Contingent Responsivity in E-Books Modeled from Quality Adult-Child Interactions: Effects on Children's Learning and Attention

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Data Transparency and Openness

The data collected in this study and the scripts used to analyze these data are available in KiltHub–Carnegie Mellon's comprehensive institutional repository, which is part of the Figshare repository platform—at the following link: https://doi.org/10.1184/R1/7740170.v1.

Abstract

Experiences of contingent responsivity during shared book reading predict better learning outcomes. However, it is unclear whether contingent responsivity from a digital book could provide similar support for children. The effects on story recall and engagement interacting with a digital book that responded contingently on children's vocalizations (contingent book) were investigated, with a focus on the role of individual differences in attention. The study used a within-subject design with 3 experiments from ninety 3- to 5-year-old children. Children were presented with a contingent book and three noncontingent control conditions: a board book (Experiment 1), a static digital book (Experiment 2), and an animated book (Experiment 3). The use of the contingent book significantly increased children's story recall, and was also found to be especially useful for children with less developed attention regulation.

Keywords: attention; individual differences; recall; educational technology; preschool-age children; contingent interactions

Contingent Responsivity in E-books Modeled from Quality Adult-Child Interactions: Effects on Young Children's Learning and Attention

Introduction

A critical feature of effective communication between an adult and child is the presence of contingent responsivity; that is, that the feedback that the child receives is dependent upon their behavior (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). In the context of spoken language, a contingent response is when an adult responds reliably, promptly, and accurately to a child's vocalizations (Roseberry, Hirsh-Pasek, & Golinkoff, 2014). Contingent responsivity enables children to feel in control, maintains their focus, permits self-pacing, and encourages children to continue the interaction when each of their vocalizations is met with an appropriate response (Hirsh-Pasek et al., 2015). This interaction is in contrast to adult-directed interactions of one-sided control in which the parent leads and the child passively complies, or resists and disengages. Contingent caregiver responsivity extends children's capacities, and is positively associated with emerging cognitive and language competence (Tamis-LeMonda, Bornstein, & Baumwell, 2001).

Importance of Contingent Responsivity During Shared Book Reading

Shared book reading is a common activity that promotes contingent responsivity. Experiences of contingent responsivity during shared book reading predict better reading and language outcomes (Dickinson, Griffith, Golinkoff, & Hirsh-Pasek, 2012). The role of contingency is especially important during shared book reading because children are given the opportunity for conversational turns that lay the groundwork for literacy skills. Adults facilitate children's learning during shared book reading when they add more information, ask follow-up questions, praise, or point to relevant story content such as pictures that match the pronounced words (Ezell, Justice, & Parsons, 2000; Flack, Field, & Horst, 2018; Hargrave & Sénéchal, 2000). Adults' contingent responsivity through pauses and prompts direct children's attention to relevant story content that engage and help children interpret and understand the story narrative (Strouse, O'Doherty, & Troseth, 2013). When children vocalize and attempt to read along, adults facilitate children's understanding of the story with reinforced responsiveness by pointing to relevant story content such as pictures that match the pronounced words (Ezell, Justice, & Parsons, 2000; Flack, Field, & Horst, 2018). These nonverbal cues or gestures can serve as forms of contingent support, such as adults pointing instead of using verbal cues (Stone, 2002). For example, consider the following: an adult is reading a book to a child and the child vocalizes details from the story aloud, "cars stop." Responding contingently on the child's vocalizations, the adult praises the child and says, "Yes, that's right, the cars stopped!" and points to the cars and a stop sign illustrated in the book. This contingent responsivity encourages the child's communicative efforts and facilitates children's ability to learn features, such as congruent pictures associated with the pronounced words, and enables them to later reproduce an understanding about the words in relation to the story (Bus, 2001; Mason, 1990).

Prior studies have found that children learn significantly more when adults ask children to repeat target words from the text through questions and comments (Ard & Beverly, 2004; Blewitt, Rump, Shealy, & Cook, 2009; Ewers & Brownson, 1999; Sénéchal, 1997). Echo reading—a common pedagogical practice at school and at home—is a shared reading book strategy that occurs when children repeat a phrase or a sentence immediately after it is read to them (Barclay, 2009; Doake, 1985; Stahl & Heubach, 2005). The repeated reading component is intended to provide practice so that children develop fluent and automatic reading (Jennings, Caldwell, and Lerner, 2013). However, it is unknown whether children receiving a nonverbal contingent response upon repeating the text in an echo reading paradigm would have similar benefits as when adults contingently respond to children through questions and comments.

