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Does intensity matter? Preschoolers' print knowledge development within a classroom-based intervention

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ABSTRACT

The present study examined the extent to which two dimensions of intervention intensity, (*dose frequency* and *dose*) of a 30-week print-referencing intervention related to the print knowledge development of 367 randomly selected children from 55 preschool classrooms. *Dose frequency* refers to the number of intervention sessions implemented per week; teachers were randomly assigned to either the high-dose frequency condition (four intervention sessions per week) or the low-dose frequency condition (two intervention sessions per week). *Dose* refers to number of print-referencing teaching strategies used per intervention session and was a naturally varying variable across classrooms. Structural models of children's spring print knowledge showed a significant interaction of dose and dose frequency in relation to children's outcomes. Follow-up analyses showed that the benefit of providing four versus two print-referencing sessions per week disappeared when teachers were providing a relatively intense number teaching strategies within sessions (i.e., the dose was high). Considered differently, findings also show that increasing the number of print referencing teaching strategies within a session (i.e., the dose) related positively to children's print knowledge development, but only when the weekly number of intervention sessions were low (i.e., two intervention sessions weekly). Overall, findings show that there is a benefit to increasing the dose or dose frequency of the print referencing intervention, but increasing both aspects of intervention intensity appeared to have a diminishing benefit to children's learning. Findings empirically support the multi-dimensional nature of intervention intensity and implications for research and practice are discussed.

Children's literacy performance shows considerable stability across the preschool and elementary years (La Paro & Pianta, 2000; National Early Literacy Panel [NELP], 2008; Storch & Whitehurst, 2002). In fact, research has demonstrated that precursory literacy skills in preschool and kindergarten (i.e., emergent literacy skills) collectively explain more than one-half of the variance in children's first grade reading ability (Storch & Whitehurst, 2002). Reciprocally, children whose emergent literacy skills lag behind peers upon school entry tend to stay behind their peers on formal tests of reading and writing in later grades (e.g., Duncan et al., 2007). Such findings have compelled the research and practice communities to rigorously explore practices that support key areas of emergent literacy development among young children, particularly those who experience risk due to environmental and developmental factors.

Research points to two particular emergent literacy skills, namely print knowledge and phonological awareness, as critical to children's early reading success (for reviews see NELP, 2008; Snow, Burns, & Griffin, 1998). *Print knowledge* reflects children's knowledge of the forms and functions of print, and encompasses multiple inter-related skills, including alphabet knowledge, emergent writing, and print concepts (e.g., Justice & Ezell, 2001; Lomax & McGee, 1987). *Phonological awareness* reflects young children's ability to isolate and manipulate the sound parts of words (i.e., syllables, sounds, onsets and rimes; e.g., Anthony & Lonigan, 2004). The present study involved an examination of how interventions implemented within the preschool classroom can support young children's emergent literacy skill development and, in particular, young children's development within the area of print knowledge. Longitudinal studies of the prospective relations between early achievements in print knowledge and later outcomes in word recognition make clear the importance of improving our understanding of how to support this aspect of emergent literacy development.

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Policy shifts over the past few years reflect the field's growing interest in promoting young children's print knowledge development within the context of the early childhood classroom. The majority of states now have explicit early learning standards mandating that state-funded preschool classrooms address developmental milestones related to print knowledge (e.g., Georgia Department of Early Care and Learning, 2007; Ohio Department of Education, 2006). Despite the field's interest in promoting young children's print knowledge within the preschool classroom, children show considerable individual differences in print knowledge at kindergarten entry (Duncan et al., 2007). Of particular concern is that children from disadvantaged homes, compared with more advantaged peers, demonstrate systematically weaker print knowledge skills and experience fewer and less frequent opportunities to engage in print at home (e.g., Downer & Pianta, 2006; Duncan et al., 2007; Storch & Whitehurst, 2001). Thus, there is an obvious need for improving the quality and extent of print knowledge support within the preschool classroom, especially for those children lacking literacy support at home. Indeed, preschool literacy experiences may be a critical, if not necessary, means of ensuring that all children enter kindergarten primed for later reading success.

Significant federal investment has gone into the design and evaluation of preschool emergent literacy curricular programs or teaching techniques over the past five to seven years (see Preschool Curriculum Evaluation Research Consortium [PCER], 2008 for a review of 14 curricula). What has become evident through this effort is the importance of examining conditions which may enhance, or detract from, an intervention's effect, particularly as interventions are scaled-up for the fields' wide-spread use across heterogeneous settings and users (McDonald, Keesler, Kauffman, & Schneider, 2006). An example of this point can be drawn from the body of work related to the instructional intervention called print referencing (e.g., Justice & Ezell, 2000, 2002; Justice, McGinty, Piasta, Kaderavek, & Fan, 2010; Lovelace & Stewart, 2007). Print-referencing involves adult-use of verbal comments and questions about print coupled with nonverbal print-focused behaviors – such as tracking the print and pointing to print – within the context of adult–child storybook reading (Justice & Ezell, 2004). In small-scale, tightly controlled efficacy trials, research shows that adults' use of print-referencing during shared reading translates to medium-to-large effects on children's print knowledge learning, relative to business-as-usual storybook reading conditions (e.g., Justice & Ezell, 2000, 2002). A recent study showed, however, that when print referencing is implemented in scaled-up conditions (i.e., implemented under authentic field conditions with large, diverse samples), effect sizes attenuate (Justice et al., 2010). In fact, Justice et al. (2010) found that 30-week of teacher-led print referencing during shared reading had a significant, but small ($d = 21$) effect on children's print knowledge outcomes, when compared against 'regular' (i.e., business-as-usual) shared reading. Understanding the reasons that an intervention effect may attenuate within scale-up efforts is critical as it speaks to generalizability of previous study findings (across heterogeneous users and settings) and implementation parameters (e.g., intensity) that may be critical to an intervention's effect.

This study examined how the *intensity* of print referencing related to children's print knowledge development over 30 weeks of preschool. Specifically, two measures of intensity were considered. The first, dose frequency, refers to the number of intervention sessions conducted within a week. The second, dose, refers to the number of print-referencing teaching strategies used per intervention session. The intent of the study was to examine how these dimensions of intervention intensity independently and interactively related to children's print knowledge development over the course of the 30-week print-referencing intervention.

It is important to note that this study is a direct extension of the recent work on print referencing by Justice et al. (2010) and extends that study in two ways. The first extension was regarding the sample. Justice et al. (2010) considered the difference in child outcomes across classrooms using print referencing four times per week (i.e., high-dose frequency print-referencing) versus classrooms using no print referencing (i.e., comparison condition where teachers conducted regular book reading four times per week). However, in the broader randomized controlled trial (RCT), a third study condition existed involving teachers' use of print referencing only two times per week (i.e., low-dose frequency print-referencing). This study focuses on comparing the high-dose frequency print referencing condition to the low-dose frequency print referencing condition in order to consider how this aspect of intervention intensity (i.e., *dose frequency* of print referencing) relates to child outcomes. A second way that this study built upon Justice et al. (2010) was in its focus on teacher *behavior* within the intervention. The majority of previous work on print referencing examined child outcomes as a function of intervention condition, but has not examined the treatment, directly. Therefore, this study considered whether, and how, the number of print referencing teaching strategies used (i.e., *dose* of print referencing) related to children's print knowledge development.

