehead, 2007; Mercer, Campbell, Miller, Mercer, & Lane, 2000; Rinaldi & McLaughlin, 1996), reading comprehension (Abrams & McLaughlin, 1997; Polk & Miller, 1994), and handwriting (DeAngelis & McLaughlin, 1995; Kubina, Aho, Mozzoni, & Malanga, 1998). Several studies have shown that frequency building leads to the better retention, endurance, stability and application outcomes specified by the RESA checks rather than training for accuracy alone (Barrett, 1979; Berens et al., 2003; Binder, 1996; Bucklin, Dickenson, & Brethower, 2000; Lin & Kubina, 2005; Johnson & Street, 1992).

Many persons associated with PT believe that the presenting problem is not always the problem that needs to be fixed to improve performance (Alessi, 1987; Andronis, Goldiamond, & Layng, 1983; Johnson & Layng 1992). This means there is often a deficit in an underlying, basic (component) skill. One example is with struggling readers; the problems may be with poor performance on letter-sound relations or phoneme segmentation not oral reading rate. The component skill deficit may be inhibiting the acquisition of a more complex (composite) skill. As these underlying component skill deficits build over the course of the student's lifetime, students may fall further and further behind academically, a phenomenon discussed as cumulative dysfluency (Binder, 1996). Analyzing content with respect to the relations between underlying and complex skills is a component-composite analysis (Haughton, 1972; Johnson & Street, 1994). For example, being able to draw lines and circles has been shown to be component skills for the composite skill of alphabet writing (Zaner-Bloser, 1999). Basically, these component skills must be learned in order for composite skills to be acquired (Binder, 1996; Carnine, Silbert, Kameenui, & Tarver, 2004; Mercer & Mercer, 2001; Stein, Silbert, & Carnine, 1997). Oftentimes, if the instructor can improve the performance on the component skill, performance on the composite skill will improve. Further, if a skill is only performed accurately but not fluently, this skill may be less likely to combine with other skills to form more complex skills and repertoires (Bucklin et al., 2000).

Component skills are those skills that have been empirically validated to have an effect (e.g., higher initial frequency, faster acquisition) on composite skills. Others have tried to substitute other terms like precursor, predictive, or foundational to discuss the effects of component skills but these terms do not fully encompass what component skills are. These terms leave out the fact that the component skills must have an effect on the composite skill and this must be shown empirically. As such, these terms describe correlational relations between skills at best. Before a skill can be descried as a component skill, the relation between the skill and the composite skill must be demonstrated empirically; this type of analysis is critical to improving instructional design, particularly related to core academic skills like reading and math.

Cumulative dysfluency is, unfortunately, very common in the educational setting where accuracy (or percent correct) is the main measure of mastery. These dysfluent skills make the progression through a curriculum increasingly difficult as more complex (composite) skills are related to the component skills (consider trying to learn multiplication if you are unable to perform simple addition). Unfortunately, the identification of these dysfluent skills usually occurs only after the person is unable to engage in some complex task (composite skill). By this point, many dysfluent components may need to be retaught (or at least built to fluency) in order for this complex repertoire to be acquired or to emerge. This is why some precision teachers view cumulative dysfluency as one of the most important factors in preventing and remediating students' long-term failure in educational settings (Johnson & Layng, 1992; Pennypacker & Binder, 1992). Precision teachers identify these deficits in component skills and use frequency building to improve performance. Once the component skills have been trained to fluent levels (i.e., performance passes RESA checks), some persons associated with PT suggest that the composite skill will emerge with little to no explicit training (Alessi 1987; Binder, 1996; Epstein, 1985; Johnson & Layng, 1992, 1994). Several researchers have tried to identify a variety of different component-composite relations (Berens et al., 2003; Kubina, Young, & Kilwein, 2004; McDowell & Keenan, 2002; McDowell et al., 2002; Smyth & Keenan, 2002). However, all component-composite relations have yet to be empirically established and many behavior analysts are still skeptical of the relation between component and composite skills (cf., Heinicke, Carr, LeBlanc, & Severtson, 2010). Given the potential benefits of identifying these relations (e.g., effective curriculum design, quicker acquisition of composite skills, reduction of cumulative dysfluency) for students, educators, and behavior analysts, expanding this literature base should be a priority. For example, if the component-composite relations in reading repertoires can be identified, component skills that must be taught before other skills can be identified in order to make more efficient curricula for teaching reading.

Research published by the Department of Education and other leading reading researchers has supported this notion of cumulative dysfluency. The National Assessment of Educational Progress (NAEP) conducts nation-wide assessments of student academic performance across 12 different curriculum areas at Grades 4, 8, and 12. Current NAEP results show that only about one-third of 4th and 8th grade students are proficient in reading (National Center for Education Statistics, 2015). This means that by the 4th grade, two-thirds of students are not proficient at reading; this may be due to dysfluencies in the component skills necessary to read. This is an alarming statistic as research has shown that students who fall behind their peers academically often stay behind (Snow, Burns, & Griffin, 1998) and that the majority of the children who struggled to read in kindergarten continued to struggle to read in 3rd grade (National Scientific Council on the Developing Child, 2007). The National Assessment of Adult Literacy (1993) found that individuals who did not develop early reading skills before entering school were three to four times more likely to drop out of school and Lesnick, Goerge, Smithgall, and Gwynne (2010) found that 3rd grade reading level was a predictor of high school graduation and college attendance. Poor reading ability at an early age can have long lasting and detrimental effects on student academic outcomes. Given these drastic and long-lasting consequences of poor reading skills, many educators have looked to additional supports for children who are "at-risk" academically, especially with respect to reading. PT and frequency building are worthwhile areas to explore what these additional supports may be. Namely, PT can be used to help to identify the component skills necessary to establish fluent reading repertoires and to preventing cumulative dysfluencies from developing.

The literature on reading interventions gives us a starting point for identifying potential component-composite relations important for reading fluency. The National Early Literacy Project Report (2009) identified six precursor skills that have a strong correlation with later, conventional literacy skills (e.g., decoding, oral reading fluency, reading comprehension, writing, and spelling). The six precursor skills include alphabet knowledge (i.e., knowledge of names and sounds of letters), phonological awareness (i.e., ability to detect, manipulate, or analyze the auditory aspects of spoken words), rapid autonomic naming of letters and digits, rapid autonomic naming of objects and colors, writing or writing name, and phonological memory (i.e., ability to remember spoken information for a short period of time). These results support the findings of the National Reading Panel (NRP [2000]). In the NRP report, the authors identified phonemic awareness and phonics instruction as crucial to developing later literacy skills. They defined phonemic awareness as the ability to engage in six tasks: phoneme isolation, phoneme identity, phoneme categorization, phoneme blending, phoneme segmentation, and phoneme deletion. They defined phonics instruction as the ability to identify letter-sound correspondences and spelling patterns. In addition to these two skill areas, the report also noted that fluency was a critical prerequisite of becoming a skilled reader. Fluency, in this context, was defined as the ability to read text with speed, accuracy, and proper expression (NRP, 2000) similar to how fluent performance is defined in PT - the fluid combination of accuracy plus speed (Binder, 1996). Most research reported by the NRP (2000) looked at fluency with repeated reading passages but not with the precursor skills identified in their report. Further, the precursor skills described have not been tested to see if they are also component skills. One interesting question then is if the precursor skills are taught to a fluent level, will the reading skill emerge without any instruction? In essence, are the precursor skills component skills?

The purpose of this study, then, is to expand the literature on component-composite relations with respect to reading repertoires. The experimenters have identified several different potential component skills, informed by the precursor skills noted above, for oral reading that were trained to fluent levels (as demonstrated by RESA) to see if/how this training affected untrained composite reading skills. The specific research question was: do known prerequisite skills (rapid autonomic naming, letter sounds, phoneme segmentation, phoneme blending, phoneme deletion, and/or phoneme isolation) function as components skills in that, when taught to fluency, they result in faster acquisition and/or emergence of composite skills (oral reading fluency, oral reading comprehension, listener comprehension, or nonsense word fluency)?

METHOD

Participants, Setting and Materials

Five children, ages of 5-8, participated in this study. Chuckie is an 8 year-old male in the 2nd grade; Angelica is a 6 year-old female in the 1st grade. Tommy is a 7 year-old male in the first grade; Phil is a 7 year-old male in the 1st grade; and Lil is a 5 year-old female in preschool. All participants provided assent and their parent or guardian provided consent. Sessions were conducted three to five times a week either in various classrooms at a non-profit private school in north Texas, at a city library, at an office at a university, or in the participant's home. All sessions were conducted in a room with a table and chairs for the participants and experimenters. In each location, the experimenter sat either next to or across from the participant, no farther than 1 m away. If present, a second observer would sit next to the experimenter.

Materials included daily per minute SCCs; a digital timer; the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) assessments; Comprehensive Test of Phonological Processing (CTOPP-2) assessments; two flashcard decks containing the 26 English letters written in red marker on individual 3" x 5" index cards in the uppercase or lowercase form; Haughton Learning Center phonemic awareness curriculum sheets; Haughton Learning Center Rapid Autonomic Naming curriculum sheets; stimulus arrays containing school supplies, toys, foods, shapes; 3" x 5" index cards with pictures of food; a stimulus array with only one stimulus visible; DIBELS grade level readers; Morningside basic element curriculum materials; Homework Helpers Reading Comprehension workbooks (1st and 2nd grade level); Scholastic Success with Reading Comprehension (1st grade); Wilbooks (kindergarten level); and Horizons Reading Curriculum.

Assessments

Prior to the study, experimenters asked teachers or parents/guardians to refer children who were struggling to read at grade level. Experimenters assessed grade level reading skills using the DIBELS and CTOPP-2 and they assessed several prerequisite skills using curriculum-based frequency measures. Error analyses were conducted to identify error patterns. Participants who tested below grade level on any skill within the DIBELS assessment or who were unable to identify all the letter names or letter sounds on the curriculum-based assessment participated.

CTOPP-2

Results from the CTOPP-2 pretest can be found in Tables 1-6. Experiments conducted the CTOPP-2 to determine participants' current age and grade level equivalents for basic literacy skills. Participants were assessed on skills based on age groups suggested in the CTOPP-2 (4-6 years old and 7-24 years old). Experimenters assessed all skills within the age group according to the CTOPP-2 instructions. Once all skills were tested, age and grade level equivalent were determined using the CTOPP-2 scoring instructions.

Chuckie (2nd grade, age 8) rated poor or very poor on every composite performance and was below grade level for each subtest. Angelica (1st grade, age 6) rated average on every composite but was below grade level for eight of the nine subtests (elision, blending words, memory for digits, nonword repetition, rapid digit naming, rapid letter naming, rapid color naming, rapid object naming).

Table 1

CTOPP-2 Raw Subtest Scores

	Participants									
	Chuckie		Angelica		Tommy		Phil		Lil	
Subtests	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Elision	7	11	15	20	13	16	7	15	14	14
Blending Words	11	23	18	18	16	21	16	17	25	25
Sound Matching	[redacted]	[redacted]	22	25	23	24	12	20	13	22
Phoneme Isolation	17	18	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Memory for Digits	11	12	15	17	16	15	12	12	18	19
Nonword Repetition	12	14	11	11	10	14	16	15	17	18
Rapid Digit Naming	:49	:29	:32	:29	:19	:20	:54	:47	:57	:58
Rapid Letter Naming	:57	:31	:44	:34	:36	:26	2:07	1:46	N/A	1:55
Rapid Color Naming	[redacted]	[redacted]	:50	:42	:28	:30	2:10	1:59	1:00	1:00
Rapid Object Naming	[redacted]	[redacted]	:50	:38	:48	:38	1:08	1:15	1:18	:53
Blending Nonwords	0	15	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Segmenting Nonwords	6	14	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note. N/A = unable to test due to low skill.

Table 2

CTOPP-2 Subtest Rating Scores

	Participants									
	Chuckie		Angelica		Tommy		Phil		Lil	
Subtests	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Elision	6	6	4	4	4	4	5	4	4	4
Blending Words	6	4	4	4	4	4	4	4	1	2
Sound Matching			3	3	4	3*	5	4	4	3
Phoneme Isolation	5	5								
Memory for Digits	6	6	4	4	4	4	5	5	2	2
Nonword Repetition	5	5	5	5	5	4	4	4	3	3
Rapid Digit Naming	6	5	4	4	4	4	7	5	4	5
Rapid Letter Naming	6	5	4	4	4	4	7	7	N/A	7
Rapid Color Naming			4	4	3	4*	7	7*	4	4
Rapid Object Naming			4	4	4	4*	7	6*	5	4
Blending Nonwords	7	5								
Segmenting Nonwords	6	4								

Note. 1=Very Superior, 2=Superior, 3=Above Average, 4=Average, 5=Below Average, 6=Poor, 7=Very Poor; N/A = unable to test due to low skills.
* indicates that the skill was graded at the 6 year 11 months benchmark.

