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Effects of Emergent Literacy Interventions for Preschoolers With Autism Spectrum Disorder

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Abstract

Combining data from a series of three planned, consecutive independent randomized controlled trials (RCTs), the present study investigates two literacy interventions for preschool children with autism spectrum disorder (ASD). For the first cohort, children were randomized to interactive book reading treatment (IBR) or a business-as-usual (BAU) control condition; in Cohort 2, children were randomized to phonological awareness treatment (PA) or BAU; in Cohort 3, children were randomized to IBR or PA. Both treatments were implemented weekly in the classroom from November to May. Combined across cohorts, data from $n=47$ IBR, $n=42$ PA, and $n=44$ BAU students from 57 classrooms in 8 districts were available for analysis. Model results showed that IBR had significantly greater pretest-posttest gains than the sample mean on expressive vocabulary and listening comprehension ($d^*=0.29$ and 0.30), whereas PA had significantly greater phonological awareness gains ($d^*=0.39$).

Emergent literacy is a period of development of skills, knowledge, and behaviors that increasingly approximate conventional literacy. It begins at birth and continues into early schooling (Sulzby & Teale, 1991; Whitehurst & Lonigan, 1998; 2002). The research base on emergent literacy and typically developing (TD) children is well-established and it is clear that the emergent literacy skills that children develop before school provide a foundation for later reading success (Lonigan, Schatschneider, & Westberg, 2008).

There is evidence to suggest that these emergent literacy skills are modular and comprise two groups: one related to print and one related to meaning (Lonigan, Purpura, Wilson, Walker, & Clancy-Menchetti, 2013; Storch & Whitehurst, 2002; Westerveld, Trembath, Shellshear, & Paynter, 2016). This Simple View of Reading (Gough & Tunmer, 1986) is widely used as a theoretical base for reading research in older readers and the evidence suggests that it has relevance to preschool emergent literacy as well. In preschool, the print-related group includes print awareness, letter knowledge and phonological awareness. The two strongest emergent literacy predictors of later reading for TD children are phonological awareness and alphabet knowledge (Lonigan et al., 2008; Whitehurst & Lonigan, 1998). Meaning-related skills and knowledge include vocabulary and oral language, which also

predict later reading success among TD children (Boudreau & Hedberg, 1999; Lonigan et al., 2008; Whitehurst & Lonigan, 1998). Although print-related and meaning-related skills are correlated during development, they predict different aspects of later conventional literacy and appear to respond to different types of instruction (Bowyer-Crane, Snowling, Duff, Fieldsend, Carroll, Miles, Gotz, & Hulme, 2008; Lonigan et al., 2008; Lonigan et al., 2013). We use this theoretical framework to guide the framing and research questions of the current study.

Emergent Literacy and Children with ASD

There is considerable heterogeneity in the reading achievement of school-aged children with Autism Spectrum Disorder (ASD) (e.g., Brown, Oram-Cardy, & Johnson, 2013; Nation, Clarke, Wright, & Williams, 2006). Wide-spread difficulties with reading comprehension, often associated with average or better word reading accuracy, have been reported (Brown et al., 2013; Nation et al., 2006; O'Connor & Klein, 2004; Ricketts, Jones, Happe, & Charman, 2013). An emerging body of research demonstrates that preschoolers with ASD show a pattern similar to that found in older readers with ASD: great heterogeneity, relatively stronger knowledge of print-related skills and relatively weaker oral language and phonological awareness skills (Davidson & Weismer, 2014; Dynia, Lawton, Logan, & Justice, 2014; Dynia, Brock, Justice, & Kaderavek, 2017; Lanter, Watson, Erickson, & Freeman, 2012; Westerveld et al., 2015) although Dynia et al. (2014) found that the difference in phonological awareness disappeared when they controlled for oral language. As well, Dynia et al. (2017) found that among young children with ASD, phonological awareness in preschool predicted later decoding achievement in kindergarten. Patterns in their data suggest this relation may be moderated by ASD status, indicating that perhaps it is more predictive of decoding for children with ASD than for TD children.

Emergent Literacy Interventions

Interactive Book Reading

Shared book reading is an important part of early childhood practices for most parents and teachers and is most effective when there is interaction between the adult and child (Paratore, Cassano, & Schickedanz, 2011). Shared book reading is positively correlated with levels of oral language (Wasik & Bond, 2001), phonological awareness (Mol, Bus, & de Jong, 2009; Skibbe, Behnke, & Justice, 2004), reading, spelling, and IQ (Stevenson & Fredman, 1990) in TD children without disabilities. Moderate effect size gains in the oral language and vocabulary of TD young children following interactive shared reading have been found (Lonigan et al., 2008; Mol et al., 2009). Because shared book reading affects skills linked to future reading comprehension, it is possible that such interventions can help ameliorate later comprehension difficulties in children with ASD (Cain & Oakhill, 2008).

Dialogic Reading (DR; Whitehurst, Falco, Lonigan, Fischel, DeBaryshe, Valdez-Menchaca, & Caulfield, M., 1988) is an interactive shared book reading intervention focused on using a series of prompts in order to actively engage children and encourage verbal interactions during book reading. DR has been extensively studied and found to increase the oral language of a wide range of TD English-speaking preschool children (Arnold, Lonigan,

Whitehurst, & Epstein, 1994; Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Whitehurst et al., 1988; Whitehurst, Arnold, Epstein, Angell, Smith, and Fischel, 1994) and Spanish-speaking TD children (Valdez-Menchaca & Whitehurst, 1992). In addition, DR has been studied with children with language impairments and found to increase (a) child verbal turns and semantic and grammatical complexity (Crowe, Norris, & Hoffman, 2000), (b) the literal and inferential language of preschoolers (van Kleeck, Vander Woude, & Hammett, 2006), and (c) the rate of verbal responses to questions, number of different words, and Mean Length of Utterance among preschoolers (Dale, Crain-Thoreson, Notari-Syverson, & Cole, 1996).

To date, only five studies of interactive repeated book reading with preschool students with ASD have been published. The first (Bellon, Ogletree, & Harn, 2000) was a case study of a 3-year old boy with ASD which lacked sufficient experimental control to determine whether the interactive book reading was effective. The second found that 1:1 sessions increased the rate of verbalization, number of communicative exchanges, and length of book reading session among preschool children with ASD as compared to baseline conditions (Fleury, Herriott Miramontez, Hudson, & Schwartz, 2014). The third included visual supports and focused on children with ASD who used little language, who were found to improve their responsiveness and engagement (Mucchetti, 2013). The fourth study was conducted with pairs of children with ASD and found that all four participating children had fewer incorrect responses and more frequent correct, spontaneous responses in comparison to baseline (Whalon, Martinez, Shannon, Butcher, & Hanline, 2015). The final study (Fleury and Schwartz, 2016) examined 1:1 interventions with 9 preschoolers with ASD and found greater gains in book-specific vocabulary and increased responses to adult question prompts for all children in comparison to baseline book reading session. This initial evidence of efficacy supports our examination of interactive book reading with larger samples of children with ASD.