1. Theoretical frame for exploring intervention intensity

Intensity seems to be a particularly important parameter of intervention to examine. Indeed, optimal effects of a specific therapeutic technique may rely largely on accurate specification and administration of the intervention, as it does in the field of medicine. Interventions terminated too quickly may not provide enough of an intervention to be beneficial whereas interventions continued too long may be costly without producing additional or larger effects. Certainly, intervention intensity information from other areas of emergent literacy development has led to increased precision in delivery recommendations. For example, in the area of phonological awareness, the National Reading Panel (National Institute of Child Health and Human Development [NICHD], 2000) has synthesized evidence to determine that optimal phonological awareness treatments last between 5 and 18 h, and that longer treatment periods had no evidence of additional benefit. To date, little equivalent specific information exists regarding recommended intervention intensities for children's print knowledge development. The present study represented a first step toward understanding whether and how intervention intensity may influence the learning young children show within the print-referencing intervention.

Intervention intensity, as defined by Warren, Fey, and Yoder's (2007) recent paper on this topic, separates intensity into five distinct dimensions: dose frequency, dose, dose form, total intervention duration, and cumulative intervention intensity (see Warren et al., 2007 for a complete definition of each of these variables). Collectively, these intensity dimensions capture the nature and extent of the practice that occurs within a particular intervention. According to current and historical discussions of learning theory, practice of a skill is an obvious and necessary component of learning (e.g., Donovan & Radosevich, 1999; Thorndike, 1912). Yet, research and theory also suggest that all practice is not equal and that *how often and how much* practice takes place is important to the extent of learning that may occur. Two of the intensity parameters described by Warren et al., namely *dose frequency* and *dose*, capture important information regarding how often and how much opportunity for practice is provided within a set intervention period. As stated earlier, dose frequency refers to the number of times an intervention is delivered within a given time period

(per week for this study; Warren et al., 2007). Dose refers to the number of times within a session intervention goals are addressed (e.g., number of print referencing teaching strategies; Warren et al., 2007).

Empirical research supports the salience of dose frequency and dose to children's learning outcomes. Laboratory-based work on learning suggests that spaced practice periods which are more frequent (e.g., higher dose frequency) and less concentrated (e.g., lower dose) lead to higher levels of performance and retention of information compared to less frequent (lower dose frequency), more concentrated (higher dose) practice periods, as in "cramming" for an exam (Janiszewski, Noel, & Sawyer, 2003). In fact, research shows that high-dose practice sessions produce overload and a certain maximum level of learning (Janiszewski et al., 2003). Implicit in this theoretical work is the possibility that dose frequency and dose may work dynamically to produce the optimal intensity of an intervention to maximize learning. The extent to which these patterns remain consistent in applied settings and in relation to learning over longer periods of time, however, have not been well explored. Indeed, applied studies of intervention intensity have focused only on the effect of varying dose (e.g., Proctor-Williams & Fey, 2007) or dose frequency (Ukrainetz, Ross, & Harm, 2009), but not both. This study builds upon a small literature examining intensity in relation to learning within applied intervention studies. Specifically, this study explored the independent and interactive effects of dose frequency and dose of the print-referencing intervention to child print knowledge development. As such, this study takes a nuanced and theoretically motivated approach to the study of intervention intensity and applies it to an intervention that currently lacks precise information regarding its implementation.

2. Dose frequency and dose of the print-referencing intervention

Currently, there are six published studies that have examined the impact of the print-referencing intervention on children's print knowledge development (Ezell, Justice, & Parsons, 2000; Justice & Ezell, 2000, 2002; Justice, Kaderavek, Fan, Sofka, & Hunt, 2009; Justice et al., 2010; Lovelace & Stewart, 2007). Across the varied efficacy studies of the print-referencing intervention, different dose frequencies of intervention have been applied. Outside of the scale-up study previously discussed (i.e., Justice et al., 2010), moderate-to-large intervention effects have been observed across the other tightly controlled efficacy trials. For example, significant gains in children's print knowledge skills, consistent with medium-to-large size effects, have been reported in the literature for one-on-one reading sessions conducted four times per week over four weeks in children's homes (Justice & Ezell, 2000), for small-group reading sessions conducted three times per week over an eight-week period in Head Start settings (Justice & Ezell, 2002), for one-on-one reading sessions conducted two times per week over a 13-week period in a targeted enrollment early learning center (Lovelace & Stewart, 2007), and for whole-class reading sessions conducted four times per week over a 30-week period in targeted enrollment preschool classrooms (Justice et al., 2009). The consistency of positive intervention effects across studies could suggest that the print-referencing intervention may exert its effects fairly easily, regardless of variation in dose frequency. Yet, across studies, dose frequency differences have also been confounded with group size differences (e.g., one-on-one, small group, large group), participant differences (e.g., children with language impairment, children from homes in poverty), and intervention setting differences (e.g., home, school). These confounding factors make it difficult to extrapolate any trends regarding the relationship between dose frequency of the print-referencing intervention and child print knowledge outcomes.

Additionally, the relationship between dose of the print-referencing intervention and child print knowledge outcomes has been largely unexplored. Descriptive data from print-referencing efficacy trials have shown that adults vary widely in the dose of print-referencing teaching strategies applied within a given print-referencing intervention session. For example, data from Justice and Ezell's (2000) home-based study of print-referencing intervention showed that parents who were instructed to use six print-referencing teaching strategies across the entire book reading session were actually quite variable in their actual implementation. Although most parents generally met the minimum dose, the range with which they used print-referencing teaching strategies per minute of book reading was wide and ranged from 0.64 times per minute to 3.6 times per minute. These data raise questions about whether such differences in dose may be associated with child outcomes and whether dose of the print-referencing intervention, rather than dose frequency, best captures the actual intensity of intervention implementation.

3. Study aims

This study investigated the extent to which two dimensions of intervention intensity (dose frequency, dose) of the print-referencing intervention related to children's print knowledge development over 30 weeks of preschool. This study involved a sample of children who were primarily from low-income households and, thus, were at elevated risk for relative lags in print knowledge development and later reading difficulties. Importantly, teachers in this study were randomly assigned to use the print-referencing intervention four times per week for 30 weeks (high-dose frequency condition), or two times per week for 30 weeks (low-dose frequency condition), thus allowing this study to examine causal relations between dose frequency (120 vs. 60 intervention sessions over the 30-week study period, respectively) and children's print knowledge development. Additionally, teachers in this study were given general recommendations regarding a recommended dose of print-referencing teaching strategies to provide per intervention session (i.e., number of print-referencing teaching strategies used per session), allowing this study to examine how natural variation in dose of the print-references may be associated with children's print knowledge development. Uniquely, this study explored how dose frequency and dose may work independently *and* interactively to influence children's print knowledge development (e.g., Fey et al., 2006; Proctor-Williams & Fey, 2007; Ukrainetz et al., 2009; Warren et al., 2007).

Three specific research questions were asked. First, to what extent does dose frequency of the print-referencing intervention associate with children's growth in print knowledge? Second, to what extent does dose of the print-referencing intervention associate with children's growth in print knowledge? Finally, do dose frequency and dose interact to influence children's growth in print knowledge?

4. Method

4.1. Participants

The present study involved 55 teachers and 367 randomly selected children (original sample) from their classrooms. All participants were part of a multi-site, multiple cohort, and longitudinal randomized controlled trial (RCT) study investigating the effects of the print-referencing intervention on children's print knowledge. As stated earlier, this RCT included three study conditions: high-dose frequency print-referencing (four times per week), low-dose frequency print-referencing (two times per week), and a compar-

ison condition (regular book reading four times per week) and research on the main effects of the print referencing intervention for the high-dose frequency and comparison conditions has been reported previously (see Justice et al., 2010). The present study, however, sought to answer research questions central to understanding the potential importance of intervention intensity within the print-referencing intervention. Therefore, this study only involved the two of the three study conditions (high-dose frequency, low-dose frequency conditions), and excluded the comparison condition.