Table 3

CTOPP-2 Grade Equivalent of Subtest Scores

	Participants									
	Chuckie (Grade 2)		Angelica (Grade 1)		Tommy (Grade 1)		Phil (Grade 1)		Lil (Pre-K)	
Subtests	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Elision	K.2	K.7	1.2	2.2	1.2	1.7	K.2	1.4	1.2	1.2
Blending Words	K.0	2.7	1.4	1.4	1.0	2.2	1.0	1.2	6.4	7.4
Sound Matching			2.0	2.0	2.0	2.0*	K.4	1.7*	K.4	2.0
Phoneme Isolation	1.2	1.4								
Memory for Digits	<K.0	<K.0	1.4	4.0	2.4	1.4	<K.0	<K.0	5.4	7.0
Nonword Repetition	<K.0	1.0	<K.0	<K.0	<K.0	1.0	2.7	2.0	3.4	5.0
Rapid Digit Naming	K.0	1.4	1.2	1.4	3.0	2.7	<K.0	K.0	<K.0	<K.0
Rapid Letter Naming	K.2	1.4	1.0	1.4	1.2	2.0	<K.0	<K.0	N/A	<K.0
Rapid Color Naming			K.4	1.4	2.0	2.0*	<K.0	<K.0*	<K.0	<K.0
Rapid Object Naming			1.0	2.0	1.2	2.0*	<K.0	<K.0*	<K.0	K.4
Blending Nonwords	<K.0	1.7								
Segmenting Nonwords	<K.0	1.2								

Note. N/A = unable to test due to low skills; < = less than.
* indicates that the skill was graded at the 6 year 11 months benchmark.

Table 4

CTOPP-2 Age Equivalent of Subtest Scores

	Participants (Age in Years-Months)									
	Chuckie (Age 8-4)		Angelica (Age 6-11)		Tommy (Age 7-4)		Phil (Age 7-2)		Lil (Age 5-7)	
Subtests	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Elision	5-3	5-9	6-3	7-3	6-3	6-9	5-3	6-6	6-3	6-3
Blending Words	5-0	7-9	6-6	6-6	6-0	7-3	6-0	6-3	11-6	11-6
Sound Matching			7-0	7-0	7-0	7-0*	5-6	6-9*	5-6	7-0
Phoneme Isolation	6-3	6-6								
Memory for Digits	4-0	4-6	6-6	9-0	7-6	6-6	4-6	4-6	10-6	12-0
Nonword Repetition	4-9	6-0	4-3	4-3	<4-0	6-0	7-9	7-0	8-6	10-0
Rapid Digit Naming	5-0	6-6	6-3	6-6	8-0	7-9	4-9	5-0	4-9	4-6
Rapid Letter Naming	5-3	6-6	6-0	6-6	6-3	7-0	<4-0	<4-0	N/A	<4.0
Rapid Color Naming			5-6	6-6	7-0	7-0*	<4-0	<4-0*	4-3	4-3
Rapid Object Naming			6-0	7-0	6-3	7-0*	<4-0	<4-0*	<4.0	5-6
Blending Nonwords	<4-0	6-9								
Segmenting Nonwords	4-6	6-3								

Note. All ages were expressed in terms of years-months. For example, if a participant had an age equivalent score of 5 years and 6 months, it would be illustrated as ‘5-6.’ N/A = unable to test due to low skill.
* indicates that the skill was graded at the 6 year 11 months benchmark.

Table 5

CTOPP-2 Composite Performance

Student	Phonological Awareness		Phonological Memory		Rapid Symbolic Naming		Rapid Non-Symbolic Naming[1]	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Chuckie	6	6	6	6	6	5	7	5
Angelica	4	4	4	4	4	4	4	4
Tommy	4	4	4	4	4	4	4	3
Phil	5	4	4	5	7	6	7	6
Lil	2	2	2	2	7	6	7	4

Note. 1=Very Superior, 2=Superior, 3=Above Average, 4=Average, 5=Below Average, 6=Poor, 7=Very Poor.
[1] This composite performance was called "Alternate Phonological Awareness" for Chuckie and comprised of the subtests 'Blending Nonwords' and 'Segmenting Nonwords.'

Table 6

CTOPP-2 Percentile Rank of Composite Performance

Student	Phonological Awareness		Phonological Memory		Rapid Symbolic Naming		Rapid Non-Symbolic Naming[1]	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Chuckie	3%	9%	3%	5%	2%	12%	<1%	16%
Angelica	68%	75%	30%	45%	53%	53%	37%	61%
Tommy	45%	63%	30%	37%	61%	61%	75%	81%
Phil	14%	30%	45%	21%	<1%	<1%	<1%	<1%
Lil	93%	95%	97%	97%	<1%	2%	2%	37%

Note. [1] This composite performance was called "Alternate Phonological Awareness" for Chuckie and comprised of the subtests 'Blending Nonwords' and 'Segmenting Nonwords.'

Tommy (1st grade, age 7) rated average on every composite performance but was below grade level for five of the nine subtests (elision, blending words, nonword repetition, rapid letter naming, rapid object naming). Phil (1st grade, age 7) rated average on the phonological memory composite and rated as below average (phonological awareness) or very poor (rapid symbolic naming and rapid non-symbolic naming) on the other composite tests. Phil also scored average on two subtests and scored either below average or very poor on the other seven subtests (elision, sound matching, memory for digits, rapid digit naming, rapid letter naming, rapid color naming, rapid object naming). Lil (Preschool, age 5) rated superior on the phonological awareness and phonological memory composite performances but rated very poor on the rapid symbolic naming and rapid non-symbolic naming composite performances.

DIBELS

Results from the DIBELS pretest can be found in Tables 7-8. Experimenters conducted several levels of the DIBELS to determine participants' current grade level reading placement. Participants' repertoires were first assessed using the DIBELS assessment that correlated with their current grade level (e.g., if the student was in 1st grade and it was within the first three months of the school year, the 1st grade assessment was conducted and scores were evaluated at the 1st grade, beginning of year [months 1-3] level). Results from this assessment indicated whether participants met the benchmark goals at grade level (likely to need only core support; proficient), fell below the benchmark (likely to need strategic support), or fell well below the benchmark (likely to need intensive support).

Table 7

DIBELS Scores (Errors in Parentheses)

	Initial Sound Fluency		Letter Naming Fluency		Phoneme Segmentation Fluency		Nonsense Word Fluency	
Student	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Chuckie	8 (2)	16 (0)	25 (7)	42 (1)	10 (8)	34 (7)	14 (9)	39 (0)
Angelica	15 (1)	16 (0)	60 (5)	62 (1)	N/A	33 (8)	30 (10)	47 (1)
Tommy	12 (4)	16 (0)	38 (11)	29 (11)	21 (5)	38 (6)	33 (10)	55 (10)
Phil	N/A	16 (0)	24 (19)	18 (4)	19 (15)	22 (6)	6 (9)	11 (4)
Lil	15 (1)	16 (0)	14 (4)	13 (7)	42 (4)	40 (2)	23 (7)	26 (1)

Note. N/A = unable to test due to low skills.

Table 8

DIBELS Benchmark Goals

		Letter Naming Fluency		Phoneme Segmentation Fluency		Nonsense Word Fluency	
Student	Grade	Pre	Post	Pre	Post	Pre	Post
Chuckie	2	Core at K-Beg	Core at K-Mid	Intensive at K-Mid[2]	Core at K-Mid[1]	Intensive at K-Mid[2]	Core at 1st-Beg
Angelica	1	Core at 1st-Beg[1]	Core at 1st-Beg[1]	N/A	Core at K-Mid[1]	Core at 1st-Beg	Core at 1st-Mid
Tommy	1	Core at K-Mid	Core at K-Beg	Intensive at K-Mid[2]	Core at K-Mid[1]	Core at K-Mid	Core at 1st-Mid
Phil	1	Core at K-Beg	Core at K-Beg	Intensive at K-Mid[2]	Intensive at K-Mid[2]	Intensive at K-Mid[2]	Intensive at K-mid[2]
Lil	Pre-K	Core at K-Beg	Core at K-Beg	Core at K-Mid[1]	Core at K-Mid[1]	Core at K-Mid	Core at K-Mid

Note.[1] indicates highest possible benchmark score for that test. [2] indicates lowest possible benchmark score for that test.

If participants performed below grade level (i.e., strategic support or intensive support), additional DIBELS tests were conducted. Experimenters tested each previous grade level in reverse chronological order until scores indicated proficiency at benchmark. For example, a participant currently in the 3rd grade would first be tested at the 3rd grade level. If they did not hit the benchmark on all the 3rd grade skills, previous grade levels (e.g., second, first, kindergarten) would be tested in reverse chronological order until s/he performed all skills at the benchmark level or the lowest grade level was tested. Error patterns are not part of the DIBELS scoring procedures; however, experimenters conducted an error analysis on all DIBELS subtests in order to identify deficits may not have been captured by typical scoring procedures. If error patterns were apparent, the experimenters conducted repeated, curriculum-based assessments to confirm skill deficits.

Chuckie (2nd grade, age 8) met benchmark goals on letter naming fluency at the kindergarten, beginning of the year level. Chuckie hit below the kindergarten, middle of the year level on phoneme segmentation fluency and nonsense word fluency. Angelica (1st grade, age 6) met benchmark goals on letter naming fluency and nonsense word fluency at the 1st grade, beginning of the year level. Angelica hit below the 1st grade, middle of the year level on oral reading fluency and was unable to complete the phoneme segmentation fluency test due to low skill. Tommy (1st grade, age 8) met benchmark goals for letter naming fluency and nonsense word fluency at the kindergarten, middle of the year level. Tommy hit below the kindergarten, middle of year level on phoneme segmentation fluency. Phil (1st grade, age 8) met benchmark goals for letter naming fluency at the kindergarten, beginning of the year level. Phil hit below the kindergarten, middle of year level on phoneme segmentation fluency and nonsense word fluency. Lil (Preschool, age 5) met benchmark goals for letter naming fluency at the kindergarten, beginning of the year level. Lil also met benchmark for phoneme segmentation fluency and nonsense word fluency at the kindergarten, middle of the year level.

Curriculum-Based Assessments

The curriculum-based assessment contained two parts, one part was developed to further assess letter-naming skills and one part was developed to further assess letter-sound relations. Results from the curriculum-based assessments pretest can be found in Table 9. Experimenters assessed letter-naming accuracy using the two, flashcard decks (upper and lowercase). The experimenter shuffled the flashcards in the uppercase deck and then asked the participants to give the letter name for each card. If the participant did not know the letter name or gave the incorrect letter name, the experimenter moved on to the next card. After all cards were shown, correct and incorrect cards were counted. The same procedure was then repeated using the lowercase deck.

Table 9

Curriculum-Based Assessment Scores (out of 26 letters)

	Uppercase Letter Sound		Lowercase Letter Sound		Uppercase Letter Name		Lowercase Letter Name	
Student	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Chuckie	17	26	15	24	23	25	19	23
Angelica	22	26	22	22	25	25	24	26
Tommy	22	26	21	23	16	21	15	19
Phil	7	19	4	15	16	23	10	20
Lil	24	26	20	25	22	22	19	20

Experimenters also assessed letter-sound relations using the same two, flashcard decks. This time, the experimenters asked participants to say the letter sound for each letter in the uppercase deck. If the participant did not know the letter sound or stated the incorrect letter sound, the experimenter went to the next card. After all cards were shown, correct and incorrect cards were counted. The same procedure was then repeated using the lowercase deck.

Chuckie (2nd grade, age 8) was unable to identify lowercase letters accurately (19 out of 26) or letter sounds accurately (32 out of 52). Angelica (1st grade, age 6) was unable to identify letter sounds accurately (44 out of 52) and lowercase letter names accurately (22 out of 26). Tommy (1st grade, age 7) was unable to identify letter names accurately (31 out of 52). Phil (1st grade, age 7) was unable to identify letter names (26 out of 52) or letter sounds (11 out of 52) accurately. Lil (Preschool, age 5) was unable to identify lowercase letter names accurately (20 out of 26) and lowercase letter sounds accurately (19 out of 26).