Phonological Awareness

Phonological Awareness (PA) is an awareness of the sound structure of language (Wagner & Torgesen, 1987), including the conscious ability to detect and manipulate sound in spoken language (i.e., to blend, segment, and delete sound parts). Skills in PA and alphabet knowledge are critical elements of emergent literacy needed for later success in conventional reading among TD children (Adams, 1990; Snow, Burns, & Griffin, 1998; Scarborough, 2002). Studies of programs that teach PA have shown positive effects on TD children's reading and spelling (Ball & Blachman, 1988; Blachman, Tangel, Ball, Black, & McGraw, 1999; Lonigan et al., 2008; NICHD, 2000). Those programs that teach phonemic awareness with letters tend to produce larger effects than PA instruction alone (Ball & Blachman, 1988; NICHD, 2000). Most studies of PA instruction have focused on early readers in kindergarten and first grade (NICHD). Those conducted in preschool have shown positive intervention effects on the PA of children with language impairments (Bower-Crane et al., 2008) and those at-risk for reading disabilities (Lonigan et al., 2013). To our knowledge, no studies of PA instruction with preschoolers with ASD have been published. Given the importance of PA in the skilled reading of TD children and relative weaknesses in PA in young children

with ASD (e.g., Dynia et al., 2017; Gabig, 2010), intervention in this area may prove helpful.

Purpose of the Present Study

Developmentally appropriate structured interventions designed to improve the emergent literacy of preschool children with ASD are important to develop given the number of children with ASD who go on to read. Ensuring that they are prepared for the reading instruction they will encounter in kindergarten and first grade is critical for later success and may help ameliorate later difficulties. The purpose of the present study is to investigate the effectiveness of an interactive book reading (IBR) intervention and a phonological awareness (PA) intervention on the vocabulary and emergent literacy of preschool children with ASD. Using a series of three planned, consecutive randomized controlled trials (RCTs), the following research questions were addressed:

1. Do preschool children with ASD exhibit significant growth on vocabulary and emergent literacy over the course of their pre-kindergarten year, regardless of what experimental condition they experience?
2. What are the effects of IBR and PA interventions on vocabulary and emergent literacy for preschoolers with ASD?
3. Are the effects of IBR and PA interventions on vocabulary and emergent literacy growth accounted for by observed time spent on related classroom literacy activities?

We anticipated that preschoolers with ASD in general would show significant gains in emergent literacy skills but not necessarily exhibit significant gains in vocabulary given the delay in social communication associated with ASD. In addition, due to the modular nature of emergent literacy skills, we expected to see IBR effects on vocabulary without seeing effects on the print-related skills, and similarly, that the PA intervention would have specific effects on PA skills and not affect the language-related skills (Bowyer-Crane et al., 2008; Lonigan et al., 2013).

Method

Participants

We recruited children with ASD to participate in the study. The inclusion criteria were (a) be identified as having ASD by their school district, (b) have an active IEP and receive services for ASD, (c) be enrolled in their last year of preschool with a plan to enter kindergarten the next year, (d) have no known co-occurring neurological or genetic disorders (e.g., Down syndrome, Fragile X), (e) be able to use 2- to 3-word phrases and follow simple directions, and (f) a minimum standard score of 55 on the *One Word Expressive Picture Vocabulary Test*.

Verbal or nonverbal intellectual functioning was not used as one of the criteria due to frequent discrepancies between intellectual domains and academic functioning (Estes, Rivera, Bryan, Cali, & Dawson, 2011). As well, children participating in this study were not

required have a clinical diagnosis of ASD conferred by a psychologist or physician. Rather we decided to enroll children who were identified as having ASD by their school district. We made this decision in order to recruit a sample of preschoolers with ASD who were representative of children in public school programs. Although the age at which ASD can be reliably diagnosed continues to drop, children from families who are economically disadvantaged or members of cultural or ethnic minority groups continue to require more visits with professionals to get diagnosed and are consistently diagnosed later than their Caucasian and more advantaged age-mates (Daniels & Mandell, 2014; Mandell et al, 2009).

To maximize sample sizes for statistical power, we planned a three-cohort design involving three randomized controlled trials (RCTs), each of which compared two of three focal experimental conditions. Each fall for three consecutive years, we recruited, consented, screened, and pre-tested a new cohort of participants. No student participated in more than one cohort, although 23 of the 57 preschool classrooms were in more than one cohort. The initial sample sizes were $N = 42, 48$, and 51 for Cohorts 1, 2, and 3. For all three cohort s, the research methodologist randomized students (using only ID numbers) to one unique pair of conditions within district using a random number generator in MS Excel (uniform distribution). In other words, each subject had an equal chance of being in any two of the three experimental conditions under investigation. Conditions included interactive book reading treatment (IBR), phonological awareness treatment (PA), and no-treatment business-as-usual (BAU). For Cohort 1, the conditions were IBR ($n = 21$) or BAU ($n = 21$); for Cohort 2, the conditions were PA ($n = 25$) and BAU ($n = 23$); and for Cohort 3, the conditions were IBR ($n = 26$) and PA ($n = 25$). For all three cohorts, treatments were implemented in winter and early spring, with post-testing in the spring. After attrition, which included student scheduling conflicts and moving from the district, there were 42, 46, and 45 students in Cohorts 1, 2, and 3, respectively, with attrition including 2 PA students in Cohort 2, and 6 PA Students in Cohort 3. There were no significant differences on demographic characteristics or pretests between these students and students who completed the study (2-group chi-square and t -test p s $> .05$). Across cohorts, final condition group sizes were 47 (IBR), 42 (PA), and 44 (BAU), for a total of 133 children.