4.1.1. Classrooms

The 55 classrooms included in this study were drawn from early childhood programs located in two states (Ohio, Virginia). The 55 classrooms consisted of all 31 classrooms randomly assigned to the high-dose frequency condition, and 24 (two classrooms eliminated due to missing data) of 26 classrooms from the RCT randomly assigned to the low-dose frequency condition. The different number of classrooms per condition is a function of random assignment procedures. Random assignment was applied at the classroom level but stratified by cohort (two cohorts of data are reflected in this final sample) and by site (Ohio, Virginia). As a result, there were sometimes small differences (± 1) in the number of classrooms per condition within a cohort and within a site. Aggregated up, these differences resulted in the final sample sizes per condition reported in this study.

Ascertainment of programs involved dissemination of information and contact with program directors who then self-selected their programs into the project. Typically conversations with program directors would occur in the summer and classrooms were formally recruited in the weeks before the start of the school year. At the end of the formal recruitment window, classrooms would be randomly assigned to one of three conditions (high-dose frequency print-referencing, low-dose frequency print-referencing, comparison). All participating programs served preschool-aged children experiencing social, economic, or developmental risk. Specifically, the present study included 24 Head Start federally funded classrooms, 26 classrooms from state-supported preschool programs, and five private preschool programs which included a large contingency of socio-demographically and/or developmentally at-risk children. In most classrooms, a teacher and aide/assistant managed approximately 16 children (1:8 teacher–child ratio).

4.1.2. Teachers

Only lead teachers took part in this project. Teachers self-selected into this study via informed consent after listening to information sessions presented at their participating program. All participating teachers ($n = 55$) agreed to attend professional development sessions, submit questionnaires, adhere to the schedule of the print-referencing intervention, and submit videotapes of their implementing the print-referencing intervention. Research personnel randomly assigned participating teachers to the high-dose frequency ($n = 31$) or the low-dose frequency ($n = 24$) condition.

The educational level of the 55 participating teachers included 26% with an advanced/graduate degree, 38% with a bachelor's degree, 29% with an Associate's degree or some college, and 7% with a high school degree. In terms of race and ethnicity, teachers identified themselves as White/Caucasian (67% of sample), Black/African American (26%), Multi-Racial (5%), or Hispanic/Spanish/Latino (2%). The average teacher had 10.7 ($SD = 8.1$) years of experience teaching preschool.

4.1.3. Children

In participating classrooms, information flyers and child consent forms were sent home to the primary caregiver via children's backpacks. Caregivers were asked to return the consent form (signed or unsigned) within two weeks to the teacher. Teachers were asked to follow-up with parents during this 2-week period. Overall, signed and returned parent consents indicating interest in the study ranged per classroom from 5 to 15. The exact number of children randomly selected from each classroom ranged from three to nine per classroom depending upon the pool of parent consents received.

The sample of children for this study originally included 367 children, comprising 201 children in the high-dose frequency condition and 166 children in the low-dose frequency condition. For the high-dose frequency condition ($n = 201$), six children had missing values on both pre- and post-measures of the outcomes variables. For the low-dose frequency condition ($n = 166$), three children did not have pre- and post-measures of outcome variables. As these nine children did not have any data on the three outcome variables used in later analyses, they were excluded from analyses. There were another 73 children who did not have complete data on all the variables used in our analysis, typically missing some post-measures. Comparison of these 73 children with those 285 children with complete data revealed no significant differences in age, family income, or initial print knowledge abilities (measured by a composite) between the two groups. Further, the racial and gender compositions were also comparable. In light of these findings, we decided to handle the missing data for these 73 children analytically by using the full information maximum likelihood (FIML) approach in structural equation modeling. As a result, for our modeling analyses described later, the total sample size was 358 ($N = 195$ for the high-dosage frequency condition, and $N = 163$ for the low-frequency dosage condition).

For the children in this study, caregiver report of annual household income was between $25,000 and $30,000, with 65% of the sample falling at or below this income range. In terms of the educational attainment by children's mothers, 2% of mothers held an advanced/graduate degree, 7% held a Bachelor's degree, 5% held an Associate's degree, 62% held a high school degree or the equivalent, and 15% did not hold a high school degree. Data were missing for 9% of children's mothers. Caregiver report of race and ethnicity identified 41% of children as White/Caucasian, 39% of children as Black/African American, 8% of children as Multi-Racial, 7% of children as Hispanic/Spanish/Latino, 0.4% of children as Asian, and 1% of children as Other. Race/ethnicity was not reported for 2.5% of children. The majority of children spoke English in the home (90.5%). Children's average age at study entry (calculated as of October 1 in the fall of children's preschool year) equaled 52.4 months ($SD = 4.46$). Of the participating children in the present study sample, 49.5% were girls and 50.5% were boys.

4.2. The print-referencing intervention

Teachers implemented the print-referencing intervention with their whole class in either two (low-dose frequency) or four (high-dose frequency) large-group shared reading sessions weekly for 30 weeks. A print-referencing intervention session required teachers to read a designated book of the week and to address two print targets two times during each reading. All teachers, regardless of condition, read the same storybook, in the same order, and followed the same scope and sequence of addressing the print targets within each session across the year. All the storybooks used in the print-referencing intervention were commercially available books and addressed topics appropriate for 3–5-year-olds. Additionally all books contained print-salient features, such as speech bubbles and font changes, and mostly included fictional stories with some representation of alphabet and informational books. Teachers received one new book per week for the entire 30-week intervention period.

The print targets teachers' addressed in the intervention consisted of utterances related to: print organization ("I'm going to

Table 1
Descriptive statistics of the study variables for two conditions.

	Low-dose frequency (24 classrooms)[b]			High-dose frequency (31 classrooms)		
	M	*SD*	Gain score fall to spring (standardized)[c]	*M*	*SD*	Gain score fall to spring (standardized)[c]
Child characteristics[a]						
Age	52.62	4.66		52.24	4.30	
Attendance	141.21	27.96		141.61	31.32	
Alphabet knowledge						
Fall	10.06	9.95		7.40	8.40	
Spring	17.55	9.06	0.96	16.88	8.91	1.21
Name writing						
Fall	4.39	2.14		3.58	2.09	
Spring	5.76	1.78	0.74	5.75	1.66	1.03
Print concepts						
Fall	7.32	3.15		5.96	3.45	
Spring	10.24	3.84	0.79	8.95	3.91	0.93
Classroom characteristics						
Dose of print-referencing (*z*-score)	0.91	3.30		−0.53	3.66	
Words (raw)	10.34	5.02		9.71	6.47	
Letters (raw)	14.27	7.61		12.55	7.71	
Book/print (raw)	8.90	4.48		7.30	4.50	
Print meaning (raw)	2.34	1.62		1.55	1.55	
Classroom quality	4.36	0.93		4.17	0.97	

[a] Age reported in months. Attendance refers to total number of days present. Alphabet knowledge scores based on scale of 0–26. Name writing scores based on scale of 1–6. Print concept scores based on scale of 0–17. Dose represents amount of print-related teaching strategies used per intervention session, reported as standardized scores (*z*-scores). Classroom quality represents average of teacher's instructional and emotional support and scores based on scale of 1–7.

[b] Sample sizes varied for different study variable due to some missing data on different variables. The final usable samples for modeling analysis were $N = 195$ and $N = 163$ for high and low-dose frequency conditions, respectively (see Section 4.1 for details).

[c] Gain score was based on the standardized mean difference between fall and spring outcome measures.

begin reading right here, at the top of the page."), print meaning ("Let's read this book to find out what it is about."), letters ("What is the name of this upper-case letter?") and words ("Wow, this word caterpillar is very long but this word sun is short."). The entire scope and sequence is presented in prior research reports on this intervention (see Justice et al., 2009). The two weekly print targets were printed on a card with accompanying examples of utterances and placed within each week's book. For example, in Week 2, all teachers read the storybook, *There's a Dragon at My School*, and talked about the way the print was organized two times ("Where should I start reading on this page?") and the concept of words in print two times ("Show me three words on this page").