Assessment Results Analysis

Given the results of the assessments, all participants showed deficits in skills that have been identified as being key prerequisite skills necessary for reading (National Early Literacy Project Report, 2009). Haughton Learning Center (2002) suggests that fluent performance for RAN occurs between 80-100 items per minute and Mercer, Mercer, and Evans (1982) suggest that fluent performance for letter sounds occurs between 100-120 letters per minute. All participants showed deficits on rapid autonomic naming tasks in the CTOPP-2 and letter sounds accuracy curriculum-based measures. Based on these assessment results, experimenters decided to start instruction with the earliest potential component skill: Rapid Autonomic Naming.

Experimental Design

A multiple probe across participants design (Sidman, 1960) was used to assess the effects of fluency training on identified prerequisite skills on each participant's composite skill repertoires. The composite skills (see Table 10) were first assessed until a stable baseline was established across all skills. Once a stable baseline was established for all skills for a particular participant, experimenters began prerequisite skill frequency building. All other prerequisite skills remained in the baseline probe condition. Fluency-based instruction on the prerequisite skill in training continued until the participant met the frequency aim for that skill. Once achieved, an endurance and stability check was conducted on the trained prerequisite skill. If the endurance and stability checks were within the frequency aim for that skill (e.g., if the endurance/retention check for letter sounds fell within the 100-120 frequency aim range; Berens et al., 2003), application probes were conducted on all untrained prerequisite skills and all composite skills. In addition, application probes for all composite skills were conducted on or about every third frequency building session to check for emergence during frequency building for prerequisite skills.

Retention checks were conducted once the next prerequisite skill met its respective frequency aim. Once application checks were completed, instruction on the second prerequisite skill began. All other prerequisite skills instruction followed the same procedure used for the first prerequisite skill. Some participants experienced slight variations to this general instructional sequence due to unexpected barriers on developing fluency on RAN. In the exceptions, several instructional variations aimed to improve frequency were employed and are described in the Results section for each individual participant. Figure 1 depicts the general order of experimental conditions for each participant; variations for individual participant modifications are shown in subsequent figures included in the results.

Procedures

Baseline and Composite Skill Application Probes

Table 10 lists the composite skills tested with their respective learning channels. Timing lengths were total time to completion for all composite skill baseline and application probes except for nonsense word fluency for which a 1-min timing length was used. Probes began when the experimenter told the participant the skill they were going to practice, placed the stimulus array in front of the participant (if necessary), and set the timer. The experimenter started the timer once the participant started the task or the experimenter asked the first question. The participant continued responding until the time ran out or they completed the stimulus array.

Table 10

List of Composite Skills

Component Skill	**Learning Channel**
Oral Reading Fluency	See-Say
Oral Reading Comprehension	Hear-Say
Listener Comprehension	Hear-Hear-Say
Nonsense Word Fluency	See-Say

Oral Reading Fluency

Participants read a passage at their current grade level. The experimenter instructed the participant to tell the experimenter if they were unsure about a word and the experimenter would then say the word. Words given by the experimenter were counted as incorrect. The experimenter started the timer once the participant starting reading the story. The experimenter stopped the timer after the student reached the end of the story. Correct and incorrect words were counted after the timing was completed.

Oral Reading Comprehension

The experimenter asked the participant who, what, where, when, and how questions about the story read for oral reading fluency. Comprehension questions were asked immediately after the oral reading fluency timing. The experimenter started the timer immediately after he asked the first question and stopped the timer once the participant responded to the final question. If participants were unsure of an answer, s/he was encouraged to say, "I don't know." The experimenter would then mark that question as incorrect and move onto the next question. Correct and incorrect answers were counted and total time was recorded after the timing.

Listener Comprehension

The experimenter read a grade-level passage to the participant (at a rate between 80-120 wpm) and then asked the participant who, what, where, and when questions about the story. Immediately after the passage was read, the experimenter asked the listener comprehension questions. The experimenter started the timer after he asked the first question and stopped the timer once the participant responded to the final question. If participants were unsure of an answer, s/he was encouraged to say, "I don't know." The experimenter would then mark that question as incorrect and move onto the next question. Correct and incorrect answers were counted and total time was recorded after the timing.

Nonsense Word Fluency.

Nonsense word fluency consisted of a 1-min timing during which participants read nonsense, consonant-vowel-consonant (CVC) words. The experimenter asked the participant to read, as many words as they could, as quickly as they could from a stimulus array that had 10 rows of 10 words .The experimenter instructed the participant to tell the experimenter if they did not know a word and the experimenter would tell them the word. Words the experimenter provided were counted as incorrect. The experimenter started the timer once the participant started reading the first word. Correct and incorrect words were counted at the end of each probe.

Prerequisite Skill Frequency Building and Prerequisite Skill Probes

One prerequisite skill was targeted at a time during frequency building for each participant. Table 11 shows the order in which experimenters arranged the prerequisite skill instructional sequence as well as the learning channel and frequency aim for each prerequisite skill. Prerequisite skill probes were conducted on all untrained prerequisite skills during frequency building.

Prerequisite Skill Frequency Building

All timings were 15 s for prerequisite skills in training and were 10 s for all prerequisite skill probes. Before each timing, the experimenter asked the participant what s/he wanted tow work for that day (e.g., computer time, playing with toys, etc.). Then, the experimenter told the participant what their goal was (e.g., “You must say 35 correct letter names in order to get the [preferred stimulus]”) for the day and marked the goal on the stimulus array. The experimenter determined goals using a frequency of one more than the participant’s previous highest frequency. Goals were left unchanged if it they were not attained. If the goal was met, the participant received the preferred stimulus/activity. If the goal was not met, up to four additional timings were conducted. Sessions were conducted until the goal was met, five timings were conducted, or the participant asked to stop (timings for each session were discontinued if at any time the participant asked to stop).

The experimenter began instruction by telling the participant which skill they were going to work on, placing the stimulus array in front of the participant (if necessary), and setting the timer. The experimenter asked the participant to say as many of the stimuli as they could within the time limit. The experimenter instructed the participant to tell the experimenter if they were unsure about any stimuli and/or to move to the next stimulus on the array (i.e., skip the unknown stimulus). If the participant did not respond within 3 s, the experimenter would tell the participant to "keep going" and prompt them to move onto the next stimulus. Skipped stimuli were counted as incorrect. The experimenter started the timer once the participant emitted their first response. The participant would continue responding until the time ran out. Correct and incorrect stimuli were counted and corrective feedback was given over incorrect responses after each timing. After participants completed their first set of timings for a prerequisite skill, the experimenter would conduct a priming session prior to the first timing of each subsequent session. During priming, the experimenter reviewed up to three missed stimuli from the previous sessions. The experimenter started by pointing to, presenting, or saying the missed stimulus and saying the correct response. The participant then repeated the correct response. The experimenter then pointed to the missed stimulus in a different location on the stimulus array and asked the participant to say the correct response (without the experimenter model).

Slicebacks. Slicebacks are described in detail in the Results. If a participant hit below their celeration aim, slicebacks were implemented in order to accelerate learning. The particular slicebacks implemented were specific to each participant; slicebacks were determined by the first and second authors and were based on participant data, component-composite analysis, and best practices in PT.

Lil's slicebacks on RAN included removing commonly missed stimuli, reducing the timing length, reducing the total number of different stimuli in the set to four, reducing the total number of different stimuli in the set to two, teaching all possible combinations of the four different stimuli in sets of two different stimuli, running timings with only one stimulus showing, using different stimulus sets, and using flashcards. Lil's slicebacks for letter sounds included removing commonly missed stimuli, reducing the stimulus set to only lowercase letters, reducing the stimulus set to only uppercase letters, reducing the stimulus set to only 13 uppercase letters, and reducing the stimulus set to only 11 uppercase letters.

Angelica's slicebacks on RAN included reducing the timings length to 15 s, reducing the number of different stimuli in the set to 16, randomizing the stimuli every timing, reducing the number of different stimuli in the set to eight, reducing the number of different stimuli in the set to four, reducing the number of different stimuli in the set to 2, and teaching all possible combinations of the four different stimuli in sets of two different stimuli.

The only sliceback made for Tommy was to reduce all timing lengths to 15 s. Chuckie's slicebacks on RAN included reducing the timing length to 15 s, changing the stimulus set from foods to shapes, and reducing the number of different stimuli in the set to four. Chuckie's slicebacks for letter sounds included reducing the timing length to 15 s and reducing the number of different stimuli to three. Phil's slicebacks for RAN included reducing the timing length to 15 s, reducing the number of different stimuli in the set to four, reducing the number of different stimuli in the set to two, using flashcards to present stimuli one at a time, changing to a different stimulus set (e.g., toys, school supplies), and randomizing the stimulus array.

Rapid automatic naming (RAN). During RAN, the experimenter asked the participant to label as many of the stimuli on the array as quickly as possible (see Appendix A for a sample stimulus array). Each stimulus array contained five rows with eight pictures in each row unless changed due to a sliceback. Stimuli were always pictures of foods unless changed due to a sliceback.

Table 11

List of Prerequisite Skills

Learning Channel	Prerequisite Skill	Frequency Aim
See-Say	Rapid Automatic Naming	80-100 items/minute
See-Say	Letter Sounds	100-120 sounds/minute
Hear-Say-Point	Phoneme Segmentation	40-60 sounds/minute
Hear-Say	Phoneme Blending	10-15 words/minute
Hear-Say	Phoneme Isolation	15-20 words/minute
Hear-Say	Phoneme Deletion	15-20 words/minute

Letter sound. During letter sound, the experimenter asked the participant to give the sound of a letter from a stimulus array. Each stimulus array contained 10 rows with 10 letters within each row.

Phoneme segmentation. During phoneme segmentation, the experimenter asked the participant to break a word into its individual sounds as quickly as possible. The experimenter said a word from a stimulus array containing 10 rows with five CVC words in each row. The experimenter then asked the participant to give each sound in the word while pointing to a block that represented that sound. For example, if the experimenter gave the word "sam," the participant was expected to give all three sounds within the word "sam", /s/, /a/, and /m/ and point to three different blocks as they said each sound.

Phoneme blending. During phoneme blending, the experimenter asked the participant to listen to a sequence of sounds and combine them as quickly as possible. The experimenter said a sequence of sounds that made up a word from an array containing 10 rows with five CVC words in each row. The experimenter asked the participant to give the word those sounds, when blended, made. For example, if the experimenter said /s/, /a/, and /m/, the participant would be expected to say “sam.”