The majority of the children were male ($n = 108$, 81% of the sample) and ages ranged from 39 to 69 months ($M = 55.77$, $SD = 4.18$). The sample cultural composition was diverse, with 63 students from various backgrounds (47% of the sample): 29 were identified by their parents as being from an Asian heritage, 8 identified as Black, and 26 identified as multiracial. The remaining sample identified as Caucasian. Finally, there were also a small number of students whose parents identified them as from Hispanic ethnicities (3 multiracial and 8 White students). Preschool teachers completed the *Gilliam Autism Rating Scale-2nd* ed. (GARS-2) for each of the participating students. The GARS-2 has three subscales, Stereotyped Behaviors, Communication, and Social Interactions. Fourteen teachers across Cohorts 2 and 3 did not provide ratings, resulting in missing data for 16 children (1 IBR, 11 PA, and 4 BAU). For the 88% of children whose teachers did respond, the average GARS-2 Autism Index Score was $M = 82.81$ ($SD = 18.20$; $Range = 40$ to 119), which is close to the “very likely Autism” cut value of 85. Simple chi-square and pairwise t -tests detected no differences among the three conditions or the three cohorts on any of these demographic characteristics (p s > 0.05), with the exception that Cohort 2 students had higher teacher

ratings on GARS-2 ($M = 89.08$, $SD = 14.81$) than Cohort 3 ($M = 78.87$, $SD = 16.58$), $p = 0.015$.

Preschool Settings

All children attended preschool for at least half a day. The majority of children attended public preschools with only 3 attending a private preschool. The composition of preschool classrooms varied considerably. Some had equal numbers of TD children and those with developmental disabilities, some had a majority of TD peers with only 1–3 children with developmental disabilities, while others were made up of only children who received services such as special education, English as a Second Language, and Head Start. Most children in the study also attended half-day programs that were limited to children with ASD and provided individualized instruction designed to meet the needs of each child. Combined across cohorts, children were from 57 different preschool classrooms in 21 schools in 8 urban and suburban school districts in one state located in the Pacific Northwest.

Interactive Book Reading Intervention

The first intervention was Interactive Book Reading (IBR) adapted from Dialogic Reading procedures (Whitehurst et al., 1988). The books were primarily from a toddler read-aloud collection with books added to make a set of 20 books with expository and narrative text structures. The emphasis was on books with clear language, engaging illustrations, and simple story lines. The books ranged in complexity from simple with one sentence per page (e.g., *The Snowy Day*) to more complex sentences with rhymes and simple story lines (e.g., *Pigs Aplenty*, *Pigs Galore*) to the most complex books in the study (e.g., *Corduroy*; *The Tale of Peter Rabbit*). All children engaged with the books in the same order, which was determined using random selection. In order to facilitate comprehension of the books and provide a familiar structure, each book was read three to four times in a row before switching to a new book.

While reading, the tutor prompted the child to speak about the book using the DR procedures of PEER AND CROWD (Whitehurst et al., 1988). Each tutor followed the PEER sequence 1–2 times per page when prompting responses: Prompt, Evaluate, Expand, and Repeat. The tutor provided an appropriate *prompt*, waited for a response from the child, *evaluated* the statement, *expanded* the statement by making the language more complex, and either *repeated* the prompt or asked the child to repeat new vocabulary or syntax. Tutors used the CROWD prompts from DR. *Completion* prompts involve the adult reading the initial part of a phrase and allowing the child to finish the sentence or phrase. *Recall* prompts ask the child to recall information about previous events or characters in the story. *Open-ended* prompts elicit more language and are designed to allow the child to talk about what he/she wants to talk about. *Wh-Questions* involve the adult asking wh-questions about the picture or text that have one correct answer. *Distancing* prompts ask children to infer, predict, or relate elements of the text to themselves or their own lives.

In addition to the CROWD prompts, the tutors also used additional supports to provide more structure to the children with ASD (CROWD+). The two most frequent additional supports were providing extra wait time for children to process the information and respond and

repeating the prompt. Other less-frequently used supports moved from less to more support and reduced language demands. They are: (a) providing the initial sound of the correct completion answer such as *This is a k___*, (b) providing choices such as *Is it a key or a banana?*, (c) asking yes/no questions such as *Is that a key?*, and (d) modeling the right answer such as *Say key*. In addition to the use of CROWD+ supports, adjustments were made for individual children as needed. The adjustments included use of a token reinforcement schedule for play time, carrying a favorite toy to the reading session, use of a visual schedule, and for one child, reinforcement with a toy related to the book after every verbal response. Most children did not need such adjustments.

Phonological Awareness Intervention

The research team developed the first 30 lessons of the PA intervention to begin at the word level and progress through the syllable, onset-rime, and beginning phoneme levels of PA. Each lesson consisted of (a) a song with a PA element (e.g., substituting the initial sound in words), (b) an activity that repeated across 5–7 lessons, and (c) a novel activity that focused on the same level and skill as the first activity. All skills were modeled by the tutor in an explicit format and systematic corrective feedback was provided after every incorrect student response.

Tutors were provided a binder of lesson plans with the sequence of activities and possible words to use in the activity. The lessons were soft-scripted, meaning the steps and possibly things to say were outlined, but tutors were not required to say each statement as it was written. All activities included manipulatives (e.g., blocks, chips, pictures), actions (e.g., tapping, clapping, sorting, matching), and provided opportunities to respond with little language. The lessons were designed to be adapted by tutors in several ways to match the capabilities of the children. For example, initial word activities consisted of 2 words to represent with blocks and count. Once children were accurate, the materials gave 3-word sequences, and then sentences of 4 and 5 words. The tutors were told to move up and down in difficulty according to the accuracy of the children. Because there was so much overlap of content between lessons and systematic correction occurred after every incorrect response, tutors continued through the materials whether or not the child appeared to master the skill.

The second 30 lessons used the *Road to the Code* (Blachman, Ball, Black, & Tangel, 2000). It was not adapted, but followed the manual and materials exactly. *Road to the Code* was chosen because of its body of research evidence of success with at-risk young children (e.g., Ball & Blachman, 1988), use of manipulatives, and a simple routine to its activities. This program built on the previous lessons by beginning with segmenting and blending phonemes and moved into letter name and sound identification. Across all 60 sessions, a visual schedule was used with images of each activity, a star the child added at the end of each activity, and a short 1 minute reinforcement period at the end of the session.

Intervention Elements Common to Both Interventions

Tutors—Intervention sessions were provided by a total of 20 interventionists hired by the project from the local school community. All were women with at least a bachelor's degree. Three were certified elementary teachers, two were school psychologists, and two were

certified special education teachers; the rest did not have certifications. One was a practicing instructional assistant. All had experience with young children and children with ASD and many had experience as behavioral technicians used to deliver 1:1 applied behavior analysis services.

Sessions—During each session, the tutor and child sat together in a space removed from the group such as the corner of a classroom, the hallway, or separate small room. Tutoring sessions occurred 3–4 days per week for approximately 7–15 minutes per session. The IBR condition averaged $M = 60.17$ sessions ($SD = 10.57$) and PA averaged $M = 52.56$ sessions ($SD = 15.82$), which was a significant difference ($p < 0.05$). Examination of the data revealed that five students in the PA condition had low attendance due to their interventionists' absenteeism. Given the rarity of this population of children, we did not exclude any student from analyses.