Storybook Interactions and Learning in the Digital Age

Children's earliest experiences with books are no longer limited to paper, and books are now accessible in the form of electronic books (e-books) through computers, smartphones, and tablets (Guernsey, Levine, Chiong, & Severns, 2012; Rideout, 2017). Many e-books have interactive features such as embedded animations, games, and sound effects that are activated by touching a spot on the screen (i.e., hotspots; Piotrowski & Krcmar, 2017). However, these kinds of interactive features have often been found to negatively affect learning in young children, in stark contrast to the contingent responsivity provided by adult co-readers (Bus, Takacs, & Kegel, 2015; Krcmar & Cingel, 2014; Parish-Morris et al., 2013). While the contingent responsivity adults provide synchronizes with children's story-related vocalizations, interactive features common in digital books—puzzles, games, hotspots, erroneous visuals and sound effects—may draw children's attention away from the story-related elements relevant to the narrative (De Jong & Bus, 2002).

There is evidence that specific types of contingent interactions using e-books promote different emergent literacy skills. Children's word reading and phonological awareness improved when the e-book interaction included adult responses that focused children's attention on the sounds of words in the story, compared to reading printed books with contingent adult responses, reading e-books alone, or receiving the regular kindergarten program (Segal-Drori, Korat, Shamir, & Klein 2010). Children's expressive vocabulary was enhanced when an e-book posed extratextual vocabulary questions, compared to e-books with hotspots, e-books without questions, or independently reading the e-book (Smeets & Bus, 2012). Tactile contingency such as requiring children to touch a relevant image improved 2- to 3-year old children's word learning compared to touching anywhere on the screen or passive interaction with the screen (Kirkorian, Choi, & Pempek, 2016). Conversely, it has been reported that children with low self-control are prone to excessive tapping of touchscreens, which may lead to more arbitrary tapping, frustration, and less learning (Troseth, Russo, & Strouse, 2016). Tactile need fulfillment and need for touch have also been found to be critical mechanisms that explain problematic digital device use and its association with depression and anxiety, an alarming finding with adults that researchers, tech designers, and policy makers should be aware of when thinking about designing the type of interactions children are encouraged to have with digital devices (Elhai, Levine, Dvorak, & Hall, 2016). One of the goals of this study was to design a paradigm in which an e-book responds contingently to children's vocalizations, reducing the need for tactile responsivity from children.

Other studies show that when comparing language exposure through contingent interactions with a person, children demonstrate quantifiably smaller amounts of learning from exposure to the same material presented noncontingently through digital media (Dore et al., 2018; Roseberry, Hirsh-Pasek, & Golinkoff, 2014; Subiaul, Vonk, & Rutherford, 2011). Research on children's verbal behaviors during shared book reading have found that children's repetition of parents' vocalizations is uniquely and positively related to children's overall story retelling abilities (Kang, Kim, & Pan, 2009); yet, little is known about whether children receiving a contingent response from an e-book upon repeating the text would have similar benefits on children's story recall. There is evidence that contingent responsivity in adult-child interactions produce large gains in learning outcomes and contingent responsivity in e-book interactions are capable of improving vocabulary knowledge and phonemic awareness in young children. It is unknown whether contingent responsivity in a digital book could provide similar support for children's ability to recall, retell, and describe key story events. As technology use in early childhood continues to exponentially grow, a greater understanding of the best design practices is needed. The effects of contingent responsivity have been extensively studied in adult-child interactions, but the effects of contingency responsivity on child vocalizations in child-to-digital book interactions on story recall and engagement are understudied in preschool-aged children.

Current Study

The current experiments examined whether a digital book that responds contingently to child vocalizations (contingent book) would increase story recall and engagement compared to three noncontingent control conditions. Children were read two commercially available stories marketed for prekindergarten children matched in age-appropriate content, length, and readability. In Experiment 1, we investigated the effects of a contingent book on children's story recall and engagement compared to a noncontingent board book control. Second, we examined whether the contingent book might be especially useful for children with less developed attention regulation. In Experiment 2, we replicated Experiment 1 with a noncontingent digital book so children were presented with both stories on a digital platform to be certain that the effects found in Experiment 1 were not due to the novel effect of technology. In Experiment 3, we replicated Experiments 1 and 2 with a noncontingent animated book to ensure that the effects found in the first two experiments were not solely driven by the illumination and movement from animations. Participants' engagement to each presentation was assessed by coding eye gaze duration towards each book condition, and children were asked questions about each narrative to assess story recall. Independent assessments of attention regulation and verbal ability were also administered.