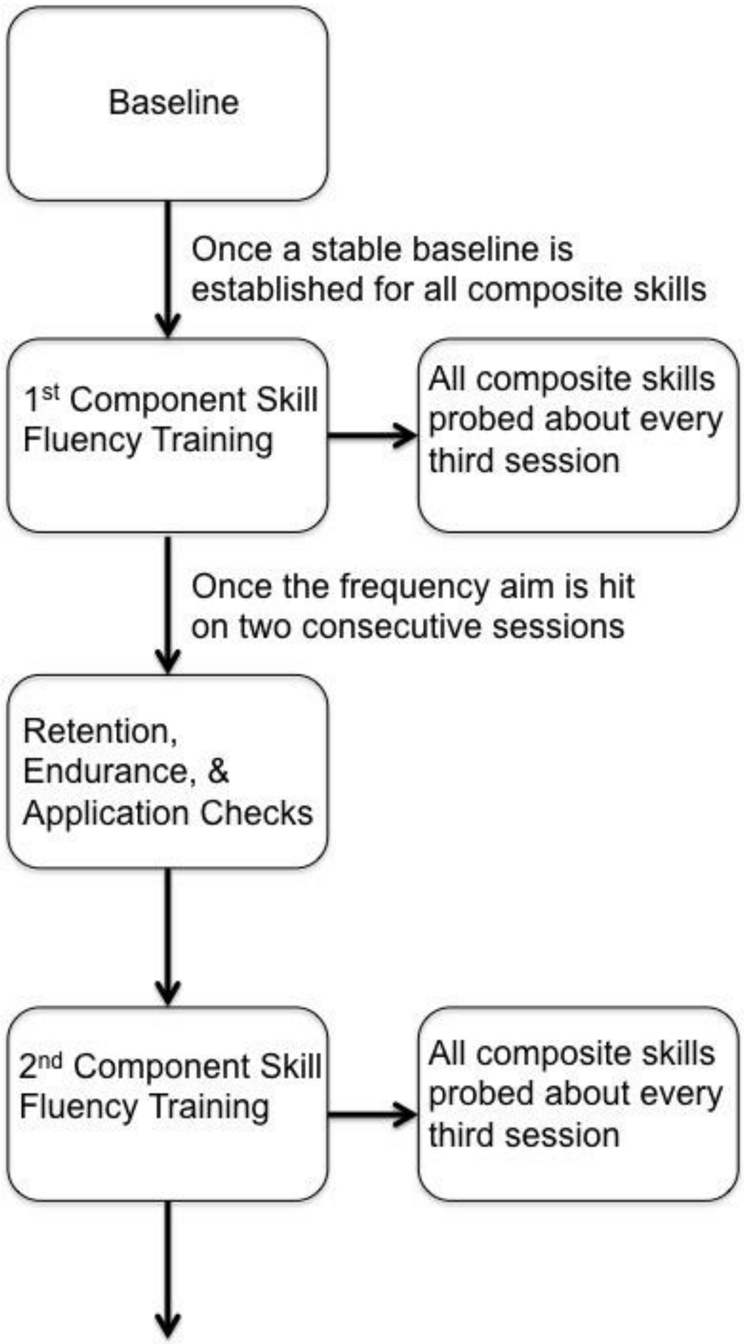

Figure 1. Visual depiction of experimental method used to identify component-composite relations

Phoneme isolation. During phoneme isolation, the experimenter asked the participant to identify different sounds within a word as quickly as possible. The experimenter asked the participant for a particular sound (e.g., first, last, middle) from a CVC word from an array containing 10 rows with five words within each row. The participant then said that corresponding sound. For example, if the experimenter asked, “What is the first sound in the word ‘sam’?”, the participant would be expected to say /s/.

Phoneme deletion. During phoneme deletion, the experimenter asked the participant to identify a word when a particular sound was removed as quickly as possible. The experimenter asked the participant to tell him what a word was without a particular sound; he selected words from an array containing 10 rows with five CVC words within each row. The participant then said the new word. For example, if the experimenter asked, “What is sam without the /s/?” the participant would have been expected to say, “am.”

Prerequisite Skill Probes

Prerequisite skill probes were conducted once the prerequisite skill in training reached the frequency aim. All prerequisite skill probe timings were 10 s. To begin, the experimenter would tell the participant which skill they were going to work on, place the stimulus array in front of the participant (if necessary), and set the timer. Once the participant started the task or the experimenter asked the first question and stared the timer. The participant would continue until the time ran out. Correct and incorrect responses were counted after the timing.

RESA

Fluency was determined by four performance characteristics, referred to as RESA (Johnson & Layng, 1992). Once the participant reached the frequency aim for the prerequisite skill and the data remained stable, the experimenter conducted tests for endurance and stability.

To test for endurance, the experimenter asked the participant to engage in the prerequisite skill for three times longer than the training sessions. To test for stability, the experimenter arranged a practice session in an environment where visual and auditory distractions were available (e.g., other children talking/playing, toys making noise). Retention was assessed after the participant completed endurance and stability checks for the next prerequisite skill (e.g., retention tests for RAN were conducted once a participant reached the frequency aim and completed the endurance and stability checks for letter sounds). The test for retention was conducted in the same way as the training session was run during frequency building. Application was assessed throughout the experiment with the composite skill probes.

Interobserver Agreement (IOA) and Treatment Integrity (TI)

Two observers were trained to score the dependent variables to at least 90% accuracy before they began collecting IOA data. IOA data were taken in 45% of RAN sessions, 37% of letter sound sessions, 50% of phoneme segmentation sessions, 50% of phoneme blending sessions, 33% of phoneme isolation sessions, and 33% of phoneme deletion sessions. IOA data were also collected for 57% of composite skill sessions. IOA data were scored by counting the smaller number of occurrences, divided by the larger number of occurrences, and multiplying the quotient by 100%. The mean accuracy of all prerequisite skill IOA data was 100% except for one session of Lil’s letter sounds where IOA accuracy was 97% (*M* = 99.96%, range, 97% to 100%). The mean accuracy of all composite IOA data was 100% except for one session of Angelica’s where the IOA was 99% (*M* = 99.98%, range, 99% to 100%).

Two observers were trained to score the dependent variables to at least 90% accuracy prior to collecting TI data. TI data were taken in 45% of RAN sessions, 37% of letter sound sessions, 50% of phoneme segmentation sessions, 50% of phoneme blending sessions, 33% of phoneme isolation sessions, and 33% of phoneme deletion sessions. TI data were calculated by dividing the number of correctly implemented steps by the total number of steps and multiplying the quotient by 100%. The mean TI for the prerequisite skill frequency building sessions was 100% and the mean TI for the composite skill probes was 100%.

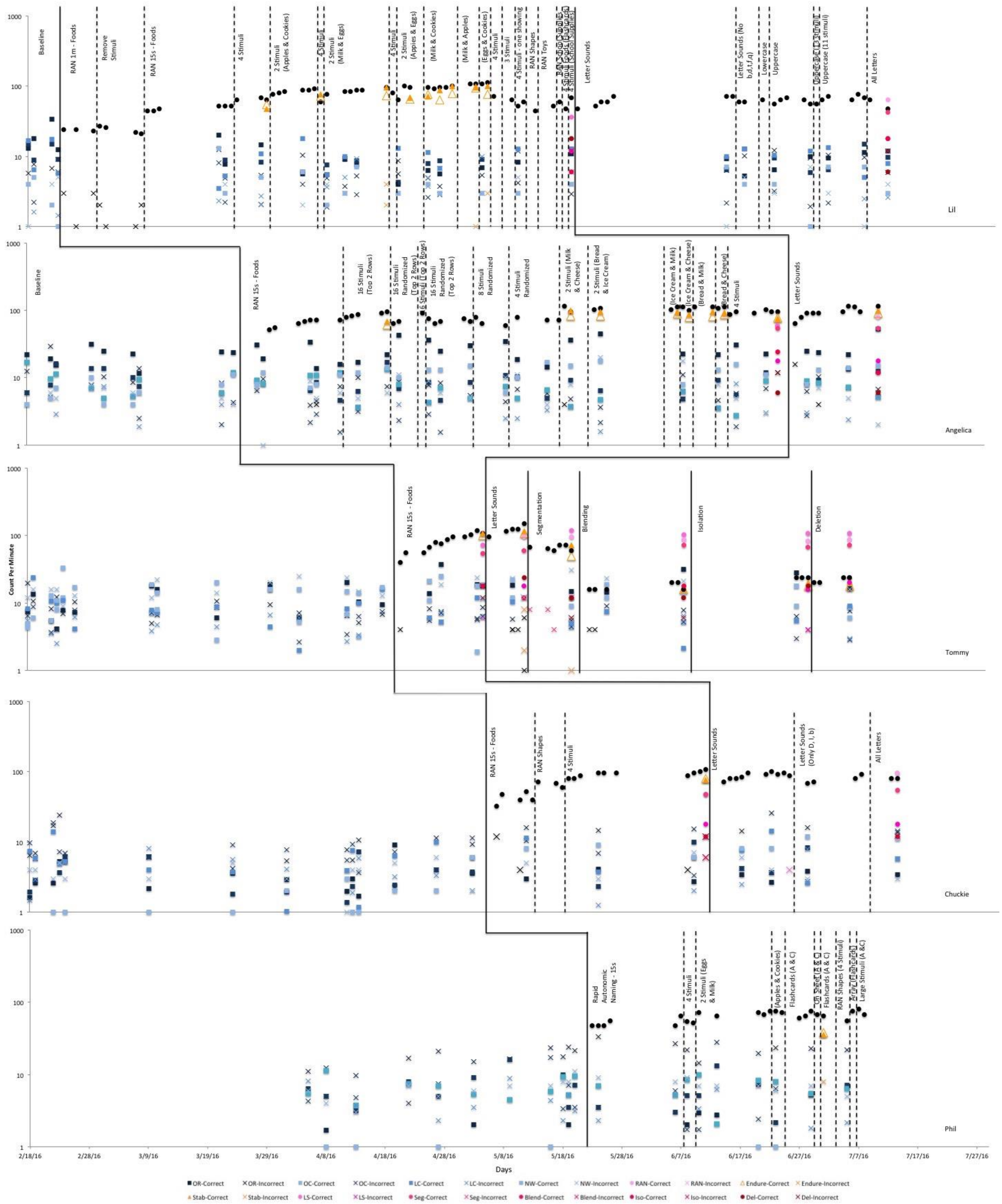

Figure 2. Response rate of prerequisite skills by participant. Prerequisite skill in training is depicted with black circles.

RESULTS

Each panel in Figure 2 shows the data for a different participant. Lil's data are depicted in the first panel; Angelica's data are depicted in the second panel; Tommy's data are depicted in the third panel, etc. Count per minute is listed on the y-axis and the days are listed on the x-axis. All prerequisite skills are black dots when they were in the frequency building sessions. All composite probes are depicted by blue squares. All endurance and stability checks are shown as orange triangles. All retention and untrained prerequisite checks are represented by red or pink circles. All errors are depicted by an "X" in the color corresponding to the specific skill.

In general, the data indicate that most participants were not able to complete training on all the prerequisite skills. Only one participant was able to complete training on all the prerequisite skills (Tommy). Most participants did not show improvement on the composite skills. Most participants did, however, improve on many of the CTOPP-2, DIBELS, and curriculum-based assessments measures.

Lil

Lil (Figure 2, first panel) was unable to complete any of the six prerequisite skills. Lil started frequency building on RAN on February 24th. During frequency building on RAN Lil initially performed at a X1 celeration; however, after three days with no celeration, the experimenters began implementing a number of slicebacks in an attempt to assist her to meet the frequency aim and maintain endurance and stability. Each sliceback is depicted in Figure 2 by the dashed lines. First, the experimenters removed commonly missed stimuli from the RAN array. Lil had not been exposed to all the foods on the array so experimenters eliminated those stimuli with which she was not familiar. After four sessions, Lil was performing at a /.75 celeration and experimenters reduced timing lengths to 15 s for 48 sessions as the experimenter noted that her endurance declined toward the end of her timing. During these sessions, Lil initially performed at a X1.25 celeration before stabilizing to no celeration over the last three sessions. Next, the experimenters reduced the number of stimuli in the stimulus set to four stimuli for three sessions, as her errors were too high; Lil maintained a X1 celeration. Next, frequency building for RAN was modified to teach all possible combinations of the four different stimuli taught in sets of two different stimuli each for 23 sessions. The authors wanted to teach all combinations of the original four different stimuli (e.g., eggs, milk, apples, cookies) in sets of two different stimuli each and then test, once performance was fluent on these stimuli, whether Lil's performance would recombine to improve performance on the stimulus set containing four different stimuli. During this modification Lil performed at a X1.2 celeration, X1.2 celeration, X1 celeration, X1.1 celeration, X1 celeration, and X1.25 celeration for each set of two different stimuli, respectively. However, when the experimenters tested on the stimulus set that included all four different stimuli, Lil's frequency dropped to below previous levels and the stimulus sets did not recombine. Next, the experimenters presented the stimulus set with only one stimulus showing at a time for two sessions. Lil's performance indicated a X2 celeration but her frequencies were still below previous slicebacks. At this time, experimenters tested RAN with several different stimulus sets (i.e., shapes [1 session], toys [1 session], and school supplies [1 session]). This was implemented in order to determine if it was the stimuli in particular (food; her family was vegan) that was inhibiting her progress. Performance frequencies for these stimulus sets were at or below the performance frequencies of the original stimulus set. Lil did not meet the frequency aim for RAN and experimenters discontinued frequency building on RAN on May 19th (52 sessions) due to lack of progress despite the numerous slicebacks. None of the slicebacks resulted in stable, fluent performance for Lil on RAN. Experimenters decided to move her to frequency building on the next prerequisite skill – letter sounds - on May 20th. Previous literature (Eaton & Wittman, 1982) had suggested that "leaping up" in the curriculum might be a potential solution to the problem presented with Willow.