Implementation fidelity—We maintained and measured implementation fidelity in several ways: (a) an in-depth 3 day training on how to do each intervention, including explicit instruction, video models, and live practice with feedback; (b) demonstration by each tutor that she could complete all the steps of the intervention with at least 95% accuracy; (c) lesson plans with suggested scripts and words to use; and (d) monthly onsite coaching visits by research assistants who observed tutoring sessions and provided feedback.

We measured procedural fidelity by using a checklist of expected tutor behaviors appropriate to the intervention and a 5-point rating scale for each behavior. For example, for a behavior such as “Adult *prompts* the child to respond at least one time every 2–3 pages,” a score of 1 = 0–10% and a score of 5 = 90–100%. Graduate research assistants and the first author individually observed a videotaped session for each child 2–6 times during treatment (average of 5 per child). The number of points were added up and divided by the total possible (i.e., all 5 s) to determine a percentage of earned points. Across these observations, procedural fidelity was found to be 98% ($SD = 5\%$), with the IBR condition averaging 98% fidelity ($SD = 7\%$) and the PA condition averaging 99% ($SD = 2\%$), which was not a significant difference, $p > 0.05$.

In addition to procedural fidelity, we measured child engagement using a 15-second partial interval time sampling procedure on the same videotaped session used for fidelity. A member of the research team (the first, third, or fourth author) observed the first five minutes of each and within each 15 second period, marked whether the student was actively engaged or not. Active engagement was defined by behaviors such as looking at the object of importance (book, blocks, or picture), pointing, speaking about the topic, looking at the tutor, or leaning toward the activity. Non-engagement was defined by behaviors such as looking away from the activity or tutor, moving away from the activity or tutor, speaking about an unrelated topic, pushing the object away, or playing with an object unrelated to the activity at hand. Across observations, the IBR condition averaged 86% time on task ($SD = 19\%$) and the PA condition averaged 94% ($SD = 8\%$), a difference that was significant, $p < 0.05$. Inter-rater reliability was established for all fidelity coding and no data were collected until agreement reached 80%. Due to staffing constraints, no inter-observer agreement was collected after initial reliability was established.

Business as Usual Control Condition

The instruction experienced by the children in the BAU condition is summarized in Table 1. Generally, children engaged with literacy activities during circle time and small groups at teacher-led centers. On average, they were exposed to 40.75 minutes per hour of observation of non-literacy instruction such as counting, numbers, calendar, self-regulation, transition, and play; 12.63 minutes of oral language instruction; 2.19 minutes of storybook reading, 2.06 minutes of print concepts, and less than one minute each per hour of observation of PA, letter identification, letter sounds, reading, and writing.

Measures

We collected all outcome measures from all children prior to intervention (October–November) and again after intervention (May–June). We conducted each session individually and adapted procedures to accommodate the needs of the children. Such accommodations included a visual schedule of tasks, planned reinforcement breaks, and the use of several short sessions to complete all assessments. All assessments were given by trained assessors familiar with special education, assessment procedures, and children with ASD. Inter-rater agreement of 90% was established on all assessments before children were assessed. Once the assessment took place, children were randomly assigned to condition by the second author.

Vocabulary and Listening Comprehension

Receptive vocabulary was measured using the *Peabody Picture Vocabulary Test-IV* (PPVT-IV Dunn & Dunn, 2007). In this test, children point to a picture that best illustrates the meaning of an orally presented stimulus word. The raw score was converted to a norm-referenced standard score. Internal consistencies (Cronbach's alpha) computed using our sample's first cohort were 0.98 at pretest and 0.96 at posttest. **Expressive vocabulary** was assessed with the *Expressive One-Word Picture Vocabulary Test-IV* (EOWPVT-IV; Brownell, 2011). For this test, children are presented with pictures and are asked to orally provide the names of the pictures. The raw score was converted to a norm-referenced standard score. Sample internal consistencies using Cohort 1 were 0.95 for pretest and 0.96 for posttest. **Listening comprehension** was measured using the Oral Communication and Following Directions subtests of the *Woodcock-Johnson III Tests of Achievement (WJIII)*. Because the children had great difficulty following directions from an audio recording, all items were read aloud verbatim by assessors. Items were read one time and were not repeated. The Oral Communication measure consists of oral cloze statements. Sample-based internal consistencies using Cohort 1 were .86 for pretest and .89 for posttest. The Following Directions measure consists of items that ask participants to point to things on a picture after being given directions. Sample internal consistencies using Cohort 1 were .93 for pretest and .92 for posttest. Raw scores were converted to a norm-referenced Listening Comprehension Cluster standard score.

Emergent Literacy

The **Phonological Awareness** subtest of the *Test of Preschool Early Literacy* (TOPEL; Lonigan, Wagner, & Torgesen, 2007) was used to measure Phonological Awareness. This

subtest measures elision and blending skills from word to phoneme level, leading to a norm-referenced standard score. Sample-based internal consistencies using Cohort 1 were 0.93 for pretest and 0.90 for posttest. **Print Knowledge** was measured using the Print Knowledge subtest of the TOPEL. This 36-item subtest measures early knowledge about written language conventions and alphabet knowledge and sounds. The raw score was converted to a norm-referenced standard score. Sample-based internal consistencies using Cohort 1 were 0.94 for pretest and 0.91 for posttest. **Word Reading** was measured using the Letter-Word Identification subtest of the *Woodcock-Johnson III Tests of Achievement (WJIII)*. The raw score was converted to a norm-referenced standard score for both subtests. Importantly, we note that this measure was not added until Cohort 2 and therefore lack scores for half of the IBR condition and half of the no-treatment business-as-usual condition (i.e., Cohort 1).

Classroom Literacy Observations

Observations of naturally-occurring preschool instruction were conducted once in the spring for each student in each cohort to quantify preschool instruction and control for time spent on activities similar to the IBR and PA interventions. All observations were conducted for a period of 60 minutes pre-determined by the researchers and teachers, typically during the first hour of school. Data were not collected during recess, PE, library, speech or OT/PT activities.

Instrument—We adapted the *Instructional Content Emphasis-Revised* (ICE-R; Edmonds & Briggs, 2003) to create an instrument entitled *Indicators of Language and Literacy* (ILL; Author). Using electronic timing devices and a log sheet, observers began recording time (hours: minutes: seconds) and the appropriate code corresponding to instructional characteristics at onset of the observation period. Every time the teacher switched instruction, the time and corresponding codes were recorded. Because many of the children experienced individual instruction or very small groups, we only coded the activity that the target child was engaged in. Time spent on each instructional code for each teacher-student pairing was computed to quantify time spent in each type of instruction.