Based on previous work on contingent responsivity in adult-child interactions increasing children's learning and engagement, we hypothesized that the contingent book would increase children's story recall and looking duration towards the book during the reading session compared to the noncontingent books. Previous studies have found that contingent responsivity supports children's limited attention skills and facilitates learning by directing attention to relevant content (Kirkorian, Anderson, & Keen, 2012; Kirkorian, Choi, & Pempek, 2016; Nussenbaum & Amso, 2016). Therefore, we hypothesized that the addition of story-related features that activate contingently on children's vocalizations would be especially beneficial for children who are easily distracted and score lower on the attention task. That is, because of these children's limited ability to focus on relevant material while suppressing extraneous details, they are the ones who might benefit the most from the guidance of self-paced story features that match their vocalizations.

Experiment 1

Method

Participants. All participants were recruited from the same pre-primary school on the campus of a private university in a Mid-Atlantic city in the United States. The school environment represents local racial and economic diversity with children being 74% White, 10% Asian or Pacific Islander, 7% Black or African American, 6% Middle-Eastern, and 3% Hispanic, with only 15% from university-affiliated households, and 33% of children attending on a partial or full scholarship. We based our target sample size on prior published work assessing the effect of e-books on child learning. The recruited and eligible children (N = 90) and sample sizes in each experiment are comparable to prior studies which examined the effects of e-books on learning in preschool-aged children (Moody, Justice, & Cabell, 2010; Smeets & Bus, 2012; Strouse, O'Doherty, & Troseth, 2013). The sample sizes in each experiment are also comparable to the Huebner & Meltzoff (2005) study, which investigated styles of book reading interventions with young children and conducted a power analysis showing that the intended sample size per experimental condition was adequate to detect group differences. Experiment 1 used a within-subject design with data from 35 children (16 males, 19 females) ages 3 to 5-years-old (M = 55.54 months, SD = 9.64 months). An additional child was tested but excluded due to equipment failure. The experimental protocol was approved by the Carnegie Mellon University Institutional Review Board (Study title: Learning and Development from Infancy to Adulthood, IRBSTUDY2015_00000471). Signed consent was obtained from the parents of participants. Children were tested individually by hypothesis-blind research assistants and given stickers for participation.

Materials and Procedure

Full descriptions of the materials, instructions, and procedure are provided in supplemental materials. Here we provide summaries of each.

Book Conditions

To maintain a high level of ecological validity, children were read two commercially available stories marketed for emergent readers written by the same author (Thacher Hurd), illustrated by the same illustrator, matched in artistic style, page length, and readability: *Cat's Pajamas* and *Zoom City*. Children were read one of the stories in the presentation of a noncontingent board book control condition, and the other story in the presentation of the experimental contingent book condition. Condition and story order were counterbalanced. Children were randomly assigned to one of the four orders:

(1) Cat's Pajamas Contingent Book First, Zoom City Control Book Second.

(2) Cat’s Pajamas Control Book First, Zoom City Contingent Book Second.

(3) Zoom City Contingent Book First, Cat’s Pajamas Control Book Second.

(4) Zoom City Control Book First, Cat’s Pajamas Contingent Book Second.

With permission from the author, both stories were converted into digital copies with the addition of contingent responsivity. The contingent responsivity was story-related animations that activated contingently on the child’s vocalizations. The responses of the contingent book were modeled from quality adult-child interactions by guiding children’s attention to relevant storybook content that follow their vocalizations (Justice & Kaderavek, 2002). When children said a word from the story aloud, the contingent book responded with story-related animations (e.g., child says, “car” and a picture of a car animates by popping off the page). The contingent book was presented to children on an Apple iPad (9.4 in x 6.6 in). When a word from the story was vocalized by the child, a congruent picture that represented the word grew in size with a short (500 millisecond) animation, and then shrunk back to its original size. For example, when children vocalized the text from *Zoom City* “fix the headlight,” the animation of a wrench turning generated when the word “fix,” was vocalized, and the animation of the car’s headlight flashing on and off generated when the word “headlight” was vocalized (see Figure 1, for static image of book page). Animations represented the meaning of verbs and nouns in the text (see Table S1 and Table S2, in the online supplemental material, for vocalized words that produced animations in each story). The word-animation mappings were chosen so that the main noun and verb for each line were represented, while prepositions and conjunctions that have difficult matching visual animations were not.