Teachers were asked to "address each print target at least twice" during each reading. Beyond these minimal guidelines of dose per reading session (i.e., four references to print; two references per print target), no other instruction was given to teachers. The data (Table 1) show that most teachers provided much more instruction than the minimal required amount and that teachers varied widely in the dose of instruction provided per reading session.

The only difference across the two treatment conditions (high-dose frequency and low-dose frequency) was the number of times the book was read during the week. The teachers in the high-dose frequency condition read the book four times per week compared to the low-dose frequency condition in which teachers read the book two times per week. Overall, the teachers in the high-dose frequency condition conducted a total of 120 print-referencing sessions over 30 weeks, whereas the teachers in the low-dose frequency condition conducted a total of 60 print-referencing sessions over 30 weeks.

4.2.1. Teacher training

Prior to beginning the 30-week print-referencing intervention, teachers participated in a one-day professional development workshop. The workshop included an information session on print knowledge development and emergent literacy instruction, a review of a manual describing the print-referencing intervention framework and teaching strategies (*Calling Attention to Print*; Justice & Sofka, 2005) and practice sessions with peers in using the intervention. As a refresher, teachers also participated in a 3-h professional development workshop approximately 15 weeks into the program in which principles of program implementation were reviewed.

4.2.2. Fidelity to intervention

Teachers were asked to videotape a print-referencing session every other week throughout the 30-week intervention; a minimum of 10 videos had to be submitted for study compliance. Teachers were provided a video camera, recording media, and stamped/addressed mailers for this purpose. For this corpus of 10 videos, a fidelity check was conducted which involved coders determining (yes/no) whether teachers addressed the two designated print-related instructional targets for the selected book at least twice during reading. At two points during the intervention, feedback letters were sent to teachers reminding him/her about the print referencing intervention guidelines and providing specific feedback regarding their adherence to the program. Overall, 92% of teachers met each of the two designated print related instructional targets at least twice across the corpus of 10 videos examined. However, there were differences by condition. All of the teachers in the low-dose frequency condition met both instructional targets across ten examined videos; 87.1% of teachers in the high-dose frequency condition demonstrated this level of fidelity (Chi-Square = 40.16, $p < 0.001$).

4.3. Measures

Three types of measures were used: (a) child print knowledge measures, (b) intensity measures, and (c) covariates. Child print knowledge measures served as the primary dependent measures in this study. Intensity measures served as the primary independent measures of this study, and included measures of dose frequency and dose. Covariates included child factors (i.e., age at study entry, preschool attendance, and fall print knowledge skill) and classroom factors (i.e., classroom quality) that have been shown to be strong independent predictors of children's print knowledge development. Coding of intensity measures (i.e., dose of print-referencing)

and classroom (i.e., classroom quality) were completed by coders who were blind to the conditions to which teachers were randomly assigned.

4.3.1. Child print knowledge measures

Measures of children's print knowledge were collected as part of a broader test battery conducted in the fall and spring of children's preschool year. The majority of examiners were research assistants, doctoral students, and project staff. All testing was completed on an individual-basis in a quiet space within each child's preschool center or school. Examiners assessed children's print knowledge along three dimensions (i.e., alphabet knowledge, name writing, and print concepts) using two standardized criterion-referenced measures. Each measure has been used previously in emergent literacy research and has demonstrated adequate reliability and validity (e.g., Invernizzi, Sullivan, & Meier, 2004; Justice, Bowles, & Skibbe, 2006; Justice, Chow, Capellini, Flanigan, & Colton, 2003).

Alphabet knowledge was evaluated using the *Phonological Awareness Literacy Screening PreK*: *Uppercase alphabet knowledge subtest* (*PALS PreK*; Invernizzi et al., 2004). Examiners presented the child with all 26 letters randomly written on a large sheet of paper and asked him/her to name each letter. Each time a child named a letter correctly, he/she received one point. Name writing was evaluated using the *PALS PreK*: *Name Writing Subtest* (Invernizzi et al., 2004). Examiners presented the child with a sheet of blank paper and asked the child to draw a picture of him/herself and then write his/her name. The *PALS PreK: Name Writing Subtest* uses a 7-point scoring system scale for rating children's name writing ability (1 = name indistinguishable from picture; 7 = legible and orthographically complete name). Print concepts (e.g., book and print organization, print meaning) were evaluated using the *Preschool Word and Print Awareness* assessment (*PWPA*; Justice & Ezell, 2001; Justice, Sofka, Sutton, & Zucker, 2006). Examiners subtly inserted print-related questions into a shared storybook reading session to test children's knowledge of 14 concepts about print (e.g., "Where do I begin to read?"). The *PWPA* provides raw scores (ranging from 0 to 17) and "trait estimates" (item-response theory (IRT)-based standard scores) to represent children's knowledge of print concepts (Justice, Bowles, et al. 2006, Justice, Sofka, et al. 2006).

4.3.2. Intensity measures

Two measures of intensity were collected for this study: *dose frequency* and *dose*. *Dose frequency* was represented by the randomly assigned study condition to include high-dose frequency condition (implementing print-referencing intervention sessions four times weekly) or low-dose frequency condition (implementing sessions two times weekly). *Dose* was represented by the number of teachers' use of print-related teaching strategies during an intervention session for four categories of print: (a) print organization (e.g., "Eric Carle is the author of this book."), (b) print meaning (e.g., "The cereal box says 'Cheerios'), (c) letters (e.g., "What letter is this?"), and (d) words (e.g., "Let's look at the words on this page."). These categories were mutually exclusive and exhaustive.

Coding related to this study's measure of dose was completed by project staff and research assistants following completion of a comprehensive training program. The training program included familiarization with print-related teaching strategies within the four categories of print, practice identifying teacher's use of print-related teaching strategies during book reading, and passing of a reliability test (i.e., 90% agreement about the frequency of teacher's use of print-related teaching strategies across five gold-standard observations). To complete coding related to dose, coders watched the teacher-submitted video in its entirety, wrote down each teacher print-related teaching strategy, and categorized it into one of the four categories of print based on key words and phrases (see Table 2). Coders were free to pause the video during coding, as necessary. The raw count of a teacher's use of print-related teaching strategies was summed within each print category to arrive at a total raw score per print category. The raw score for each of the four print categories was then converted to a standardized score (*z*-score). The standardized scores for each of the four print categories were then summed for a total dose score for each intervention session. Totaling scores across print categories is supported by the significant and high correlation among the standard scores of each print category ($r = 0.7$ and above, $p < 0.01$). Further, principal components analysis supports a single factor structure for print-related teaching strategies across print categories (Eigen value = 3.12; 71 of the total variance explained). To ensure the reliability of the coding for dose of the print-referencing intervention, a random selection (10%) of the videos were independently double coded. Point-by-point inter-rater agreement averaged 81.6% for print organization, 76% for print meaning, 86.4% for letters, and 94.4% for words.