Although the ICE-R is based loosely on the five elements of reading developed by the National Reading Panel (NICHD, 2000), those elements do not quite capture early language and literacy in preschool elements of instruction for children with developmental disabilities. Thus, similar to Vadasy, Sanders, and Nelson (2015), we adapted and added to some of the categories to construct the ILL. The final ILL categories were: Concepts of Print, Phonological Awareness, Alphabetic Knowledge, Word Study/Phonics, Oral Language Development, Oral Storybook Reading, Student Reading, Emergent Writing, Play, Transition, and Non-Literacy Instruction.

Observer reliability—Trained observers conducted all classroom observations for all cohorts. Prior to the onset of each year, observers studied coding instructions and participated in 2–3 formal training sessions with the first author. To establish reliability prior to data collection each year, observers independently coded 8–13 videotapes of instruction from preschool and kindergarten and data were entered into a spreadsheet. Then Cronbach's alpha was computed for each content code (i.e., treating videos as subjects and observers as

variables). Across cohorts, median reliability for the nine content codes ranged from $r = 0.81 - 0.99$; median reliability was $r = 0.98, 0.90$, and 0.96 , for Cohorts 1, 2, and 3, respectively. Due to staffing and scheduling constraints, no inter-observer agreement was collected after initial reliability was established.

Activity Time Estimates—We tabulated the time in minutes spent on each content code for each teacher-student pair. Across cohorts, we observed all but two students from the IBR condition in Cohort 3 for a total of 131 children, each observed for 60 minutes for a total of 7860 minutes across the study. Descriptive data in Table 1 show that “other” non-literacy activities (e.g., counting, calendar, play, transitions, self-regulation, art) were most prevalent ($M = 37.68$ minutes, or 63% of the time), and that oral language was the most frequently observed literacy instruction activity ($M = 13.01$ minutes, or 22% of the time). Oral storybook reading, print concepts, and writing were next most frequently observed, accounting for 6%, 4%, and 2%.

Analytic Approach

The present study represents a set of three planned, consecutive RCTs. For each of the three cohorts, participants were randomized to one of two conditions, with each cohort representing a unique pair of three treatments. In Cohort 1, the conditions were IBR or no treatment (BAU; typical preschool classroom instruction only); in Cohort 2, PA or BAU; and in Cohort 3, IBR or PA. Data from across all three cohorts were combined to ensure sufficient statistical power for testing the research questions. And, although treatments were delivered to students individually, multilevel modeling was used to test there search questions to account for non-independence in children’s scores due to preschool teacher and district memberships.

Using three-level intercept-only “unconditional” models in which preschoolers ($N = 133$, Level 1) were nested within their teacher ($N = 57$, Level 2), within their preschool district ($N = 8$, Level 3), we found that the estimated intraclass correlation (ICC) across pretests ranged from 0.00 to 0.28 for teachers within districts (mean ICC = 0.09) and from 0.05 to 0.08 for districts (mean ICC = 0.06). On posttests, ICCs averaged 0.10 and 0.06 for teachers and districts, respectively, while on pretest-posttest gains, ICCs averaged 0.04 and 0.02, respectively.

Prior to final models, we conducted a preliminary check to determine whether any cohort differences on pretest measures were evident and found no evidence of differences ($ps > 0.05$). As such, cohort was dropped for subsequent analyses. Our final analyses involved a series of three models for each pretest-posttest standard score gain. Model 1 was an intercept-only model on gains that tested our first research question; Model 2 tested our second research question by adding treatment effects (effect coded into two predictors testing the IBR effect and PA effect, with no-treatment coded -1) and corresponding pretest (in z -scores) as student-level predictors. Model 3 tested our third research question by adding time on classroom activities related to treatments (in z -scores). The models, conducted in *HLM7*, were as follows.

$$\begin{aligned}
 \text{Model 1: } Pre - Post\ Gain_{ijk} &= \gamma_{000} + U_{0jk} + U_{00k} + r_{ijk} \\
 \text{Model 2: } Pre - Post\ Gain_{ijk} &= \gamma_{000} + U_{0jk} + U_{00k} + r_{ijk} \\
 &+ \gamma_{100} * Pretest_{jk} + \gamma_{200} * ConditionDR_{jk} + \gamma_{300} * ConditionPA_{jk} \\
 \text{Model 3: } Pre - Post\ Gain_{ijk} &= \gamma_{000} + U_{0jk} + U_{00k} + r_{ijk} \\
 &+ \gamma_{100} * Pretest_{jk} + \gamma_{200} * ConditionDR_{jk} + \gamma_{300} * ConditionPA_{jk} \\
 &+ \gamma_{400} * ClassPA_{jk} + \gamma_{500} * ClassOralLang_{jk} + \gamma_{600} * ClassStorybook_{jk}
 \end{aligned}$$

To avoid inflating Type I error, we employ a family wise Dunn-Sidak (DS) p -value adjustment for two families with three measures each: vocabulary (receptive, expressive, and listening comprehension) and emergent literacy (phonological awareness, print knowledge, and word reading). Finally, for Models 2 and 3, we computed the *approximate* effect size of each coefficient using d^* , which we determined by dividing each model-estimated coefficient by the pooled approximate pooled standard deviation, and which is interpreted similar to Cohen's d .

Results

Descriptive Statistics

Table 2 reports the unadjusted sample descriptive statistics for each of the three experimental conditions at pretest and posttest. Using the measure norm-referenced standard scores ($M = 100$ and $SD = 15$), the sample averaged approximately at the 13th percentile across the vocabulary measures, and 42nd percentile across the emergent literacy measures. It is also notable that the sample had large standard deviations relative to the normative sample.

Whole Sample Growth on Vocabulary and Emergent Literacy

Prior to testing our first research question, we tested for pre-treatment differences among our conditions using 3-level models; results showed no evidence of group effects on pretests ($p > 0.05$). Results of our first outcome model for each pretest-posttest gain are provided in Table 3. As can be seen, on average all of the children made significant gains in two vocabulary outcomes and phonological awareness, with estimated gains of 6.20, 3.99, and 8.03 standard score points, respectively. This gain is beyond the norm-referenced expectation of no gain that would be expected from age-based norm-referenced scores. No significant changes were observed for listening comprehension, print knowledge, or word reading.

Effects of IBR and PA Interventions

The results of our second multilevel model, which tested treatment effects on pretest-posttest gains after adjusting for the respective pretest, are provided in the first set of columns in Tables 4 and 5 for vocabulary and emergent literacy outcomes. As can be seen, significant IBR effects were observed on listening comprehension (an estimated 3.33-point greater pretest-posttest gain compared to average, $p = 0.017$). There were also trends for positive IBR effects on gains in expressive vocabulary (an estimated 3.09-point greater pretest-posttest gain for IBR students compared to average, $p = 0.021$) as well as receptive vocabulary ($p = 0.096$). The mean approximate effect size across these measures was $d^* =$

0.26. As anticipated, the only PA treatment effect was observed for gains on phonological awareness (an estimated 5.45-point greater improvement than the average gain, $d^* = 0.39$, $p < 0.017$).