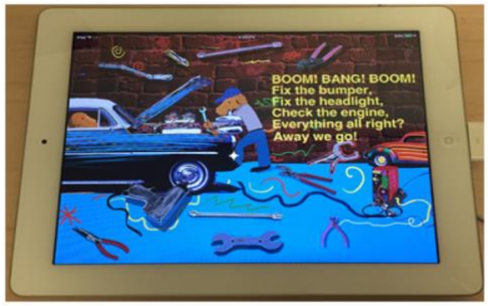

Figure 1. Example book page from *Zoom City*

The contingent book responded only to the child's vocalizations, not the reader's. To make this feature possible, the digital versions of *Cat's Pajamas* and *Zoom City* were converted into Apps using Framer Software, a design tool engineered for interaction work. Framer Software permitted the iPad to partner with another device so that the visual display on the iPad was also mirrored on a MacBook Pro 15-inch laptop. When the reader-child dyad swiped to the next page on the iPad, this was also displayed on the laptop. As the reader in the reader-child dyad read the contingent book to the participant on the iPad, a trained experimenter in an operations control room activated the content-related animations contingently on the child's vocalizations using the laptop. If a child vocalized the word from the story "car," the experimenter using the laptop activated the animation of the car growing. The testing room with the reader-child dyad was connected to the operations control room, but the rooms were separated with a curtain (see Figure S1 in the online supplemental material for layout of how the experimenter activated animations contingently on the child's vocalizations). This setup made it possible for the pronounced vocalizations of the child audible to cue the experimenter when to generate the animations. It was established during pilot testing that all child vocalizations were audible to the experimenter in the other room who deployed the animations.

The reader in the reader-child dyads was a trained hypothesis-blind research assistant who was instructed to read the books aloud to participants. For both book conditions, the reader was the same and started each session by reading the first line of the story, and then said "Now it's your turn to read!" to the child and then paused. This prompt was stated for the first page of each story and children responded by repeating the first line segment. This prompt encouraged children to vocalize similar to how adult readers in dialogic shared reading interactions pause and encourage children to repeat the words in the story during the shared reading sessions (Strouse, O'Doherty, & Troseth, 2013). For both conditions, the reader followed the protocol of pausing after each line in the story for five seconds, until the child vocalized the words to model prior research paradigms finding a positive association between the duration of time adults pause for children to respond and the information children retain from the story (Read, Macauley & Furay, 2014; see Table 1, for total pages, lines, and animations, by story). The reader continued reading each line in the book like traditional shared book reading and if the child did not practice reading the line after 5 seconds, the reader moved on and read the next line. Because the amount of feedback is highly variable from adults during shared book reading and the quantity and quality of feedback influences children's learning outcomes, these instructions were implemented to ensure the effects of the contingent book and noncontingent control book could be examined with minimal influence from extra-textual talk from the reader. Readers were specifically instructed to pause and give children time to respond to mimic a feature of shared reading sessions that children typically encounter in their classroom or at home when reading with their teacher and caregivers (Crain-Thoreson & Dale, 1999). On average, each story had approximately three words per line because short segments suited for beginning readers have been found to be optimal length in echo reading interactions (Hitchcock, Prater, & Dowrick, 2004; Jennings, Caldwell, and Lerner, 2013). In both reading conditions, the reader listened attentively to children's vocalizations and as in traditional shared book reading if children made any extratextual queries or comments—if any—were answered with the prompt: "That's interesting, what do you think?" so children's extratextual comments and queries were neither encouraged or discouraged (Sénéchal, 1997). Vocalizations were coded as the percentage of words the participant said aloud out of the total words in the story. Across all 3 experiments, there were no significant differences in vocalizations and there was a ceiling effect: children were inclined to vocalize all of the words in the stories after the reader across conditions. Therefore, vocalization data were not included in subsequent analyses (see Table 1, for mean vocalizations, by story; see the online supplemental material for vocalization coding and reader protocol).

Table 1
Pages, lines, animations, and vocalizations, by story

	Zoom City	*Cat's Pajamas*
Total Pages	14	14
Total Lines	29	31
Total Animations	32	30
Mean Vocalizations (*SD*)	96.74% (5.67%)	96.80% (6.16%)

Note: Vocalizations were computed as the percentage of story words children said aloud out of the total words in each story.