4.3.3. Covariates

The present study controlled for a number of child-level and classroom-level characteristics that have been demonstrated in the literature to be key predictors of young children's print knowledge and emergent literacy development (e.g., Justice, Mashburn, Pence, & Wiggins, 2008; Lomax & McGee, 1987; Mashburn et al., 2008; NELP, 2008). Child-level characteristics included as covariates were: age at study entry, preschool attendance, and fall print knowledge. Fall print knowledge was measured as a latent construct based on the observed measures of print knowledge described previously (see subsequent section on Data Analysis for a discussion of modeling print knowledge as a latent construct). Child's age at study entry was calculated through a chronological age calculator based on the child's birthday (parent-reported), with study entry designated as October 1 of the intervention year. Preschool attendance was based on school attendance records provided to the research team from teachers or administrators at the end of the school year (i.e., end of the intervention year). Attendance was calculated for each group condition and for each child. For the high and low-dose frequency intervention groups, attendance refers to the average number of days students in each condition attended school (see Table 1). To specifically determine attendance for each participating child, the percentage of possible days present for each child was calculated (i.e., total days attended/total possible operating days of the school). A single classroom-level covariate was that of global classroom quality. Global classroom quality was measured through the *Classroom Assessment Scoring System-PreKindergarten* (*CLASS-PreK*; Pianta, La Paro, & Hamre, 2005). The *CLASS PreK* captures 11 dimensions of classroom quality (rated along a 7-point scale) that comprise three domain areas: instructional support, emotional support, and behavioral support. For the present study, a single composite measure of classroom quality was created by averaging two of the three domains, namely instructional support and emotional support. These two dimensions were selected given their relevance to child academic outcomes and were averaged as they demonstrated generally high correlation in this and other study samples ($r = 0.83$; see also Hamre & Pianta, 2005; Pianta & Stuhlman, 2004). *CLASS PreK* ratings were made by trained and reliable coders who had demonstrated 90% agreement with six gold-standard observations.

5. Data analysis

For the purposes of this study, we considered hierarchical linear modeling (HLM) versus structural equation modeling (SEM) as our analytical tool. HLM framework easily accounts for the issues of a nested data structure (i.e., non-independence of individual observations, and the resultant inflation of Type I error in statis-

Table 2
Codes for defining teaching episodes (Dose).

Print domain	Abbreviated definition	Abbreviated list of key words and phrases	Teaching episode example
Book and print organization	The order in which the pages are read, the job of the author, reading occurs from top of the page to bottom, the role of the title, reading occurs from left to right	Author, writer, written/wrote	"I'm going to begin reading right here, at the top of the page".
		Title Print Page (s)	
Print meaning	Print function, words in the environment, discussion about the role and function of print and books for sharing information	Read (s/ing)	"Let's read this book to find out what it is about."
		The "why" of reading Book/story + front, back, spine, beginning, end	
Letters	Letters come in 2 forms, names of different letters, the same letter can be used in many ways	Letter (s)	"What is the name of this upper-case letter?"
		Uppercase, etc. Any letter name	
Words	Some words are short, others are long; letters make up words, words are distinct units of print that are different than letters	Word (s)	"Wow, this word caterpillar is very long but this word sun is short."

Note. Adapted from Justice, Sofka, et al. (2006).

tical testing if the nested data structure were ignored (Raudenbush & Bryk, 2002). On the other hand, HLM, as a univariate analytical framework, cannot account for the relationships among the print knowledge measures, as it does not accommodate multiple outcome variables in the same analysis (i.e., multiple print knowledge measures). In addition, HLM does not account for measurement error of the predictor variables. As is well known in the research and measurement literature (e.g., Fan, 2003; Gulliksen, 1987), measurement error may considerably attenuate the relationships among variables/constructs. For our research involving young children, this could be an important concern, as it is usually more difficult to obtain reliable measurements for young children.

As a multivariate analytical framework, structural equation modeling (SEM) can accommodate the two issues (accounting for the relationships among multiple print knowledge measures; modeling measurement error in analysis) discussed above (e.g., Fan, 2003; Jöreskog & Sörbom, 2001; Loehlin, 2004; Thompson, 2000). However, for our data, if an SEM approach is used, a statistical correction should be applied to account for the nesting effect (i.e., children are nested within classrooms), so as to avoid the problem of an inflated Type I error rate. After weighing the strengths and weaknesses of both approaches, we used SEM approach for our analysis, and used a statistical correction procedure to address the issue of inflated Type I error as a result of nested data structure. However, it is important to note that all results were corroborated using Hierarchical Linear Modeling as the analytic technique, a spring print knowledge factor score as the outcome, and the fall print knowledge factor as a covariate. Although these results are not presented, there was general agreement between the two analytic approaches (SEM, HLM).

To correct for data nesting within SEM models, the "root design effect" (DEFT; Kish, 1965; NCES, 2002) was estimated and then applied as a correction factor in statistical testing, by multiplying the standard error of an estimator with this correction factor (NCES, 2002; Fan, 2001; Warren, LePore & Mare, 2001). By applying this correction, the problem of inflated Type I error caused by the nested data structure can be avoided.

In this study, estimation of the root design effect (DEFT) was based on the cluster sample size (n) and the intraclass correlation coefficient (ρ) of the nested data, based on the following equation (e.g., Kerry & Bland, 1998):

$$\text{DEFT} = \sqrt{1 + (n-1)\rho} \quad (1)$$

The intraclass correlations on the three univariate models were 0.18 (alphabet knowledge), 0.23 (name writing), and 0.29 (print concepts). The cluster sample size (i.e., children under each participating classroom teacher) was approximately five to six. To correct for the cluster sampling in statistical testing, the average of the intraclass correlations (0.23) was chosen, yielding a correction factor magnitude of 1.47. This correction factor value indicated that the standard error when accounting for the nested data structure was 1.47 times larger than the standard error obtained when assuming simple random sampling. This correction factor was applied in all SEM analytic models reported.

5.1. Print knowledge as a latent construct

Three aspects of print knowledge were measured, namely alphabet knowledge, name writing, and print concepts. Rather than creating a separate model per outcome, measures of intervention intensity were modeled on the latent construct of "print knowledge." By representing print knowledge as a latent construct, the model also could account for measurement error when estimating the association between intervention intensity and print knowledge development. Thus, the SEM model was conceptually a multivariate ANCOVA model in which the effects of dose frequency, dose, and their interaction were modeled on the latent construct of spring print knowledge, while controlling for the latent construct of fall print knowledge and extracting measurement error from the model estimates.

5.2. Covariates

The covariates initially tested included child age at study entry, preschool attendance, fall print knowledge, and classroom quality. In the preliminary analyses, once fall print knowledge was included as a covariate in the model, none of the remaining covariates were statistically related to the outcome measures (i.e., spring

print knowledge skills). For the sake of model parsimony, these other covariates (i.e., age at study entry, attendance, classroom quality) were not included in the final model.

6. Results

A SEM model was implemented to empirically examine how dose frequency (i.e., a dummy variable representing low vs. high-dose frequency conditions), dose (i.e., a continuous variable representing the number of print-referencing strategies per intervention session, on average), and the interaction between the two, affected children's print knowledge development (i.e., spring print knowledge after controlling for fall print knowledge). Within the two intervention conditions, dose was free to vary and therefore served as a continuous variable. The probability of testing for close fit was statistically non-significant ($p = 0.29$), leading to the conclusion that one should *not* reject this model. Model fit assessment information indicates the extent to which the model reproduced data and also indicated that the model fitted the data very well. There were a number of fit indices examined and these are described here (see also Table 3). The root-mean-square error of approximation (RMSEA) is an adjusted χ^2 based on the degrees of freedom in the model and lower values suggest better fit (0.05 = good fit, 0.08 = reasonable fit, 0.10 = poor fit). The Comparative Fit Index (CFI) is the extent to which the model fits the data better than a model assuming no association among variables and it imposes a penalty for the number of parameters estimated. CFI scores range from zero to slightly above one. The Tucker–Lewis Index (TLI) is a non-normed index measuring the extent to which the model fits the data better than a model assuming no association among variables and scores range from zero to slightly above one. The normed Tucker–Lewis Index (NFI) was also examined and scores range from zero to one.