During the instruction on letter sounds with Lil, experimenters again assessed the effects of several slicebacks in an attempt to help her to meet her frequency aim and maintain endurance and stability. Lil initially performed at a X1.5 celeration before leveling off to a /.75 celeration for the last three sessions. The experimenters then removed commonly missed stimuli from the stimulus set. After two sessions of a X1.1 celeration, the experimenters limited the stimulus set to contain only lowercase letters. This was implemented to reduce the number of different stimuli to only 26 letters due to a high frequency of errors and past performance on RAN indicating that the number of different stimuli in a set may produce challenges for Lil to reach frequency aims. This change resulted in a decrease of the initial frequency to below previous sliceback levels. The experimenters then limited the stimulus set to include only uppercase letters. This resulted in an initial X1.35 celeration for the first two sessions before performance shifted to a /.85 celeration for the last three sessions. Next, the experimenters reduced the number of uppercase letters in the stimulus array to 13 letters but the initial frequency was again below the frequency achieved prior to the previous sliceback. Next, experimenters reduced the number of letters in the stimulus set to 11 letters that Lil had always emitted correctly in previous timings. This sliceback resulted in a X1 celeration; however, the study was discontinued on July 11th after 23 sessions. None of the slicebacks resulted in stable, fluent performance for Lil on letter sounds.

During frequency building, experimenters continued to probe composite skills. Lil showed improvement on one of the four composite skill probes; there was a slight decrease in errors during listener comprehension as compared to baseline. All other composite skills remained at or below baseline levels.

Lil's CTOPP-2 assessment (pre- and post-) results are depicted in Tables 1-6. Lil improved on three of the nine subtests (sound matching, rapid letter naming, and rapid object naming) on the CTOPP-2, maintained the same performance on four skills (elision, memory for digits, nonword repetition, and rapid color naming) and preformed worse on two skills (blending words and rapid object naming). Lil made gains of 1.6 years on sound matching, memory for digits, and nonword repetition skills, 0.4 years on rapid object naming, and was able to complete the rapid letter naming skill for the first time during the posttest. Lil also improved on two of the four composite performances (rapid symbolic naming and rapid non-symbolic naming).

Lil's scores on the DIBELS pre- and post-assessments are shown in Tables 7-8. Lil increased her performance frequency on two of the four skills (initial sound fluency and nonsense word fluency) and increased in accuracy on three of the four skills (initial sound fluency, phoneme segmentation fluency and nonsense word fluency). Her ratings did not change from the pretest to the posttest for all three ratable skills.

Lil's curriculum-based assessment scores are in Table 9. Lil increased in accuracy on three of the four tests (uppercase letter sounds, lowercase letter names, lowercase letter sounds) and but did not increase her accuracy on uppercase letter names.

Angelica

Angelica was able to complete two of the six prerequisite skills (see Figure 2, second panel). She started frequency building on RAN on March 30th. When RAN was first introduced, Angelica maintained a X1.3 celeration during the first five sessions before leveling off to a X1 celeration for the last three sessions. At this time, experimenters began to explore a number of slicebacks in an attempt to assist Angelica at meeting the frequency aim and maintaining endurance and stability. First, the experimenters reduced the stimulus set to contain only 16 different stimuli. This resulted in performance at a X1.2 celeration. The experimenters then tested for endurance and stability and Angelica met her frequency aim. However, Angelica's performance dropped to below the target frequency aim. Based on previous timings and other interactions with the participant, the experimenters hypothesized that Angelica was likely memorizing the order of the stimulus array. To prevent this, the experimenters randomized the stimuli prior to each timing. This led to an initial X1.2 celeration in her performance during the first three sessions after this sliceback before her performance leveled off to a X1 celeration for the last four sessions.

The experimenters then reduced the number of different stimuli in the stimulus set to eight which shifted performance to a /.07 celeration. Experimenters then reduced the number of different stimuli in the array to four, but Angelica performed at a X1 celeration after only three sessions. Next, frequency building for RAN was modified to teach all possible combinations of the four stimuli taught in sets of two different stimuli each for 12 sessions. The authors wanted to teach all combinations of the four stimuli (e.g., ice cream, milk, cheese, bread) in sets of two different stimuli and test if these stimuli would recombine once all the possible combinations were taught to fluency. During this sliceback, Angelica performed at a /0.8 celeration (within frequency aim), X1.2 celeration, X1.45 celeration, /0.9 celeration (within frequency aim), X1 celeration, and X1.2 celeration for each set of two different stimuli, respectively. After all combinations were taught to the frequency aim, the experimenters then tested original stimulus set that contained four different stimuli for six sessions. Angelica maintained a X1.1 celeration until she met the frequency aim. Endurance and stability checks were conducted and both were within the frequency aim range for this skill. Frequency building for RAN was completed on June 24th after 42 sessions.

Angelica started frequency building on letter sounds on June 27th. Angelica performed at a X2 celeration for the first three sessions and then declined to a X1.1 celeration for the remaining seven sessions. Endurance and stability checks were conducted and performance remained within the frequency aim range. Fluency-based instruction for letter sounds was completed on July 11th after 10 sessions.

Angelica showed improvement in one of the four composite skill probes; there was a slight increase in her nonsense word performance frequencies as compared to baseline. All other composite skills remained at or below baseline levels.

Angelica's CTOPP-2 pre- and post-scores are shown in Tables 1-6. Angelica did not improve her rating on any subtests or prerequisite skills performances on the CTOPP-2. However, Angelica made gains of 2.6 years on the memory for digits skill; gains of 1.0 year on the elision, rapid color naming, and rapid object naming skills; gains of 0.4 years on rapid letter naming; and gains of 0.2 years on the rapid digit naming skill.

Angelica's scores on the DIBELS pre- and post-assessments are shown in Tables 7-8. Angelica's performance improved on all four skills (initial sound fluency, letter naming fluency, phoneme segmentation fluency, and nonsense word fluency). She was also able to complete the phoneme segmentation fluency skill for the first time during the posttest (she was unable to complete the task at the pretest). Angelica achieved higher benchmark scores on two of the three ratable skills (phoneme segmentation fluency and nonsense word fluency) but did not rate higher on letter naming fluency.

Angelica's curriculum-based assessment scores are in Table 9. Angelica increased her accuracy on two of the four tests (uppercase letter sounds, lowercase letter names) and performance maintained from pre- to post-tests on uppercase letter names and lowercase letter sounds.

Tommy

Tommy was able to complete all of the perquisite skills (see Figure 2, third panel). He started frequency building on RAN on April 21st and completed it on May 5th (12 sessions). During frequency building on RAN, Tommy maintained performance at a X1.75 celeration during the 12 sessions. Once the frequency aim was met, endurance and stability checks were conducted and both were within the frequency aim range. Fluency-based instruction for letter sounds began on May 6th and was completed on May 12th (5 sessions). During this instruction, Tommy maintained a X1.5 celeration. Endurance and stability checks were within the frequency aim range. Fluency-based instruction for segmentation began on May 13th and was completed on May 20th (6 sessions). Tommy maintained a X1 celeration for these six sessions as his initial frequencies were already within the frequency aim. Endurance and stability checks were conducted and were within the frequency aim range.

Fluency-based instruction for blending began on May 23rd and was completed on June 8th (6 sessions). During these six sessions, Tommy maintained a X1 celeration; his initial frequencies were already within the frequency aim range. Endurance and stability checks were also within the frequency aim range. Fluency-based instruction for isolation began on June 27th and was completed on June 29th (3 sessions). Tommy maintained X1 celeration for these three sessions as his initial frequencies were already within the frequency aim range. Endurance and stability checks were also within the frequency aim range. Fluency-based instruction for deletion began on June 30th and was completed on July 6th (4 sessions). Tommy maintained a X1.2 celeration for these four sessions as his initial frequencies were already within the frequency aim range. Endurance and stability checks were also within the frequency aim range. The only sliceback that was introduced for all prerequisite skills was to reduce the timing length to 15s. All of Tommy's retention checks were within the frequency aim range for each respective skill.

Tommy showed improvement in one of the four composite skill probes. He had a slight increase in his oral reading frequencies as compared to baseline. All other composite skills remained at or below baseline levels.

Tommy's CTOPP-2 pre- and post-assessment scores are shown in Tables 1-6. Tommy improved on two of the nine subtests (sound matching and nonword repetition), maintained the same rate on four skills (elision, blending words, memory for digits, rapid digit naming, rapid letter naming, and rapid object naming) and preformed worse on rapid color naming. Tommy made 1.2 years of progress on blending words, 1.0 years of progress on nonword repetition, 0.8 years of progress on rapid letter naming and rapid object naming, and 0.5 years of progress on elision. Tommy improved on one of the four composite performances (rapid non-symbolic naming).

Tommy's results on the pre- and post-DIBELS assessments are shown in Tables 7-8. Tommy improved from pre- to posttests on three of the four tests (initial sound fluency, phoneme segmentation fluency and nonsense word fluency) and performed worse on one skill (letter naming fluency). Tommy rated higher from pre- to posttests on the benchmarks for two of the three ratable skills (phoneme segmentation fluency and nonsense word fluency) and worse on one skill (letter naming fluency).

Results from Tommy's curriculum-based assessment are depicted in Table 9. Tommy improved on all four skills (uppercase letter sounds, uppercase letter names, lowercase letter sounds, and lowercase letter names).

Chuckie

Chuckie was able to complete one of the six prerequisite skills (see Figure 2, fourth panel). He started frequency building on RAN on May 6th and completed it on June 10th (19 sessions). During frequency building on RAN, experimenters assessed the effects of numerous slicebacks in an attempt to assist him to meet the frequency aim and maintain endurance and stability. The following slicebacks were made based on celeration and/or stability in his data following each change to the original method and are depicted by dashed lines. After beginning instruction on RAN, Chuckie performed at a X1.25 celeration for five sessions. Due to a high rate of errors on the initial stimulus set, the experimenters decided to change the stimulus set to shapes. During these three sessions, Chuckie performed at a celeration of /0.75. The experimenters then reduced the stimulus set to four different stimuli. During the first six sessions, Chuckie performed at a X1.2 celeration and during the last four sessions had a X1.35 celeration. Endurance and stability checks were conducted and both were within the frequency aim range.

Fluency-based instruction for letter sounds began on June 13th. During frequency building on letter sounds, experimenters assessed the effects of numerous slicebacks in an attempt to assist him to meet the frequency aim and maintain endurance and stability. The following slicebacks were made based on celeration and/or stability in his data following each change to the original method and are depicted by dashed lines. Chuckie showed an initial celeration of X1.4 during the first five sessions but then leveled off at a X1 celeration for the last five sessions. The experimenters then reduced the number of stimuli to only three different stimuli as his most commonly missed stimuli seemed to be inhibiting his progress. Chuckie maintained a X1.25 celeration for four sessions but then the study was discontinued on July 11th after 15 sessions

Chuckie showed improvement in two of the four composite skill probes. He showed a slight increase in his nonsense word and listener comprehension frequencies as compared to baseline levels. He also demonstrated a decrease in his listener comprehension errors compared to baseline. All other composite skills remained at or below baseline levels.

Chuckie's CTOPP-2 pre- and posttest scores are shown in Tables 1-6. Chuckie improved on three of the nine CTOPP-2 subtests (blending words, blending nonwords, and segmenting nonwords) and maintained performance on six skills (elision, phoneme isolation, memory for digits, nonword repetition, rapid digit naming, and rapid letter naming). Chuckie made 2.7 years of progress on the blending words skill, 1.7 of years progress on the blending nonwords skill, 1.4 of years progress on the rapid digit naming skill, 1.2 years of progress on the rapid letter naming and segmenting nonwords skills, 1.0 year of progress on the nonword repetition, 0.5 years of progress on the elision skill, and 0.2 of years progress on the phoneme isolation skill. Chuckie improved on two of the four composite skills (rapid symbolic naming and alternate phonological awareness).

Chuckie's pre- and post-DIBELS assessment scores are shown in Tables 7-8. Chuckie scored higher on all four skills (initial sound fluency, letter naming fluency, phoneme segmentation fluency, and nonsense word fluency). He also improved his rating on the benchmark scores for three of the three ratable skills (letter naming fluency, phoneme segmentation fluency, and nonsense word fluency).

Chuckie's pre- and post-curriculum-based assessment results are depicted in Table 9. Chuckie improved on all four tests (uppercase letter sounds, uppercase letter names, lowercase letter sounds, and lowercase letter names).