Procedure

All sessions took place in the same testing room that allowed for detailed audio and video recordings. Reader-child dyads were taped with two digital cameras: a Logitech C920 HD Pro Webcam and a Panasonic HDC-HS80 Camcorder. Each session was recorded using a Talent USB-1 Studio Condenser Microphone to obtain high-quality recordings of children's responses to the recall questions. Audacity 2.1.3 software was used to record and create an audio file (sample rate 44100 Hz, sample format 16-bit, bit rate 96 kbps) of each session. Once produced, the audio file was exported to MP3 format for analysis. Engagement and responses to the recall questions were subsequently coded offline based on video and audio recordings of the testing sessions.

Measures

Story Recall Measure

Story recall is considered one of the most appropriate assessments for children, and is assessed through narrative reconstruction of retelling events that play a central role in the structure of stories (Kendeou et al., 2005; Morrow 1990; Nilsson, 2008; Paris & Paris, 2003). Narrative reconstruction consists of children recalling the characters, settings, character goals, and solutions from the stories (Gibbons, Anderson, Smith, Field, & Fischer, 1986). At the end of each book condition, children were asked questions that probed their memory for details about the story that fit the narrative reconstruction criteria, which were pilot tested on twenty 3 and 5-year-olds who were read both stories in the lab. Questions were adjusted so assessments were equally challenging between stories, with neither presenting floor or ceiling effects. The final assessment included 10 questions, scored out of a total of 14 points for each story about the setting, plot, theme, resolution, and character descriptions, goals, and actions (see the online supplemental material for recall assessments, by story). There were seven 1-point questions, two 2-point questions and one 3-point question. For example, in *Zoom City* the main character's actions were fixing the bumper, headlight, and engine on a car. For the 3-point question, children were asked to recall which parts on the car the character fixed. Children could receive full credit if in their response they identified the 3 car parts that were fixed, 2 points if they identified 2 parts, 1 point if they identified 1 part, and 0 points if they failed to recall the parts that were fixed or provided an incorrect response. Similarly for scoring, in *Cat's Pajamas* the main character's actions were making music using drums, cans, and a horn. For the 3-point question, children were asked to recall which instruments the character played. Children could receive full credit if in their response they identified the 3 instruments that were played, 2 points if they identified 2 instruments, 1 point if they identified 1 instrument, and 0 points if they failed to recall the instruments that were played or provided an incorrect response. Story recall was measured as the percentage of correct responses (out of 14 possible points). Hypothesis- and condition-blind research assistants who received extensive training on using the audio recordings of each session listened to session recordings and coded story recall performance. Inter-rater reliability using Cohen's kappa (Cohen, 1960) was .86, indicating substantial coder consistency.

Engagement Measure

Time on task (i.e., attending to the book while being read to) was measured via gaze fixation duration, which is a common measure of engagement in a variety of settings and is a particularly appropriate measure in the context of reading (Rayner, Ardoin, & Binder, 2013). Hypothesis-blind research assistants reviewed the video recordings of the testing sessions to calculate the child's fixation duration to each book condition from the direction of the participant's gaze. A "look" to the contingent book or control book was coded each time the child's gaze was directed at the book presentation. When the participant's gaze shifted (i.e., to the reader or off-task), a look to the new direction was coded. Each eye shift was judged as either towards or away from the book, and the duration of the resulting looks was analyzed to calculate total looking time. Total reading time was calculated as the time period from the moment the first word of the book (the title) was read aloud by the reader and continued until the book was finished. Engagement was measured as the percentage of time children spent looking at the book condition out of total reading time. For eye gaze durations towards each book condition, inter-rater reliability (Cohen's kappa = .93) was established for at least 20% of the entire sample.

Attention Measure

Between the reading sessions, children participated in a modified attention subtest from the Developmental NEuroPSYchological Assessments (NEPSY; Cuevas & Bell, 2014; Korkman, Kirk, & Kemp, 1998). The attention subtest is a visual cancellation task in which participants are asked to maintain selective attention and focus on targets with speed and accuracy. Children actively scanned a visual environment and pointed only to items that matched that target stimuli (i.e., bowling pins) on a page containing both distractors and targets as quickly as possible in 180 seconds (see Figure 2). Performance on the task was calculated using the total number of attention task errors and the total amount of search time to complete the task (Mahone & Hoffman, 2007). Accuracy (distractor hits) and speed (search time out of 180 seconds) from the attention task were standardized using Z-scores and averaged together to create the composite variable: *Distractibility.* This composite variable measured children's ability to stay on task by determining whether children completed the task accurately without getting distracted, and fluently with speed.