6.1. The measurement model

The factor loadings for the observed print knowledge measures (alphabet knowledge, name writing, and print concepts) suggested that these measures were statistically reasonable indicators for the print knowledge latent construct, but each measure had a considerable amount of residual (i.e., variance not shared with other measures). It was likely that part of the residual for each observed measure (e.g., alphabet knowledge) represented its unique content, and such unique content would materialize as correlated residuals across times. For this reason, the model included correlated residual variances for each print knowledge indicator across fall and spring (see Fig. 1). Not surprisingly, the standardized coefficient from fall print knowledge to spring print knowledge outcomes was strong (0.77).

Table 3
SEM model (Fig. 1) fit assessment.

Model fit indices	Model with dose frequency, dose, and interaction term ($N = 358$)
χ^2	37.26 ($p < 0.05$)
df	17
RMSEA	0.06 CI_{90} = (0.03, 0.08) p (for close fit) = 0.28
CFI	0.98
TLI	0.95
NFI	0.97

Note. Fit indices indicate the extent to which the model reproduced data (typically the variance-covariance matrix of the data). *RMSEA* = Root-mean-square error of approximation is an adjusted χ^2 based on the degrees of freedom in the model and lower values suggest better fit, 0.05 = good fit, 0.08 = reasonable fit. 0.10 = poor fit; *CFI* = Comparative Fit Index is the extent to which the model fits the data better than a model assuming no association among variables and it imposes a penalty for the number of parameters estimated, range is from 0 to slightly above 1; *TLI* = Tucker–Lewis Index is a non-normed index measuring the extent to which the model fits the data better than a model assuming no association among variables, range from 0 to slightly above 1; *NFI* = is the normed Tucker–Lewis Index, range is 0–1.

6.2. The structural model

Overall, the model accounted for 67% of the variance in children's print knowledge development ($R^2 = 0.67$), suggesting the model accounts for children's print knowledge development well. The most salient finding in this SEM model was the statistically significant interaction between dose frequency (i.e., a dummy variable

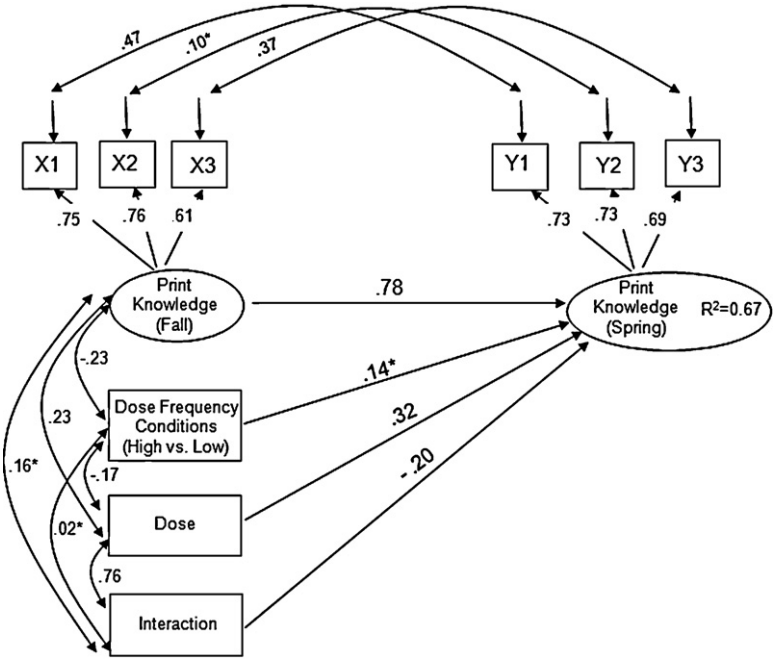

Fig. 1. Modeling the effects of dose frequency, dose, and their interaction on children's print knowledge development.
*Not statistically significant at $\alpha = 0.05$. All others are statistically significant after correction for clustering design effect.

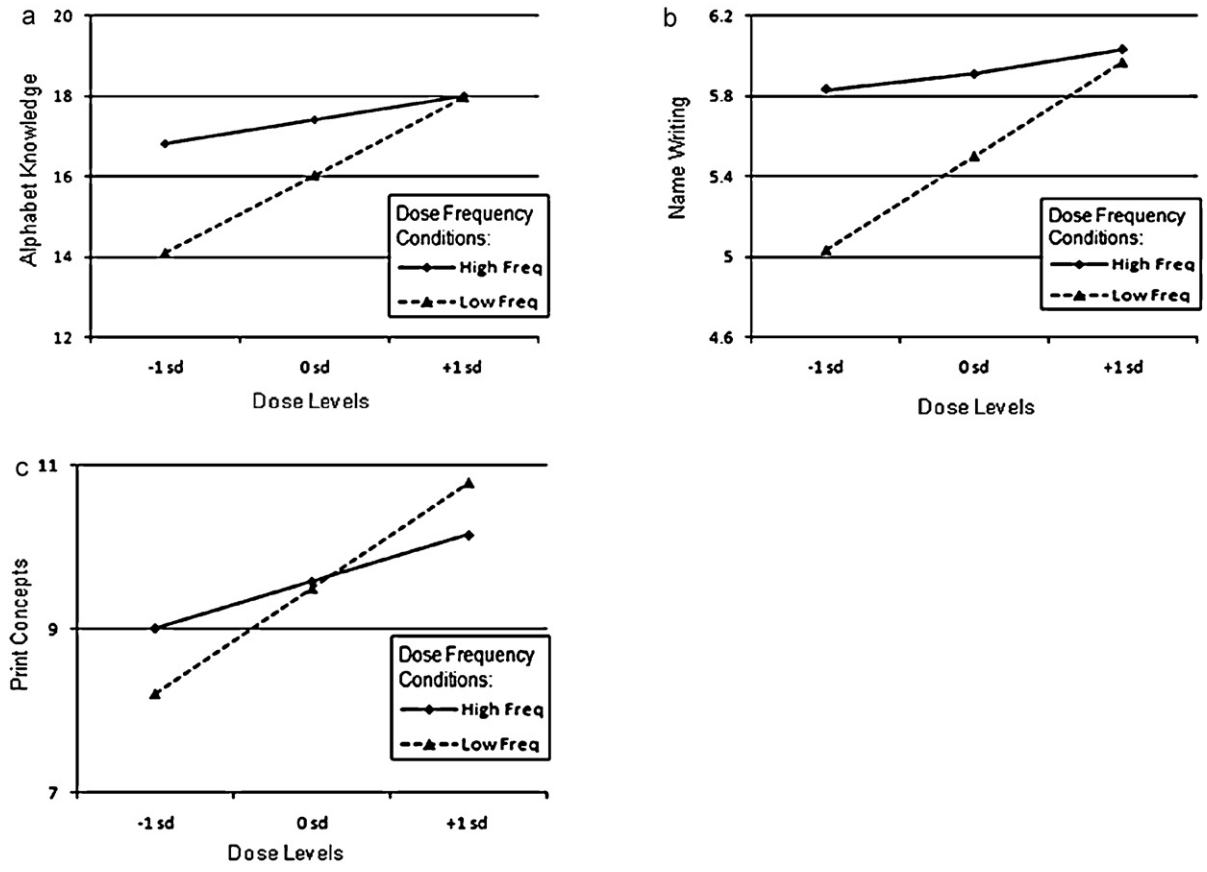

Fig. 2. Interaction patterns between dose frequency conditions and dose on three measures of print knowledge.

for two different treatment conditions) and dose (i.e., the number of print-referencing strategies per session) on print knowledge development. This statistically significant interaction suggested that the main effect of the dose frequency ($\beta = 0.12$; $p > 0.05$) and that of dose ($\beta = 0.32$; $p < 0.05$), as shown in this model, should *not* be interpreted as they are. Instead, the interaction indicated that the effect, or lack thereof, of the treatment conditions (high vs. low dose frequency conditions) on children's print knowledge development is moderated by dose. As such, it would not be appropriate to provide a general answer to the research question about how dose frequency influenced print knowledge development; nor would it be appropriate to provide a general answer to the research question about how dose influenced print knowledge development.