Another noteworthy finding about Model 2 is that pretest negatively predicted growth for all but two measures ($ps < 0.017$); the exceptions were expressive vocabulary and listening comprehension, both of which showed trends in the same direction. This indicates that preschoolers with ASD who started out with lower skills exhibited greater gains in their intervention than did students who started out with higher skills. Figure 1 displays predicted mean gains by condition for each outcome, paneled by type (vocabulary or emergent literacy).

Model 3 evaluates whether the effects observed in Model 2 are maintained after controlling for treatment-related classroom literacy activities; at the same time, Model 3 also tests the unique effects of amount of classroom instruction in these activities on gains. These results, provided in the third and final set of columns in Tables 4 and 5, show that the IBR effect previously detected on listening comprehension becomes a trend, with the approximate effect size averaging $d^* = 0.23$. The positive effect for PA treatment on phonological awareness growth remains significant. Finally, inspection of the classroom activities effects in Model 3 across Tables 4 and 5 show two trends: greater classroom time on oral language was related to greater growth in expressive vocabulary ($p = 0.032$) and listening comprehension ($p = 0.054$) and increased classroom storybook reading time was linked with better listening comprehension gains ($p = 0.059$).

Discussion

To our knowledge, no prior study has examined preschool emergent literacy interventions for children with Autism Spectrum Disorder (ASD) using a set of three planned, consecutive RCTs. Overall, these results indicate that young children with ASD can improve in some areas of emergent literacy (receptive and expressive vocabulary, phonological awareness) in comparison to a typically developing norming sample while maintaining a similar growth pattern in others (listening comprehension, print knowledge, and word reading). In addition, interventions using Interactive Book Reading (IBR) and Phonological Awareness (PA) had positive and specific effects in the expected domains. Whereas all children improved in expressive and receptive vocabulary and phonological awareness, only children in the IBR condition improved in listening comprehension and those children experienced more growth in vocabulary than children in the control condition. As well, children in the PA condition also improved more in phonological awareness than children in the control condition. Effects were observed only in the skill domain that was the focus of the intervention; print knowledge and letter-word reading were not affected in either condition. Moreover, when we controlled for classroom time on activities similar to the interventions, the pattern of findings remained.

Notably, the PA condition elicited significantly greater on-task behavior than IBR. It may be that the use of a visual schedule and consistent play reinforcement at the end of each session

resulted in greater child attention. It is also possible that our lesson plans and use of three short activities provided more structure for tutors, resulting in greater child attention as well.

The results of this study also support the findings of other studies of preschool children with ASD that the pattern found in older readers with ASD of relative strength in word reading and weakness in reading comprehension (e.g., Brown et al., 2013; Nation et al., 2006) appears to be established early (Davidson & Weismer, 2014; Dynia et al., 2014; Dynia et al., 2017; Lanter et al., 2012). In the young children, it is print-related skills that are stronger and listening comprehension and vocabulary that are weaker, but the pattern appears to be similar. This leads one to speculate that if greater attention is paid to developing vocabulary and listening comprehension in preschool, perhaps later difficulties may be prevented or attenuated. This speculation is supported by evidence from our study suggesting that children whose preschool teachers spent more time on language development and storybook reading had greater growth in expressive vocabulary and listening comprehension.

The measures on which these effects were found were broad measures of the skills. That is, they did not measure the vocabulary words taught by the particular books in the study or specific phonological skills taught in the intervention. Consequently, the obtained effects reveal a generalized increase in children's vocabulary, listening comprehension, and phonological awareness. We view this as a strength of the study because it is easier to increase vocabulary knowledge on a taught set of words than to increase vocabulary more broadly. Other studies have used language measures that were aligned with the specific content of the interventions and found positive results (e.g., Bowyer-Crane et al., 2008; Whitehurst et al., 1994), but our results were more generalized and have potential to provide lasting benefit. As well, the standard scores used in this study were based on age norms from a norming population that did not include more than a few children with ASD. Any gains found in this study are in comparison to the developmental patterns of typical preschool children who were also improving over time.

Limitations

Like any intervention study, there are several limitations to this study. One is our use of a multiple RCT design in which students were randomized to only two of three treatments in each cohort. Although we endeavored to keep all recruitment, enrollment, measurement, fidelity, and intervention procedures identical across the cohorts, differences among cohorts are inevitable and it is not possible to untangle cohort from which pair of treatments were compared. Despite this limitation, there were remarkably few differences detected on student demographic characteristics and measures; indeed, we found only one significant difference among the three cohorts. Despite our careful planning of the three consecutive RCTs, our findings are limited by the size of the combined sample's group sizes as we were only able to detect modest effect sizes. Another limitation is our lack of measurement of inter-observer agreement for treatment fidelity and classroom observations. Due to staff and scheduling constraints, this was not possible, but some of the fidelity data may not be as reliable as we prefer. Another limitation is our use of outside tutors and not naturally occurring school personnel to carry out our intervention. Without data at the start of this study that demonstrated effectiveness with this population, we did not think it a good use of school

resources to conduct the interventions and thus provided our own tutors. Our findings are further limited by variability among the population we studied. We relied on parent and educator identification of an ASD diagnosis and did not independently verify this diagnosis. Finally, our measures may require further refinement for children with ASD. All of the measures we employed have norm-referenced scores based on a TD population; as such, it may be the case that the children in our sample exhibited more growth than we could measure.

Implications for Practice

One noteworthy aspect of our findings is that the obtained effects of intervention were the result of children's exposure to no more than 20 minutes of focused intervention activities 3 to 4 days a week. Treatment students in the present study received approximately 12 hours of intervention, on average. This is a parsimonious amount of time across the 20 weeks of the study, and although 1:1 intervention requires great resources, 7 to 20 minutes a day is not outside the realm of possibility for many preschool programs that serve children with ASD. Also noteworthy is our finding that children who started out with lower skills had better gains than those who began the year with higher skills. We are conducting moderation and mediation analyses to further understand why this is the case. However, because the goal is to ameliorate areas of relative weakness in areas critical for emergent literacy, we think this finding is particularly promising. This finding also flies in the face of some teacher beliefs that only children with strong verbal skills are ready for literacy-based activities designed to expand vocabulary and phonological awareness. In other words, the evidence from our study suggests preschoolers with ASD who use at least some language might benefit in some way from instruction in PA and IBR.