Phil

Phil was not able to complete any of the six prerequisite skills (see Figure 2, fifth panel). He started frequency building on RAN on May 23rd and the study was discontinued on July 11th (25 sessions). During frequency building on RAN, experimenters assessed the effects of numerous slicebacks in an attempt to assist him to meet the frequency aim and maintain endurance and stability. The following slicebacks were made based on celeration and/or stability in his data following each change to the original method and are depicted by dashed lines. Prior to the first sliceback, Phil performed at a X1.2 celeration for six sessions. Then, the experimenters reduced the number of different stimuli to four and he maintained a celeration of /0.9 for two sessions. At this point, the experimenters reduced the stimulus set to only two different stimuli and Phil maintained performance at a X1 celeration for five sessions. The experimenters then changed the stimulus set but Phil performed at a celeration of /0.75 for two sessions. After this, the experimenters tried presenting the stimuli on flashcards rather than an array for three sessions because Phil had a high rate of self-corrections. Further, experimenters wanted to ensure that Phil could look at only one stimulus at a time until he emitted a response. This resulted in a X1.5 celeration. The experimenters then tested him on the stimulus array again but his performance returned to the same frequency as prior to the sliceback. At this point, the experimenters changed the stimulus set include only four different shapes. This was implemented to assess whether or not the stimulus set itself that was inhibiting his progress. The result was a reduction of frequency to that of prior sliceback levels. The experimenters then switched back to the original two stimuli, stimulus sets and used the flashcards to create a randomized array. This was implemented to ensure that the order of the stimuli was not having an effect on Phil's performance. The result was a frequency of performance similar to that prior to the sliceback. Lastly, the experimenters changed the size of the stimuli; stimuli were changed to be twice the size (20 stimuli per array) of the original stimuli. This shifted performance to a celeration of /0.5. At this point, the study was discontinued. Phil did not show improvement in any of the four composite skill probes. All composite skills remained at or below baseline levels.

Phil's CTOPP-2 pre- and post-assessment results are shown in Tables 1-6. Phil improved on four of the nine subtests (elision, sound matching, rapid digit naming, rapid object naming) and maintained the same rating on five skills (blending words, memory for digits, nonword repetition, rapid letter naming, rapid color naming). Phil made 1.3 years of progress on the sound matching skill, 1.2 years of progress on the elision skill, and 0.2 of years progress on the blending words skill. Phil also improved on three of the four composite performances (phonological awareness, rapid symbolic naming and rapid non-symbolic naming).

Phil's pre- and posttest results from the DIBELS are shown in Tables 7-8. Phil improved his rate of response on three of the four tests (initial sound fluency, phoneme segmentation fluency, and nonsense word fluency) and improved in accuracy on all four tests (initial sound fluency, letter naming fluency, phoneme segmentation fluency and nonsense word fluency). Phil's ratings did not change from pre- to posttest on all three of the ratable skills.

Results from Phil's pre- and post-curriculum-based assessments are in Table 9. Phil's performance improved on all four skills (uppercase letter sounds, uppercase letter names, lowercase letter sounds, and lowercase letter names).

DISCUSSION

Tommy was the only one of the participants to achieve fluent levels on all six of the prerequisite skills. Angelica reached fluent levels for two of the six prerequisite skills and Chuckie reached fluent levels for one of the six prerequisite skills. Lil and Phil did not reach fluent levels for any of the six prerequisite skills. Most participants did not show improvements on their composite skills; however, given that only Tommy reached fluent levels for all six prerequisite skills, this was not surprising. Nonetheless, even Tommy did not show much improvement on the composite skills. For Angelica, who completed RAN and letter sounds, experimenters might have expected to see improvements on nonsense word tasks; however, her data on the composite skill probes did not support this.

Lil and Phil did not reach their frequency aims for RAN as indicated by RESA. Specifically, Lil was unable to reach fluent levels with RAN stimulus sets that included more than two different stimuli and Phil was unable to reach fluent levels on RAN regardless of the number of different stimuli in the stimulus set. RAN is widely used as a predictor of future reading ability and as diagnostic tool for determining reading disabilities such as dyslexia (Bowers, 2001; Huff, Sorenson, & Dancer, 2002; Swanson, Trainin, Necoechea, & Hammill, 2003; von der Bos, Zijlsrta, & Spelberg, 2002). Low performance on RAN is often an indicator of dyslexia (cf., Denckla & Rudel, 1976). Some have indicated that RAN can be difficult to teach (de Jong & Vrielink, 2004), especially with individuals with disabilities such as dyslexia. However, unless a neurological or physiological abnormality corresponds to dyslexia, one should be able to conduct a component analysis of the skills needed to perform RAN at fluency and to teach individuals to reach frequency aims for RAN. Neither Phil nor Lil had been diagnosed with a reading disability at the time of the study despite their challenges reaching frequency aims for RAN.

Experimenters attempted several variations of frequency building from a component-composite perspective for both Lil and Phil but were still unable to help them achieve fluency for RAN. Specifically, we reduced timing lengths, reduced the number of different stimuli within stimulus sets, changed stimulus sets, changed the format in which the stimuli were presented, randomized stimuli for every timing, and reduced the number of stimuli visible. Future research should consider what other component skills (e.g., scanning, ways to arrange the number of stimuli in each set) might be able to be taught to fluency in an effort to find a procedure that can improve RAN performances. Further, future research should evaluate exactly what effect dysfluency with RAN has on later academic and reading skills.

Given that only Tommy was able to complete all the prerequisite skills and he did not show a corresponding increase in responding in composite skill probes, it is difficult to determine if the component-composite relations sought were empirically demonstrated. We can say with certainty that for Tommy, there was not a component-composite relation between skills but for the other participants, additional data would need to be collected. Moreover, three of the five participants did complete RAN to fluency and we still did not see a corresponding improvement on composite skills (or other prerequisite skills) when they reached fluent levels with RAN. We can say with some certainty that RAN alone is likely not a component skill for any of the composite skills experimenters selected. This is interesting given the important of RAN in predicting future reading ability and diagnosing dyslexia and reading disabilities. There are several potential explanations for why RAN did not result in corresponding improvements in any of the other prerequisite or composite skills. First, we might not have taught RAN with enough stimuli (i.e., participants tested out of RAN with stimulus sets of only four different stimuli) for RAN training to have affected performance on any other skills. Most other skills in reading require the organism show discriminated responding between many different stimuli. For example, the letter sounds task included 56 different stimuli between all the uppercase and lowercase letters. Reading passages requires even more discriminated responding, as each novel word would be another opportunity for discriminated responding. Second, in order to see an improvement on the composite skill, it might be necessary for the other prerequisite skills to be taught to fluent levels so that these skills can recombine. This would mean that RAN is only one of several different component skills and that each component skill on its own would not have an effect on the composite skills we assessed. It is also possible that RAN is a component skill for other composite skills we did not assess. Nevertheless, one might expect to see improvement on the tested composite skills only after teaching all the component skills to fluent levels first. Additional research should be conducted to provide clarification to the phenomena discussed here. For example, future researchers should look to identify the component skills for RAN in order to find more efficient ways to teach this skill. This would also allow experimenters to teach stimulus sets larger than four stimuli if the necessary components are taught. RAN might better apply to other composite skills where the number of stimulus discriminations is more similar to other tasks associated with reading (e.g., letter sounds, oral reading).

Even though most participants did not improve on their composite skills probes, many participants did show an improvement on the CTOPP-2, DIBELS, and curriculum-based assessments. For example, Lil improved on several of the CTOPP-2 subtests. The skills she made the largest gains on were sound matching, memory for digits, and nonword repetition skills, on which she made 1.6 years of growth. This is intriguing given that she was only in frequency building, most of it with respect to RAN, for a little less than 5 months. This lends some support to the notion that RAN is an indicator of subsequent performance on other reading skills. It is also possible that the two skills targeted for instruction with Lil (RAN and letter sounds) might be components of the skills for which she improved her performance on the CTOPP-2 (sound matching, memory for digits, and nonword repetition skills). Sound matching relies on the person's ability to identify words with phonemes in the same position as other words (e.g., first sound, last sound, middle sound; /k/ is the first sound in both "can" and "cat"). Nonword repetition relies on the person's ability to segment nonsense words into their individual phonemes (e.g., sound out the word) or to read it outright. It is likely that improved performance on the identification of letter sounds is an extremely important precursor skill, if not a component skill, for these other repertoires. Had Lil finished (e.g., reached fluent levels) frequency-based instruction on letter sounds, we might have seen a larger increase on these CTOPP-2 subtests.

Lil also showed an improvement on the nonsense word fluency subtest of the DIBELS and on three of the four curriculum-based assessments. Lil showed the largest improvements on the letter sounds tests of the curriculum-based assessments. It is probable that these gains were directly correlated with the frequency building she received on letter sounds

Angelica improved on several of the different CTOPP-2 subtests but her largest improvements were on the memory from digits (2.6 years of progress) and elision (1.0 years of progress) subtests. Elision targets the person's ability to remove phonemic segments from words in order to form other words. Angelica was in frequency building on RAN and letter sounds for about three and a half months. This likely explains her progress from pre- to posttest on rapid naming and elision skills. Elision relies on the fact that the person is able to manipulate different phonemes and identifying a letter's sound is a clear precursor skill, if not a component skill, of this. Had Angelica reached the phoneme deletion component skill during this study, we might have seen a larger increase on the elision skill.

Angelica also improved over baseline on all of the DIBELS subtests, with phoneme segmentation fluency and nonsense word fluency showing the largest increases from pre- to post-testing. Both of these skills rely on the person's ability to correctly identify letter sounds in order to segment the words. As Angelica was unable to complete the phoneme segmentation fluency subtest during the pretest, her ability to correctly and fluently identify letter sounds likely influenced this change.

Tommy also improved from pre- to posttest on a number of the CTOPP-2 subtests. His largest improvements were with respect to blending words, nonword repetition, rapid letter naming, and rapid object naming skills (1.2, 1.0, 0.8, 0.8 years of progress, respectively). Tommy was only in frequency building for less than three months but his gains were greater than that of the time in instruction. Some of the skills in the *CTOPP*-2 subtests were targeted directly with frequency building. For example, blending words and rapid naming skills were both targeted and the nonword repetition skill is a likely a recombination of the letter sounds and phoneme blending skills that were also targets of frequency building.

Tommy also improved on the three of the four DIBELS subtests (initial sound fluency, phoneme segmentation fluency, and nonsense word fluency) as well as all four of the curriculum-based assessments. The only skill that Tommy did not improve on was the letter naming fluency skill, which was not a skill that was targeted during this study. Although Tommy did not improve his rate of responding on letter naming, he did show improvements in accuracy from the pre- to post-curriculum-based assessments. Even though Tommy did not show much improvement on the composite skills probed in this study, he did improve on most of the assessments. This could mean that these tests are more sensitive to the skills we taught or the assessment targeted skills that we did not. Given the wide use of these particular assessments in education, the improvement on these tests might suggest the skills we taught were beneficial to his overall reading repertoire even though they were not empirically shown to be component skills. It is also possible that procedurally, how the skills are probed in the educational assessments differs from how experimenters arranged composite probe sessions; however, this is unlikely given the DIBELS, at least, is a time-based assessment like our composite skill probes. Future research should look at identifying composite skills that might better predict long-term reading ability (e.g., skills probed on the DIBELS and *CTOPP*-2) or pick composite skills that are not as specific as the ones chosen for this study (e.g., only CVC words on the nonsense word composite probe). If correctly done, we should see improvements on both the composite skills and the more widely used educational assessments.

Chuckie improved on most of the CTOPP-2 subtests; his largest improvements were on blending words, blending nonwords, rapid digit naming, rapid letter naming, and segmenting nonwords (2.7, 1.7, 1.4, 1.2, 1.2 years of progress, respectively). Chuckie was in frequency building for just over two months. During that time, he made almost three years progress on blending words and almost 2 years progress on blending nonwords. Chuckie was able to reach fluent levels on RAN and was working on letter sounds at the time the study was discontinued. Given that RAN was targeted during this study, it is likely that this explains the differences on the rapid naming skill pre- to posttest scores. As for the blending tasks, identification and correctly producing letter sounds is at least a precursor skill, if not a component skill, of blending words.

Chuckie also improved on all four subtests of the DIBELS assessment and all four curriculum-based assessments. He showed the most improvements from pre- to posttests on the phoneme segmentation fluency and nonsense word fluency subtests of the DIBELS and the letter sound subtests of the curriculum-based assessment. It is likely that the tasks that Chuckie showed the most improvement on were the skills for which the identification and manipulation of letter sounds is a precursor, if not a component skill.