Figure 2. Attention task in which children were required to actively scan this visual environment for targets (bowling pins) among other objects (distractors)

Verbal Ability Measure

The Peabody Picture Vocabulary Test (PPVT-IV; Dunn & Dunn, 2007) was administered to children at subsequent laboratory visits within 3 weeks of the initial lab visit to determine receptive vocabulary and verbal comprehension. A trained researcher presented a series of pictures to the child (four pictures per page), and verbally said a word that matched one of the pictures. Children were asked to point to the picture that the word described. The PPVT is a nationally standardized instrument, and the measure of interest was participants' age-based standardized scores.

Data Analytic Approach

The data collected in this study and the scripts used to analyze these data are available in KiltHub–Carnegie Mellon University's comprehensive institutional repository, which is part of the Figshare open access repository platform of research data and scholarly outputs–at the following link: https://doi.org/10.1184/R1/7740170.v1.

First, to investigate our primary hypothesis—that contingent interactive features would improve story recall—we assessed how well children could answer questions related to the content of the story they had heard, administered immediately after each story was finished. Story recall was measured as the percentage of correct responses out of 14 possible points (see Table 2, for raw and scaled scores). To assess possible order effects and sex differences, we conducted a mixed factorial analysis of variance (ANOVA) on story recall, factoring order and sex as between-subjects variables and book condition as the within-subject variable.

Second, we investigated whether the use of the contingent book might be especially useful for children with less developed attention regulation. For this analysis, a recall difference score for each child was calculated by subtracting the noncontingent control book recall score from the contingent book recall score. Difference scores estimated changes in story recall performance from using the contingent book, such that higher and positive scores indexed greater gains in story recall. To examine the association between changes in recall from the contingent condition and attention regulation, attention task distractors and time to complete the attention task were standardized using Z-scores and averaged together to create the composite variable: *Distractibility*. Prior research has found that children's attention regulation in preschool is related to receptive vocabulary and later reading acquisition (Casco, Tressoldi, & Dellantonio, 1998; Conners, 2009; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Gianvecchio & French, 2002). To control for the potential role of verbal ability in the association between attention and recall difference scores, participants returned to the laboratory within 3 weeks of the initial lab visit and were administered the PPVT to ensure that findings would not be entirely due to variance shared with verbal ability (see Tables S3 and S4 in the online supplemental material for correlation coefficients between measures of attention, recall, engagement and verbal ability). To examine the extent to which Distractibility uniquely predicted how much children's story recall changed from the contingent condition, a multiple regression analysis was conducted that included Distractibility and verbal ability as predictors of children's recall difference scores, and age in months as a covariate.

Results

Story Recall

There was a main effect of book condition, in that children's recall scores were significantly higher in the contingent book condition (M = 60.20%, SE = 3.13%) compared to the noncontingent board book condition (M = 47.36%, SE = 2.94%), $F(1, 30) = 39.57$; $p < .0005$; $\eta_p^2 = .57$. There was no main effect of order, $F(3, 30) = 1.04$, $p = .39$, or sex, $F(1, 30) = .12$, $p = .74$, or significant interactions between any of these factors and story recall (all ps > .19). The outcome for each condition of the recall measure followed a normal distribution and there were no outliers. Follow-up pairwise comparisons after Bonferroni corrections revealed that on average, children scored 12.65% (*SE* = 2.01%) higher on the recall assessment in contingent book condition compared to the noncontingent book condition, 95% CI [8.55%, 16.76%], $p < .0005$. All but six participants exhibited higher recall scores using the contingent book compared to using the noncontingent board book, two of which exhibited identical scores across conditions. Taken together, these results indicate that children's mean story recall scores after being read to from the contingent book were higher compared to being read to from the noncontingent board book, regardless of the story or order in which the books were presented (see Figure 3, for paired box plot).