6.3. Follow-up analysis

To explore the interaction between dose and dose frequency, follow-up analyses were conducted for each measure of print knowledge. For the SEM model in Fig. 1, when we conduct univariate follow-up analysis for one variable at a time (e.g., spring Alphabet Knowledge measure with its fall measure as a covariate), the model is essentially a regression model for nested data. As a result, mixed-model analyses were conducted for each post-test measure (i.e., alphabet knowledge, name writing, and print concepts), while controlling for the corresponding pre-test measure. Results indicated that there was a main effect of dose across all measures ($p <$ or ≤ 0.001), but the effect dose frequency was only significant in relation to name writing ability. Importantly, the interaction between dose and dose frequency was statistically significant in relation to children's name writing ability ($p = 0.014$), but only showed a trend toward significance in relation to print concepts ($p = 0.052$) and alphabet knowledge ($p = 0.082$).

Fig. 2 plots the interaction pattern for each outcome. These figures represent the adjusted means of the three outcomes (i.e., posttest score, or spring measure) corresponding to three different levels of dose: low dose level (one standard deviation below the mean [−1 *SD*]), average dose level (at the mean [0 *SD*]), and high dose level (one standard deviation above the mean [+1 *SD*]), while controlling for the pretest score (i.e., fall measure), when dose frequency was high and low. The graphs suggest a similar pattern of interaction between dose and dose frequency across outcomes, despite the lack of statistical significance for this interaction on some univariate outcomes. These patterns, however, allow for interpretation of the significant interaction observed when print knowledge is conceptualized in a multivariate way (i.e., as a latent construct). The pattern of interaction shows that the effect of the treatment conditions (high vs. low dose frequency conditions) is not consistent across different levels of dose. In general, children under the high dose frequency condition outperformed those under the low dose frequency condition (although not statistically so in all cases). But the difference between the two conditions changed depending on dose level per session. More specifically, when dose level per session was low (e.g., at −1 *SD*), those in the high frequency condition appeared to outperform those in the low frequency condition. But when dose level per session was high (e.g., +1 *SD*), the performance difference between the high and low frequency conditions almost disappeared (alphabet knowledge, name writing), or even reversed (print concepts).

Given these findings about the interactive patterns between dose frequency and dose on outcomes of print knowledge, we are in the position to answer our research questions, which considered the effect of dose and dose frequency in relation to the broader, latent construct of print knowledge. For the first research question about the effect of dose frequency (i.e., to what extent does dose

frequency of the print-referencing intervention influence children's print knowledge development?), high dose frequency condition is more effective in enhancing children's print knowledge development than the low dose frequency condition, but only when the level of dose per session is low. If the level of dose per session is high, low dose frequency condition is almost as effective as the high-dose frequency condition.

For the second research question about the effect of dose level per session (i.e., to what extent is dose of the print-referencing intervention associated with children's growth in print knowledge?), level of dose per session has a positive effect on children's print knowledge development, but this positive effect is larger for those under the low-dose frequency condition; for those under the high-dose frequency condition, dose per session shows a much smaller effect.

7. Discussion

The present study examined the extent to which two dimensions of intervention intensity, (dose frequency and dose) of the print-referencing intervention related to children's print knowledge development over 30 weeks. Dose frequency represented a planned variation of intervention intensity, with classrooms being randomly assigned to conduct the print-referencing intervention two (low-dose frequency) or four (high-dose frequency) times per week. Dose reflected the average number of print-referencing strategies used per print-referencing session and was an aspect of intervention intensity that naturally varied across classrooms. The outcome, print knowledge, was conceptualized in this study as a complex ability represented by three distinct skills (i.e., name writing, alphabet knowledge, and print concepts). Findings revealed that these two dimensions of intervention intensity interacted in a compensatory pattern to contribute to children's print knowledge development. Specifically, when teachers provided a low dose of print-referencing teaching strategies per session (i.e., low dose), there was a benefit to receiving more print-referencing sessions per week (i.e., high-dose frequency vs. low-dose frequency). However, when the dose of print referencing per session was high, the two dose frequency conditions appeared to be almost equally effective in enhancing print knowledge development. Overall, findings empirically support the multi-dimensional nature of intervention intensity (see also Warren et al., 2007). The remainder of this discussion explores implications of the study findings, as well as how these basic findings may differ slightly across individual indicators of print knowledge.

The first key finding was that the dose of instruction, or the number of instructional episodes between adults and children, was a very powerful factor in children's learning. In fact, the present study found that, when session dose level was high, 60 print-referencing intervention sessions over 30 weeks was equally effective at fostering young children's print knowledge development as 120 print-referencing intervention sessions over 30 weeks. Further, across each individual print knowledge indicator, dose, rather than dose frequency, was the significant predictor of children's learning. Our findings are consistent with other intervention studies which show little benefit to repeating instructional sessions multiple times per week if the dose of instruction during any single instructional session is relatively high (NICHD, 2000; Proctor-Williams & Fey, 2007; Ukrainetz et al., 2009). These findings are also consistent with a broader literature that emphasizes the importance of the interactions between adults and children, rather than setting or activities, as the drivers of development (Mashburn et al., 2008; NICHD, 2002).

Given the importance of dose to children's learning, the natural question that arises is, what constitutes a high dose of instruction? In fact, there is little empirical guidance for defining high or low doses of instruction within focused, and explicit emergent literacy interventions. Ukrainetz et al. (2009), for example, defined an adequate dose as 20 teaching trials within an hour when targeting phonemic awareness. In the present study, definitions of high- and low doses of instruction were empirically generated and reflect whether teachers fell above (+1 *SD*) or below (−1 *SD*) the mean on a standardized composite of print referencing. Given the nature of this composite, there is not a clear translation between the measure of dose used in analytic models and teacher's actual print referencing behavior. Nonetheless, raw descriptive data of teacher's print referencing behavior can provide a useful context for interpreting this study's findings and, therefore, post hoc descriptives of teacher's print referencing behavior were examined. On average, teachers in our study used approximately 33.28 (*SD* = 17.68) print-referencing teaching strategies per session. Teachers providing low amounts of print referencing used approximately 15.6 teaching strategies per session, whereas teachers providing high amounts of print referencing used approximately 50.96 strategies per session. Notably, the average amount of print-referencing behavior occurring within this sample was a fairly high when considered next to that of teachers who have not been trained in the print-referencing intervention. For example, Justice et al. (2010) reported that teachers who had not been trained in print referencing ($n = 28$) made, on average 7.0 (*SD* = 6.0) references to print during an observed shared reading session in the fall and 12.0 (*SD* = 18.3) references to print during a spring observation. The fact that teachers in this study were providing children fairly high levels of print-referencing, when compared to the more general population of preschool teachers (i.e., those not trained in the intervention) is important. In the context where teachers may be using print referencing techniques, but not participating in a print referencing intervention study, it may be unlikely that such very intense doses of instruction would be provided. As such, this study's findings should not be extrapolated to mean that children in preschool classrooms do not benefit from having print-related instruction, or print referencing, on a daily basis. The findings suggest, rather, that there may be flexibility in how instructional intensity can be increased (via dose or dose frequency) to maximize children's print knowledge learning within print referencing.