Implications for Research

Based on the findings from this study, several implications for research emerge. One is whether the results found immediately after intervention maintain over time or change as children go through their kindergarten year. As well, it is important to ascertain whether one group of children was differentially prepared for the reading instruction they received in kindergarten; an effect measured by examining reading and reading comprehension at the end of the year. Another is to begin to understand the "active ingredients" of the IBR intervention through examination of mediation of the intervention effect due to differences in tutor prompting and dosage. We also plan to examine moderation effects on the IBR and PA intervention effects due to child characteristics such as autism symptomology and initial language status. As well, a study of the two interventions with school personnel and small groups would help move these interventions closer to school practice. Finally, we think future research should concentrate on determining the patterns of early achievement that predict later reading comprehension success in children with ASD in order to better guide intervention efforts during crucial early years.

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Panel A: Vocabulary **Panel B: Emergent Literacy**

Figure 1.
Model-Implied Gains for Vocabulary (Panel A) and Emergent Literacy (Panel B)

Table 1

Classroom Observations of Literacy Activities

Activity	IBR (<i>n</i> = 45)		PA (<i>n</i> = 42)		BAU (<i>n</i> = 44)		All Conditions (<i>n</i> = 131)	
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
Print Concepts	2.19	(2.47)	2.08	(2.44)	2.06	(3.35)	2.11	(2.77)
Phono Aware	0.24	(0.77)	0.62	(1.62)	0.47	(1.98)	0.44	(1.53)
Alphabetics	0.54	(1.14)	0.81	(2.23)	0.42	(1.21)	0.59	(1.59)
Phonics	1.10	(1.64)	0.74	(1.59)	0.44	(1.31)	0.76	(1.53)
Oral Language	13.16	(5.93)	13.24	(8.78)	12.63	(7.47)	13.01	(7.40)
Oral Storybook	4.28	(5.43)	3.60	(3.93)	2.19	(2.84)	3.36	(4.28)
Student Reading	0.73	(1.36)	1.21	(1.78)	0.54	(1.59)	0.82	(1.60)
Writing	1.36	(2.11)	1.87	(3.19)	0.53	(1.26)	1.24	(2.35)
Other (Non-Lit)	36.41	(6.54)	35.83	(10.00)	40.75	(9.45)	37.68	(8.96)

Note. IBR = Interactive Book Reading condition, PA = Phonological Awareness condition, BAU = no-treatment Business-as-Usual condition. Values are observed minutes during one midyear preschool observation for each student afforded to literacy activity or grouping strategy during the first 60 minutes of teacher-designated literacy focused classroom activities; missing observations for two IBR students (with their teachers) from Cohort 3.

Sample Descriptive Statistics

	IBR (<i>n</i> = 47)						PA (<i>n</i> = 42)						BAU (<i>n</i> = 44)					
	Pretest		Posttest				Pretest		Posttest				Pretest		Posttest			
Measure	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)	<i>Gain</i>		<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)	<i>Gain</i>		<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)	<i>Gain</i>	
<i>Age (Months)</i>	55.89	(3.73)	--	--			55.10	(4.80)	--	--			56.30	(3.99)	--	--		
<i>Autism Index</i>	83.89	(19.16)	--	--			80.84	(16.07)	--	--			83.10	(18.93)	--	--		
<i>Vocabulary</i>																		
Recept Voc	78.62	(16.93)	87.77	(18.88)	<i>9.15</i>		81.50	(18.83)	86.45	(19.23)	<i>4.95</i>		83.05	(18.67)	86.93	(17.01)	<i>3.89</i>	
Express Voc	86.87	(17.34)	94.54	(20.31)	<i>7.67</i>		88.26	(16.98)	90.60	(19.78)	<i>2.34</i>		86.73	(18.07)	89.14	(18.22)	<i>2.41</i>	
Listen Comp	78.15	(16.69)	83.78	(18.42)	<i>5.63</i>		82.21	(13.86)	82.29	(17.03)	<i>0.08</i>		80.93	(17.68)	80.48	(18.68)	<i>-0.45</i>	
<i>Emerg Literacy</i>																		
Phono Aware	75.21	(15.33)	83.23	(15.83)	<i>8.02</i>		79.21	(15.22)	91.74	(22.65)	<i>12.53</i>		77.88	(18.94)	82.11	(17.96)	<i>4.23</i>	
Print Know	103.09	(14.74)	105.17	(11.88)	<i>2.08</i>		102.73	(15.57)	103.64	(15.30)	<i>0.91</i>		106.14	(13.92)	105.36	(10.15)	<i>-0.77</i>	
Word Read	109.31	(17.97)	109.08	(12.26)	<i>-0.23</i>		110.55	(16.82)	112.64	(20.10)	<i>2.09</i>		112.30	(17.52)	114.16	(20.85)	<i>1.85</i>	

Note. IBR = Interactive Book Reading condition, PA = Phonological Awareness condition, BAU = Business-as-Usual condition. For Word Reading, $r_s = .26$, .42, and .23, for IBR, PA, and BAU, respectively. Age = months old at pretest; Autism Index = Gilliam Autism Rating Scale-2 total index percentile; Recept Voc = receptive vocabulary as measured by the Peabody Picture Vocabulary Test IV; Express Voc = expressive vocabulary as measured by the Expressive One-Word Picture Vocabulary Test IV; Listen Comp = listening comprehension as measured by the Woodcock Johnson III Listening Comprehension cluster; Phono Aware = phonological awareness as measured by the Comprehensive Test of Phonological Processing Phonological Awareness subtest; Print Know = print knowledge as measured by the Test of Preschool Early Literacy Print Knowledge subtest; Word Read = word reading as measured by the Woodcock Johnson III Letter-Word Identification subtest. All tests in standard scores.