Phil improved on a few of the different skills tested in the CTOPP-2. He showed the largest improvements on the sound matching and elision skills (1.3 and 1.2 years of progress, respectively). Phil was in frequency building for about a month and a half. Given that Phil was unable to complete any of the component skills targeted in this study, it is hard to draw conclusions on how these growths were made during this time. During his time targeting RAN, he could have learned to "go faster" (i.e., increased the oral production of sounds) during RAN instruction and that could have lead to faster production of responses during these tests. Or, as with all of the participants, it is possible that his general, school-based instruction contributed to these gains.

Phil also improved on three of the four subtests in the DIBELS (initial sound fluency, phoneme segmentation fluency, and nonsense word fluency) as well as all four subtests of the curriculum-based assessments. Again, as only RAN was targeted during this study, it might be possible that Phil learned the skill of "going quicker" but he must have learned to be accurate on these skill through instruction (e.g., school or home) that occurred outside of the experimental conditions.

One interesting finding in this study was the difference in results on the composite skill probes and the educational assessments. Most participants saw little to no improvements on the composite probes yet all participants improved on the pre- to posttest educational assessments. Each assessment targeted different skills (except for overlap between the curriculum-based assessment and the letter naming fluency on the DIBELS), which means that 16 different skills were tested for each participant. The differences between the composite skill probes and the educational assessments may be due to the fact that the assessments assessed a wider array of skills; some of which might be composites for the skills we targeted in this study. Put in an example that illustrates your point here…. Three of the subtests of the CTOPP-2 (elision [phoneme deletion], blending words, and rapid object naming) and one of the subtests on the DIBELS (phoneme segmentation fluency) were taught explicitly in the study. Thus we should expect to see improvements on these skills if participants received training on those skills during the course of the study. Tommy, who did receive training on all these skills, also improved on all of these skills. Chuckie (who received training to fluency on one skill) made progress on all of these skills. Angelica (who received training to fluency for two skills) made progress on three of the four skills (elision, rapid object naming, phoneme segmentation fluency). Phil (who was unable to reach fluent levels with any skill) made progress on one of the four skills (elision). Lil (who was unable to reach fluent levels with any skill) made improvements on rapid object naming but none of the other skills. It seems likely that we would see progress on RAN at a minimum as she spent a majority of her training working on RAN. Interestingly, Chuckie was able to make as much progress as Tommy on these skills but had reached fluent levels with only one of the prerequisite skills (RAN). This may be due to the fact that Chuckie was less accurate on his letter sounds than Tommy at the onset of the study and his training on this skill (even though it was not to fluency levels) could have resulted in his improvements on these skills.

Another reason why we might see these differences between the composite skill probes and the educational assessments might be that the composite skill probes were too specific or that we did not teach all the necessary component skills in order to see an effect. Even though teaching letter sounds might have had an effect on a participant's ability to segment, this skill could break down if the letters do not make the sounds like what was taught for each individual letter-sound relation (e.g., hard vs. soft 'c,' diagraphs, irregular vowel sounds, etc.). We tested the participants' ability to read using grade level materials but this might been a poor choice by the authors given the questions they sought to answer. Had the authors chose stories that were similar to the reading level at which the participants were given the pretests, the participants might have encountered success at the application of the skills taught in the study. Specifically, had experimenters tested all participants using solely kindergarten or 1st grade materials (i.e., where there is a higher concentration of CVC words), we might have seen a component-composite relation emerge.

Overall, our data seem to support previous research that letter sounds might be an important prerequisite, if not component skill, to teach. As previously discussed, one reason for the disparity between the results of the composite skill probes and the educational assessments might have been that additional component skills might need to be taught to fluent levels in order to see the effects on the composite skills. The skills tested in the educational assessments might be sensitive enough (i.e., letter sounds might be the only or one of the only components of the skills tested in the assessment) to show the effects of frequency building on these component skills. We interpret these data with caution as all participants were trained on RAN before letter sounds so we are unable to distinguish the effects of one prerequisite skill without the impact of prior instruction on the other. Therefore, future research might explore the effects of only one precursor skill at a time on only one composite skill. It is important that we empirically validate component-composite relations so that we can identify which skills are actually component skills and which skills might be only precursor skills. Until this happens, we cannot have a truly efficient curriculum sequence.

Limitations

There were several limitations of this study. First, as previously discussed, each participant was not taught all the prerequisite skills to fluent levels. Additional research is needed to identify potential component skills in order to expedite teaching as well as to replicate our methods to determine if these skills are actually components of larger composite skills. Second, even in the case in which all the prerequisite skills were taught to fluency, the prerequisite skills included targeted only CVC words. This meant that the participants were fluent on the prerequisite skills only as they applied to CVC words. However, CVC words comprise only a small percentage of words in the English language and English is not a transparent language, meaning that in most words, every letter does not always produce the same sound. Therefore, when English readers are presented with oral reading passages like those used in the current experiment (selected based on participant grade level), the participants contact word structures besides CVC words such as words that include a silent "e" or a long vowel sound rather than a short vowel sound. This likely impacted the potential for the application the targeted prerequisite skills on the composite skill of oral reading rate, especially for the older participants. Future researchers should try to identify the skills necessary to teach more complex word structures (e.g.,. CVCE, CVVC, CCVVC, CVCC). This could include teaching these rules using Direct Instruction (c.f., Englemann & Carnine, 1982) to participants before beginning frequency building on these skills.

Third, we taught only six prerequisite skills. These skills are not the only prerequisite skills necessary for a complete instruction of reading in a non-transparent language. As such, to see a greater impact reading, particularly at grade level, experiments would likely need to teach other prerequisite skills for reading beyond CVC words (e.g., silent ‘e’ rule, blends, diagraphs, irregular vowel sounds). Additional analyses are needed to identify the most efficient teaching hierarchy such that instructors know when skills should be taught concurrently and which skills must be taught before other skills (i.e., component-composite relations). Fourth, the participants were all enrolled in school during part of the study (February – May). Any improvement could have been a result of outside practice and not from the experimenter-manipulated variables manipulated. Lastly, the untrained prerequisite skills were not probed until after the first prerequisite skill (e.g., RAN) was taught to a fluent level. This means that it is impossible to tell from this study if RAN alone had any impact on the other skills.

Contributions

Despite the limitations, this study offers several contributions to the literature base. First, this study provided another analysis of potential component-composite relations using frequency building. Even though not all participants were able to complete the study and component-composite relations were not experimentally demonstrated, it provides a framework for potential investigation of component-composite relations regarding reading repertoires. Identifying these additional component skills is necessary in order for us to have a complete analysis of reading behavior and all its components. The National Reading Panel (2000) lists the skills targeted in this study as only part of the necessary skills in order to have a complete reading repertoire. Other skills like identifying blends, diagraphs, long and short vowels, irregular vowel sounds, regular vowel sounds are necessary to learn in order to have the ability to decode a variety of different words these participant might come in contact with.

This study also provides another example of how the effects of PT and frequency building can evaluated while adhering to mainstream behavior analysts' preference for steady state responding (cf., Cooper, 2005). One challenge Precision Teachers face is conducting experimental analyses that rely on steady-state baselines to demonstrate functional relations and experimental control. People within precision teaching typically do not look at experimental questions with steady states, as they are able to show differences between experimental phases without relying on steady state (e.g., changes in trends, bounce, and celerations). This is because of the standardization of the SCC. With it, Precision Teachers are able to use celeration during the different experimental phases in order to differentiate between them. Using non-standardized graphs (e.g., linear), this would be impossible to do, as there is no standardization between these graphs (c.f., Kubina, Kostewicz, Brennan, & King, 2015). Using these non-standard graphs, it is much easier to show experimental control using steady state logic but this is not necessary when using a standardized graph like the Standard Celeration Chart (J. Eshleman, personal communication, July 11, 2016). Given that most people within behavior analysis use non-standardized graphs and steady state logic, precision teachers are challenged to try to combine these two methodologies in order to distribute their findings to a larger audience. The design used in this study (adapted from Twarek et al., 2010 and Cihon et al., accepted for publication), was an attempt to implement PT while adhering to steady state baseline logic. Using steady state baseline logic, we were able to maintain a steady baseline with composite skills while allowing for bounce, variability, celeration and within session data-based decision making that is indicative of PT on the prerequisite skills. Further, this design allows for an empirical demonstration of component-composite relations if claims regarding recombination of skills (i.e., cumulative fluency) are valid (Alessi, 1987; Johnson and Layng, 1992). Although, as Cooper (2005) notes, the field might be best served if Precision Teachers did not try to change how they ask or measure their experimental questions in order to fit them into mainstream designs. In this study, not all participants were able to complete all of the prerequisite skills training; this could have been partially due time constraints. As with multiple baseline designs, participants must start at different time periods in order to show experimental control. Cooper notes that using replication logic without steady state might be good scientific practice as well. With this, the experimenters could have started all participants at the same time instead of waiting for a steady-state baseline before implementing the procedure. Given the additional time and had more participants been taught all the prerequisite skills, we might have been able to see replication of the results which might further support any claims being made regarding cumulative fluency.

This study also adds to the literature base on the component-composite analysis of academic skills. We were not able to identify any component skills of the four composite skills that we tested in this study as none of the prerequisite skills led to the emergence or faster acquisition of the composite skills. This suggests that the skills we targeted for frequency building might not have been component skills or might not have been the only component skills necessary in order to see emergence of the composite skills. Even though we did not see any improvements on the composite skills we targeted, all participants did improve on their assessments measures. This suggests that the skills we targeted for frequency building might be component skills, at least of some of the composite skills the educational assessments measure. Overall, all participants made several improvements on their educational assessments that might predict improvement in their overall reading repertoires rather than just the four composite skills we tested.

Given participants did not acquire the desired repertoires from the procedures employed in this study, experimenters plan to continue instruction with each child based on their progress through this study and the results of their assessments. Lil and Phil both fit the profile for dyslexia based on both their DIBELS *and* CTOPP-2 scores as well as their challenges meeting frequency aims for RAN in this study. Research suggests that students with dyslexia benefit from multisensory instruction (cf., Morrison & Trezek, Paul, 2008). As such, experimenters are going to continue their instruction using See the Sound/Visual Phonics (STS/VP) which has been shown to produce gains in reading repertoires for young children who are at-risk for school failure (Cihon, Gardner, Morrison, & Paul, 2008; Gardner, Cihon, Morrison, & Paul, 2013). Angelica and Chuckie were making progress when data collection was stopped for thesis purposes so the experimenters plan to continue running them through the remaining experimental conditions. Tommy completed all of the experimental conditions but is still not reading at grade level. Therefore, experimenters plan to teach additional skills that are relevant to developing a grade-level reading repertoire. Fluency-based instruction will be developed for skills such as decoding blends and diagraphs and other forms of instruction to teach irregular/regular vowel sounds, the silent ‘e’ rule, etc. will be researched and implemented.

APPENDIX A

ADDITIONAL FIGURES BY PARTICIPANT

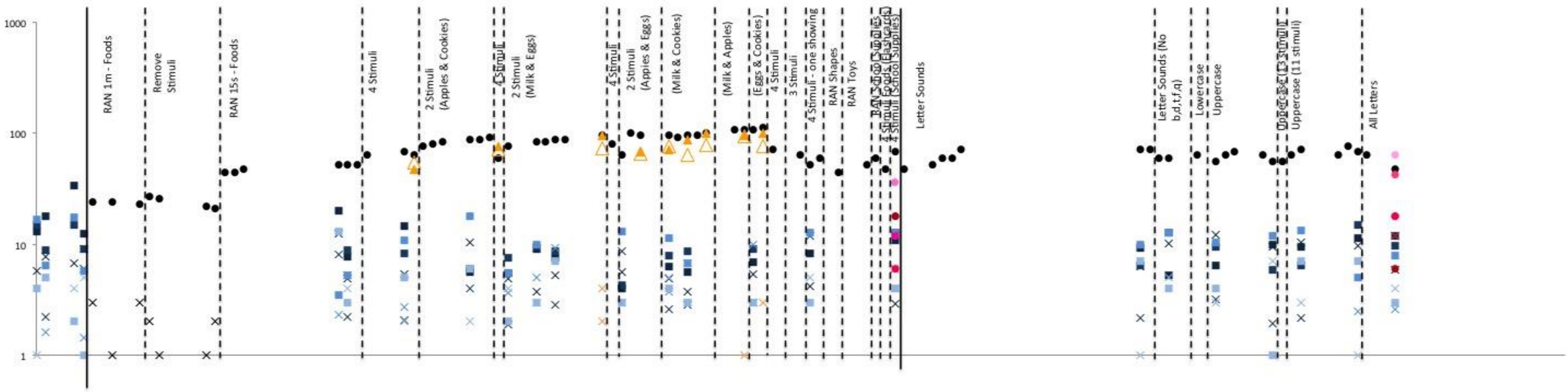

Figure A.1. Response rate of prerequisite skills for Lil. Prerequisite skill in training is depicted with black circles.