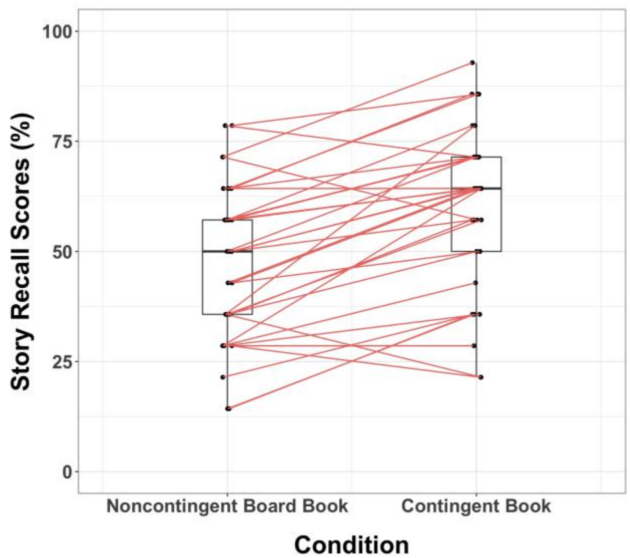

Figure 3. Paired box plot of recall scores in the noncontingent book and contingent book conditions. Data points were jittered in R by .02 to prevent overplotting (Team, 2018).

Engagement

The percentage of time children spent looking at the book condition out of total reading time did not significantly differ between the contingent book condition and the noncontingent board book condition (see Table 2, for mean reading time and mean looking time towards book conditions). The results indicated a ceiling effect: children attended to the book throughout the entire reading session for both conditions (see the online supplemental material for the analyses on the effect of book condition on engagement).

Table 2
Recall and Engagement measures, by condition

Measure *M* (*SD*)	Noncontingent Board Book	Contingent Book
Story Recall Raw Scores	6.63 (2.44)	8.43 (2.59)
Story Recall (% of 14)	47.35% (17.42%)	60.20% (18.52%)
Total Reading Time (ms)	141364 (37795)	142909 (34787)
Total Looking Time at Book (ms)	137303 (31290)	141182 (32214)
Engagement (Looking/Reading Time %)	97.89% (4.52%)	99.01% (2.87%)

The Role of Individual Differences in Attention

Recall difference scores ranged from -14.29% to 42.86%, with a mean of 12.86% (*SD* = 12.23%). Standardized z-scores of attention task distractors (*M* = 2.83; *SD* = 3.82) and time to complete the attention task (*M* = 125.40 *s*; *SD* = 55.61 *s*) were combined to create the composite variable of Distractibility (*M* = -.22; *SD* = .71). Twenty-six participants returned to the laboratory and were administered the PPVT (*M*=117.65, *SD* =12.83). Higher Distractibility scores, $r(35)$ = .57, 95% CI [4.82, 14.79], $p < .0005$ (see Figure 4A), and lower verbal ability scores $r(26)$ = -.42, 95% CI [-.85, -.04], $p < .04$ (see Figure 4B), were both associated with how much children's recall changed from the contingent condition.

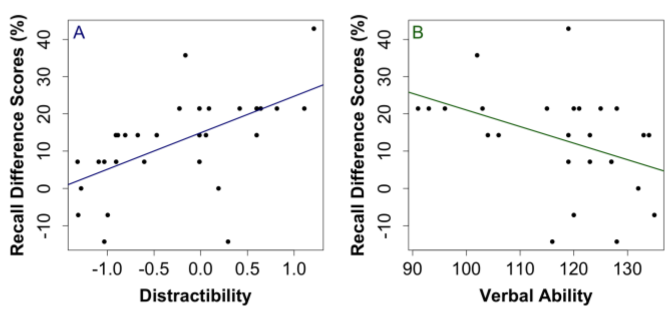

Figure 4. Scatterplots of correlations between recall difference scores and performance on the attention task and PPVT. (A) Greater Distractibility was associated with higher recall difference scores. (B) Lower verbal ability was associated with higher recall difference scores. There were no outliers.

There was not a statistically significant interaction (F_{change} = 1.36, *df* = 6, 19, *p* = .29) between Distractibility, age, and verbal ability and their effects on recall difference scores. Therefore, the final multiple regression analysis performed excluded the interaction terms as they were not significant. The additive model (F_{change} = 6.03, *df* = 3, 22, *p* = .004) revealed that Distractibility accounted for unique variance in changes in recall using the contingent book (β = 9.76, *t* = 3.33, *p* = .003, 95% CI [3.67, 15.85]), but verbal ability and age did not (*p*s > .21; see Table 3). About 45.12% of the variability in recall difference scores is accounted for by taking the values of Distractibility, verbal ability, and age into account. Thus, when accounting for other types of variables that may affect how much children's recall changes from the contingent book condition such as age and verbal ability, children's Distractibility was the only unique predictor.