Table 3

Multilevel Model Gains Results (Model 1)

	Vocabulary Outcomes						Emergent Literacy Outcomes					
	Recept Voc		Express Voc		Listen Comp		Phono Aware		Print Know		Word Read	
	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p	Coeff	p
Fixed Effects												
Intercept (Gain)	6.20	.001	3.99	.004	2.15	.151	8.03	.001	0.31	.851	0.91	.541
Random Effects	Var	p	Var	p	Var	p	Var	p	Var	p	Var	p
Teachers	8.04	.087	0.10	.250	0.08	.342	0.89	.293	0.01	>.500	23.62	.012
Districts	0.01	>.500	0.01	>.500	5.26	.092	4.45	.196	11.37	.007	0.04	>.500
Residual	169.53		121.24		129.41		220.30		123.83		122.45	
Model Indices												
No. Parameters	4		4		4		4		4		4	
Deviance (-2LL)	1066		1008		1013		1032		1016		710	

Note. N= 1 33 students (47 Interactive Book Reading (IBR), 42 Phonological Awareness (PA), and 44 Business-as-Usual(BAU)), 57 teachers, and 8 districts. Cohort 1 missing word reading outcome; thus word reading, *ns* = 27, 43, and 21, for IBR, PA, and BAU, respectively. Recept Voc= receptive vocabulary as measured by the Peabody Picture Vocabulary Test IV; Express Voc= expressive vocabulary as measured by the Expressive One-Word Picture Vocabulary Test IV; Listen Comp = listening comprehension as measured by the Woodcock Johnson III Listening Comprehension cluster; Phono Aware = phonological awareness as measured by the Comprehensive Test of Phonological Processing Phonological Awareness subtest; Print Know = print knowledge as measured by the Test of Preschool Early Literacy Print Knowledge subtest; Word Read = word reading as measured by the Woodcock Johnson III Letter-Word Identification subtest. All tests are in standard scores. Observed *p*-values reported; significant adjusted *p*-values (*p* < 0.017) are in boldface.

Table 4

Multilevel Model Treatment Effects Results for Vocabulary Outcomes (Models 2–3)

Fixed Effects	Recept Voc						Express Voc						Listen Comp					
	Model 2			Model 3			Model 2			Model 3			Model 2			Model 3		
	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*
Intercept (Gain)	6.02	.001		5.91	.001		3.93	.004		3.89	.004		1.99	.138		1.87	.148	
IBR Effect	2.53	.096	.21	2.50	.109	.20	3.09	.021	.29	2.96	.030	.28	3.33	.017	.30	2.55	.068	.23
PA Effect	−0.92	.551	−.07	−0.97	.529	−.08	−1.53	.256	−.14	−1.55	.249	−.15	−1.62	.247	−.15	−1.60	.248	−.15
Pretest	−4.57	<.001	−.37	−4.73	<.001	−.39	−1.16	.223	−.11	−1.37	.154	−.13	−1.97	.051	−.18	−2.02	.045	−.19
Class Obs: PA				0.98	.369	.08				0.02	.982	.00				−0.81	.400	−.07
Class Obs: OL				1.77	.117	.15				2.13	.032	.20				1.98	.054	.18
Class Obs: SR				−0.40	.728	−.03				0.03	.978	.00				1.99	.059	.18
<i>Random Effects</i>																		
Teachers	Var	p		Var	p		Var	p		Var	p		Var	p		Var	p	
	0.45	.267		0.21	.342		0.11	.227		0.10	.217		0.14	.287		0.17	.435	
Districts	0.01	.317		0.01	>.500		0.00	>.500		0.01	>.500		3.17	.149		2.68	.142	
Residual	151.12			148.54			115.05			112.37			120.34			115.55		
<i>Model Indices</i>																		
No. Parameters	7			10			7			10			7			10		
Deviance (−2LL)	1045			1027			1001			983			1002			981		

Note. $N = 13$ 3 students (47 Interactive Book Reading (IBR), 42 Phonological Awareness (PA), and 44 Business-as-Usual(BAU)), 57 teachers, and 8 districts. For Model 3, IBR $n = 45$ due to two missing Cohort 3 students' classroom observations. Recept Voc = receptive vocabulary as measured by the Peabody Picture Vocabulary Test IV; Express Voc = expressive vocabulary as measured by the Expressive One-Word Picture Vocabulary Test IV; Listen Comp = listening comprehension as measured by the Woodcock Johnson III Listening Comprehension cluster. All tests in standard scores. Pretest = respective pretest standard score, in z-scores; Class Obs = minutes observed during classroom observation that student participated (within 60-minute period), in z-scores (PA = phonological awareness, OL = oral language, and SR = storybook reading). Observed p -values reported; significant adjusted p -values ($p < 0.017$) are in boldface.

Table 5
Multilevel Model Treatment Effects Results for Emergent Literacy Outcomes (Models 2–3)

Fixed Effects	Phono Aware						Print Know						Word Read					
	Model 2			Model 3			Model 2			Model 3			Model 2			Model 3		
	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*	Coeff	p	d*
Intercept (Gain)	7.96	.003		8.18	.001		-0.02	.990		0.13	.924		0.55	.718		0.80	.601	
IBR Effect	-1.62	.354	-.12	-1.20	.507	-.09	0.93	.411	.10	1.50	.198	.16	-1.30	.466	-.11	-0.77	.670	-.07
PA Effect	5.45	.003	.39	5.00	.007	.36	-0.24	.836	-.02	-0.61	.607	-.06	1.24	.434	.11	0.98	.533	.09
Pretest	-4.79	<.001	-.34	-4.60	.001	-.33	-6.77	<.001	-.70	-7.06	<.001	-.74	-4.13	<.001	-.36	-4.60	<.001	-.41
Class Obs: PA				1.53	.217	.11				0.43	.601	.04				2.34	.060	.21
Class Obs: OL				1.85	.159	.13				0.74	.388	.08				1.29	.307	.11
Class Obs: SR				-0.17	.902	-.01				-1.02	.262	-.11				-0.78	.616	-.07
Random Effects																		
Teachers	Var	p		Var	p		Var	p		Var	p		Var	p		Var	p	
	14.77	.110		14.57	.161		6.41	.129		7.62	.092		40.45	<.001		39.08	<.001	
Districts	10.60	.057		4.47	.179		11.65	.002		7.63	.015		0.03	>.500		0.02	>.500	
Residual	173.01			172.80			76.44			74.72			92.65			87.13		
Model Indices																		
No. Parameters	7			10			7			10			7			10		
Deviance (-2LL)	1013			994			950			933			697			677		

Note. $N=13$ 3 students (47 Interactive Book Reading (IBR), 42 Phonological Awareness (PA), and 44 Business-as-Usual (BAU)), 57 teachers, and 8 districts. For Model 3, IBR $n=45$ due to two missing Cohort 3 students' classroom observations. Cohort 1 missing word reading outcome; thus for both models on word reading, $ns=26, 42$, and 23, for IBR, PA, and BAU, respectively. Phono Aware = phonological awareness as measured by the Comprehensive Test of Phonological Processing Phonological Awareness subtest; Print Know = print knowledge as measured by the Test of Preschool Early Literacy Print Knowledge subtest; Word Read = word reading as measured by the Woodcock Johnson III Letter-Word Identification subtest. All tests in standard scores. Pretest = respective pretest standard score, in z -scores; Class Obs = minutes observed during classroom observation that student participated (within 60-minute period), in z -scores (PA = phonological awareness, OL = oral language, and SR = storybook reading). Observed p -values reported; significant adjusted p -values ($p < 0.017$) are in boldface.