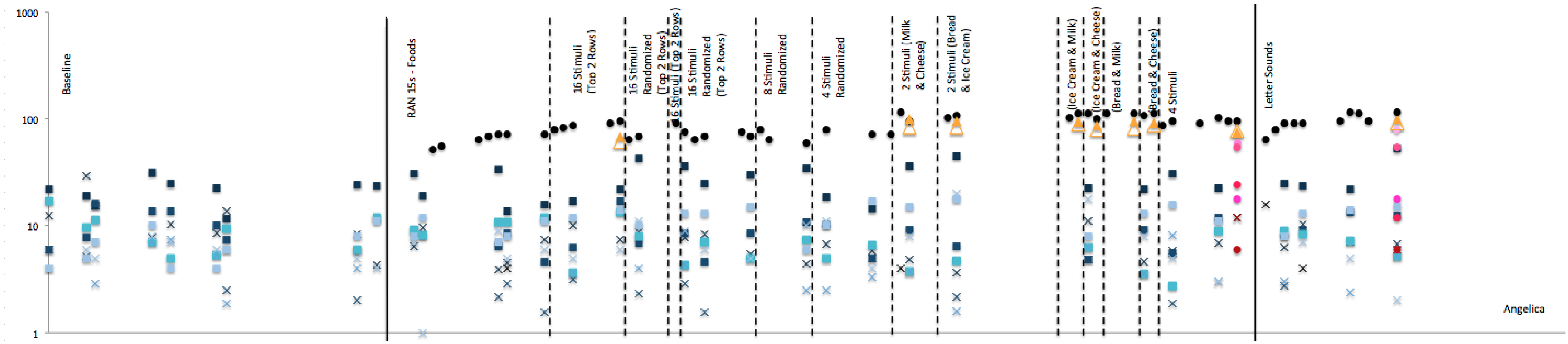

Figure A.2. Response rate of prerequisite skills for Angelica. Prerequisite skill in training is depicted with black circles.

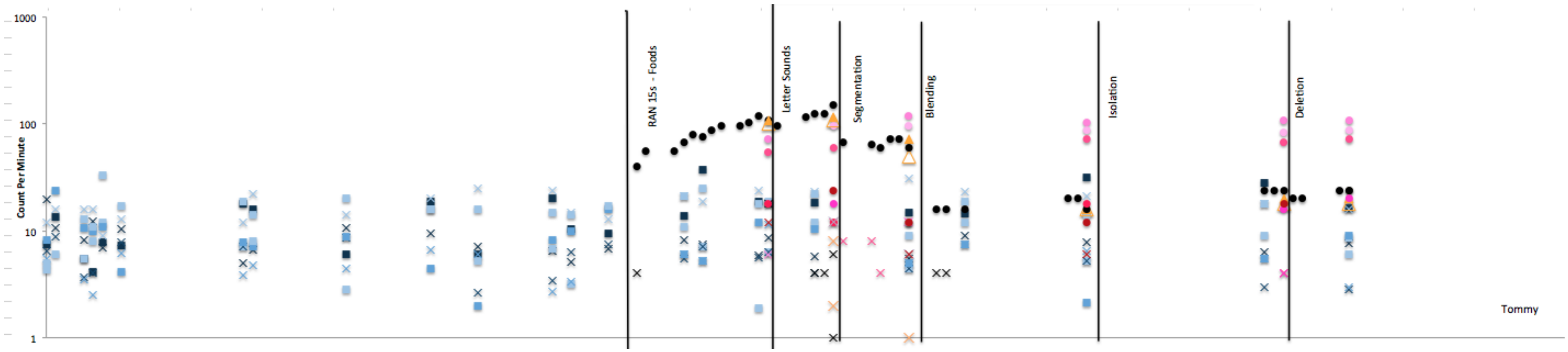

Figure A.3. Response rate of prerequisite skills for Tommy. Prerequisite skill in training is depicted with black circles.

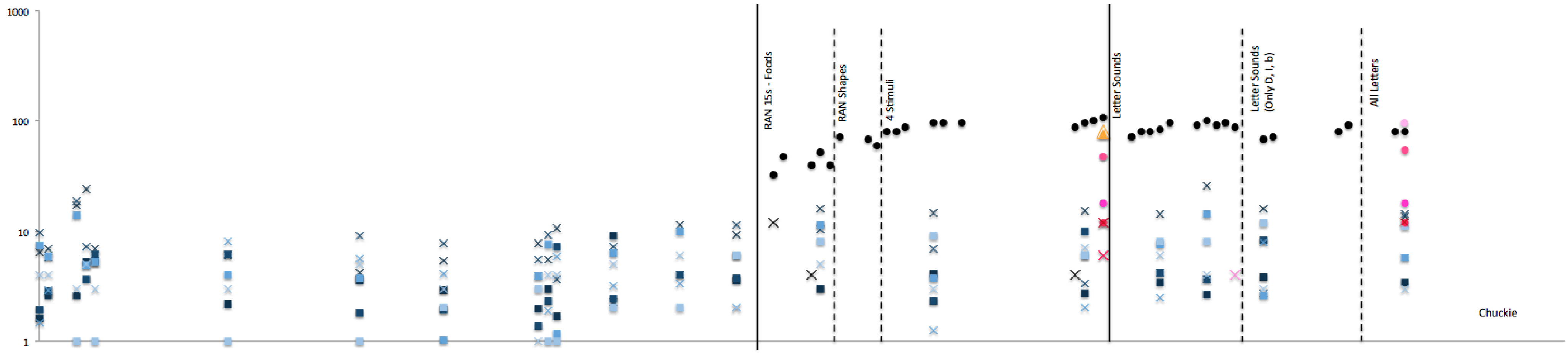

Figure A.4. Response rate of prerequisite skills for Chuckie. Prerequisite skill in training is depicted with black circles.

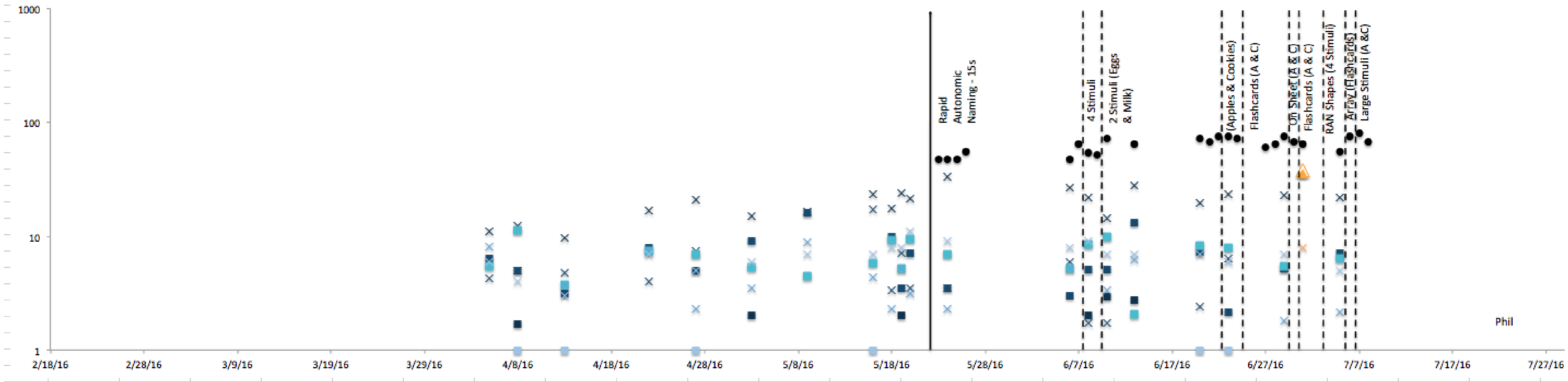

Figure A.5. Response rate of prerequisite skills for Phil. Prerequisite skill in training is depicted with black circles.

APPENDIX B

TREATMENT INTEGRITY DATASHEETS

Observer: ____________ Treatment Integrity Checklist: Component & Composite Skill Probes Date: ________

Experimenter: _________ Participant: __________

Instructions:
Mark a ( ) for correct, (-) for incorrect, or (n) if step is not applicable

Timings (mark for each skill using table below):

1. Experimenter conducts probes in order listed below on table (e.g., untrained component probes first then composite probes)
2. Experimenter places the stimulus array in front of participant (if necessary).
3. Experimenter sets the timer for the appropriate length.
   - 10 s for component probes
   - 1 m for oral reading and nonsense composite probes
   - Total time for oral reading comp and listener comp composite probes
4. Experimenter begins the timer when learner emits first response.
5. Experimenter records responses on datasheet and/or SCC.

	Composite Probes				**Component Probes**					
	Oral Reading	Comprehension	Listener Comp	Nonsense	RAN	Letter Sound	Segmentation	Blending	Isolation	Deletion
1										
2										
3										
4										
5										

Observer: ____________ Treatment Integrity Checklist: Endurance, Stability, & Retention Checks Date: __________

Experimenter: _________ Participant: __________

Instructions:
Mark a ( ) for correct, (-) for incorrect, or (n) if step is not applicable

Endurance, Stability, & Retention Checks:

1. If component skill in training reaches the frequency aim, the experimenter will conduct an endurance check (3x the length of a timing) on the component skill in training.
2. If component skill in training reaches the frequency aim, the experimenter will conduct a stability check in an environment that contains visual and auditory distractions.
3. If component skill in training reaches the frequency aim, the experimenter will conduct a 1 m retention check on all previously mastered component skills.

	Component Skills					
	RAN	Letter Sound	Segmentation	Blending	Isolation	Deletion
1						
2						
3						

Observer: __________ Treatment Integrity Checklist: Fluency Building Date:__________

Experimenter: ______ Participant: ________

Skill:____

<u>Instructions:</u>

Mark a ( ) for correct, (-) for incorrect, or (n) if step is not applicable

<u>Priming:</u>

					1. Experimenter selects up to 3 items that the learner is missing or having trouble pronouncing.
					2. Experimenter points and models the correct response for the participant to echo.
					3. Experimenter points to the same stimulus at a different location on the stimulus array for the participant to identify.

<u>Timings:</u>

					4. Experimenter identifies a preferred item/activity that the participant wants to work toward.
					5. Show participant on stimulus array what stimulus s/he needs to get to in order to achieve his/her goal while also telling him/her how many correct responses s/he needs to achieve his/her goal.
					6. Experimenter begins timer for 1 m when learner emits first response.
					7. If learner hesitates or stops responding for more than 3 s the experimenter gives the instruction “keep going”.
					8. When 1 m is completed the experimenter emits a praise statement.
					9. Experimenter records responses on datasheet or SCC.
					10. If learner achieves their specified goal the experimenter provides the preferred item/activity, praise, and the session is ended.
					11. Experimenter will run up to five 1 m timings, until the learner is able to hit their goal, or the participant requests to stop the session.

APPENDIX C

IOA DATASHEETS

Observer:______________ **IOA Datasheet - Component Fluency Training** Date:__________________

Experimenter:___________ Participant:_________________

Skill:____

	IOA Total		IOA Point-to-Point	
	Number of **Correct Responses**	Number of **Incorrect Responses**	Stimuli graded the **same** as the experimenter	Stimuli graded **differently** than the experimenter
Timing 1				
Timing 2				
Timing 3				
Timing 4				
Timing 5				

Timing 1				
Timing 2				
Timing 3				
Timing 4				
Timing 5				

Observer:______________ **IOA Datasheet - Probes** Date:__________________

Experimenter:___________ Participant:_________________

	IOA Total		IOA Point-to-Point	
	Number of **Correct Responses**	Number of **Incorrect Responses**	Stimuli graded the **same** as the experimenter	Stimuli graded **differently** than the experimenter
RAN				
Letter Sound				
Segmentation				
Blending				
Isolation				
Deletion				
Oral Reading				
Comprehension				
Listener				
Nonsense				

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