The second key finding of the study was that increases to the intensity of instruction supported children's learning, but only up until a point. Fig. 2 illustrates this point. Across all three print knowledge indicators, there appears to be a diminishing benefit to increasing both the dose *and* dose frequency of the intervention. Statistical findings also speak to this idea, namely that there may be a threshold effect, or level of instructional intensity of print referencing beyond which children gain little benefit (Burchinal, Vandergrift, Pianta, & Mashburn, 2010). As stated earlier, dose, but not dose frequency was found to be statistically related to children's outcomes on measures of print concepts and alphabet knowledge. These data imply that children receiving moderate amounts of instruction across the week (i.e., high dose, but low dose frequency) will perform similarly to children receiving substantially more instruction in the same timeframe (i.e., high dose and high dose frequency). Similarly, the significant interaction between dose and dose frequency in relation to children's name writing ability followed a compensatory, rather than additive, pattern. These findings also suggest that 'more intensity' is not always an effective, or efficient, approach to implementing the print referencing intervention.

The idea of thresholds within instructional intensity is consistent with basic learning and memory research, which point to plateaus in learning after a certain amount of practice is amassed (Ambridge, Theakston, Lieken, & Tomasello, 2006; Janiszewski et al., 2003; Riches, Tomasello, & Coti-Ramsden, 2005). Further, applied work examining children's learning within instructional

contexts (e.g., the classroom, therapy session) have also suggested that there are discrete points related to the amount or quality of instruction, above which, children glean little benefit (Burchinal et al., 2010; Proctor-Williams & Fey, 2007; Ukrainetz et al., 2009). Yet, the data from this study were not always consistent with research suggesting that *the way* practice unfolds (e.g., with breaks, with spaced intervention sessions; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Janiszewski et al., 2003) is also central to children's learning. For example, some research points to the importance of spacing between intervention sessions to allow for cognitive recovery time and integration of information over time (Cepeda et al., 2006; Janiszewski et al., 2003). The findings related to alphabet knowledge and print concepts knowledge somewhat support this idea. Indeed, for these outcomes, increases to the dose of instruction per session, but not increases to the frequency of instructional sessions per week, supported children's learning. Yet, for the broader construct of print knowledge and for name writing ability, specifically, no configuration of intervention intensity appeared optimally suited to children's learning (i.e., increasing dose or dose frequency provided a similar benefit to children's learning). The fact that the configuration of intervention intensity mattered for some outcomes, but not others, emphasizes the point that relations between instructional intensity and learning are not likely to be consistent across different areas of development. It is beyond the scope of this paper to explore, in detail, how instructional intensity effects vary across different developmental areas; however, this represents an important direction for future research.

As a related point, it is important to acknowledge that intervention intensity findings, particularly findings suggesting a threshold of instructional intensity benefits, must be considered in light of the design of the print referencing intervention. The print referencing intervention is, by design, highly repetitive. Each lesson within a week uses the same materials (i.e., same storybook) and addresses the same few print-related instructional targets. Thus, teachers in the high-dose frequency condition were essentially repeating the same exact lesson (i.e., the same book, the same print-related targets) four times. As such, increases in intervention intensity (either dose or dose frequency) reflect higher levels of instructional repetition, rather than opportunities to use skills in novel situations or contexts. It is not necessarily surprising, then, to observe limits in the relationship between intervention intensity and child outcomes (see also Proctor-Williams & Fey, 2007). Yet it is possible that this plateau effect might largely disappear, should intervention sessions within a week vary their content (e.g., cycling across a variety of print knowledge skills within a week) or context (e.g., a different book, play versus storybook reading; Hodson, 2006; Hodson & Paden, 1991; Tyler, Lewis, Haskill, & Tolbert, 2003). It is also important to consider that the relationship between intervention intensity and child outcomes is somewhat a function of how intervention intensity was defined in this study and for this intervention. The nature of the print-referencing intervention made it easy to quantify dose of instruction based on the moment-by-moment interactions between adults and children. Yet, when dose of instruction must be defined differently, as may be the case in broader-based, more globally oriented interventions, it is not clear how dose, dose frequency, and child outcomes may relate.

7.1. Educational implications

Two educational implications may be drawn from this study. First, the findings from the present study suggest that dose is an especially important aspect of intervention to attend to; yet dose is often overlooked when planning intervention services for children. For example, early childhood educators often designate intervention in terms of dose frequency and duration (e.g., two times per week for 30 min), with little explicit consideration given to the intensity of exposure to instructional targets within an intervention session. At least for the print-referencing intervention, the intensity with which children are exposed to instructional targets within an intervention session can have a significant influence on their print knowledge outcomes. A further nuance in intervention intensity includes the content and context of the intervention. The present study found that straight repetition of instruction was actually helpful to young children's print knowledge learning, although limits were observed. Thus, early childhood educators might perhaps consider how to use classroom time most efficiently for promoting young children's print knowledge. This study suggests that simply repeating the print referencing intervention more often may not be the best use of classroom time. In fact, the study showed that providing a high dose of print referencing twice weekly affords the same benefit as providing print referencing four times weekly (regardless of dose). Therefore, it may be more useful to conduct print referencing twice weekly and consider ways of extending the instruction into other contexts, thus providing children repetition and opportunity to practice, but also chances to extend learning into novel materials or activities.

The second implication of the present study involves intervention planning. This study's findings suggest that there may be flexibility in how the print-referencing intervention is organized throughout a week. Indeed, the study suggests that children benefit equally should a teacher provide a moderate amount of instruction per session four times weekly or a high amount of instruction per session twice weekly. As such, configurations of intervention intensity are amenable to a variety of considerations (such as use of classroom time, children's preference and engagement) as the effect of dose and dose frequency appears less important than their combined, and cumulative, influence (although more work is needed to understand how this message may shift with respect to individual print knowledge skills). This has some significant implications to the design of emergent literacy interventions, especially those in the classroom.

7.2. Limitations and future research

Several limitations warrant note in this study. First, our analysis could not use growth modeling to potentially identify non-linear patterns in the relationship between intervention intensity and children's print knowledge development. As such, the data and analyses of this study do not allow for the identification of a specific threshold of intervention intensity which could more clearly guide implementation decisions around the print referencing intervention. Another limitation to this work involves the lack of information regarding the amount or degree of print practice children received across the day, outside of the intervention context. Perhaps teachers participating in the print-referencing intervention actually used these behaviors at other reading times throughout the day and week. More importantly, it also may be that teachers who provided a higher dose of print referencing were also more likely to apply the knowledge gained from the print-referencing intervention to other contexts and situations within their classroom. Thus, it is difficult to say that children's print knowledge learning was solely a function of the observed variables of dose and dose frequency in this study. Finally, and as previously discussed, these findings are not necessarily able to be generalized to samples beyond that of this study. Understanding the relationship of dose and dose frequency to children's outcomes when examined within a more typical sample of preschool classrooms (i.e., those who had not been trained in print referencing) is important for understanding intensity as a mechanism of children's learning within the print-related instruction, more globally. Furthermore, children in this study came from backgrounds of risk associated with low maternal education and low house-

hold income. It is unclear if these findings of intervention intensity apply to children experiencing other types of academic risk, such as children with language impairments or other developmental disabilities. Therefore, future research should consider whether the findings presented here might offer similar effects across different classrooms and populations of children.

8. Summary

This study examined the extent to which intensity of the print-referencing intervention related to children's print knowledge learning over 30 weeks. Specifically, this study considered how the number of intervention sessions provided per week (dose frequency) and the amount of practice provided per intervention session (dose) related to children's print knowledge learning. Study findings showed that these two dimensions of intervention intensity were related to children's outcomes, but in a compensatory, rather than additive way. In other words, findings demonstrated that increasing the dose (i.e., number of teaching strategies per session) or the dose frequency (number of weekly intervention sessions from two to four) of the intervention positively influenced children's learning; however, increasing both showed little additional benefit to children's outcomes. Findings suggest that increasing the intensity, or the extent of instructional repetition, within the print-referencing intervention can be beneficial to children's print knowledge learning, but that after a certain point, there are diminishing returns for this effort.

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