Table 3
Multiple Regression Analysis Predicting Changes in Recall from Contingent Condition

	β	*SE*	*t*	*p*	95% CI	*F*	*df*	R^2
Model				0.004		6.02	3, 22	.45
Distractibility	9.76	2.94	3.33	0.003	[3.67, 15.85]			
Verbal Ability	-0.23	0.18	-1.28	0.213	[-0.61, 0.14]			
Age	1.04	2.97	-0.35	0.730	[-5.13, 7.21]			

Note. N = 26 for children who completed the PPVT

Discussion

Results from Experiment 1 indicate that the use of the contingent book resulted in higher mean story recall compared to the use of the noncontingent board book. It was also found that children with less developed attention regulation exhibited the greatest gains in recall from the contingent book. However, it is an open question as to whether story recall was enhanced from the contingent book because of the contingent responsivity, or because presenting a story on a digital platform is superior to a traditional board book, perhaps due to a novelty effect. A novelty effect occurs when a new technology is instituted and performance improves simply because participants are exposed to a new device, not necessarily because participants are exposed to a more effective one (Clark, 1985). Experiment 2 begins to explore this possibility by replicating Experiment 1 with the control condition of a noncontingent static digital book, eliminating the possibility of the effects being driven by the novel effect of technology. Experiment 2 also attempts to replicate the results of investigating whether the contingent book might be especially useful for children with less developed attention regulation.

Experiment 2

To ensure the results from Experiment 1 were not solely because exposure to a book on a digital platform is superior to a board book, perhaps due to a novelty effect (that is, children may have been more attentive to the iPad than the board book simply because they were less familiar with iPads). To assess this possibility, in this experiment both a contingent and a noncontingent story are presented to children via an iPad. If the effects on recall observed in Experiment 1 are due to the contingent responsivity of the story (rather than the presence of an iPad), the story recall advantage for the contingent book should be reproduced in this experiment.

Method

Participants. All participants were recruited from the same pre-primary school and none of these children participated in Experiment 1. The study used a within-subject design with data from 33 children (20 males, 13 females) ages 3 to 5-years-old (M = 53.32 months, SD = 7.15 months). An additional child was tested but excluded due to speaking English as a second language with low proficiency; this child could not understand the stories or the recall questions.

Materials and Procedure

Procedure and apparatus (recording equipment, reader protocol) were identical to those described in Experiment 1. The materials were nearly identical to those of Experiment 1. The one difference was that the noncontingent control condition was a static digital book presented on an

Apple iPad (9.4 in x 6.6 in). The contingent and static books were identical in platforms, but the contingent book responded contingently on children's vocalizations while the static book remained motionless. As in Experiment 1, children were read *Cat's Pajamas* and *Zoom City.* Each story was read on an iPad, presented either with noncontingent static images or with animations that contingently responded to the child's utterance. Condition and story order were randomly assigned and counterbalanced.

Measures

Measures of story recall, engagement, attention, and verbal ability were identical to the measures described in Experiment 1.

Results

The same data analytic approach as in Experiment 1 was used.

Story Recall

There was a main effect of book condition, in that children's recall scores were significantly higher in the contingent book condition (M = 64.72%, SE = 2.47%) compared to the noncontingent static book condition (M = 45.89%, SE = 1.89%), $F(1, 28) = 42.34$; $p < .0005$; $\eta_p^2 = .60$ (see Table 4, for raw and scaled scores). There was no main effect of order, $F(3, 28) = .19$, $p = .91$, or sex, $F(1, 28) = 2.18$, $p = .15$. There were also no significant interactions between any of these factors and story recall (all ps > .37). Follow-up pairwise comparisons after Bonferroni corrections revealed that on average, children scored 18.17% (SE = 2.79%) higher on the recall assessment in contingent book condition compared to the noncontingent book condition, 95% CI [12.45%, 23.89%], $p < .0005$. All but five participants exhibited higher recall scores using the contingent book compared to using the noncontingent static book, all five of whom exhibited identical scores across conditions. The outcome for each condition of the recall measure followed a normal distribution and there was one outlier with a recall score of 28.57% in the contingent book condition. With the removal of this outlier, there was still evidence of a main effect of book condition on recall, $F(1, 27) = 48.00$; $p < .0005$; $\eta_p^2 = .64$. Taken together, these results indicate that children's mean story recall scores after being read to from the contingent book were higher compared to being read to from the noncontingent static book, regardless of the story or order in which the books were presented (see Figure 5, for paired box plot).

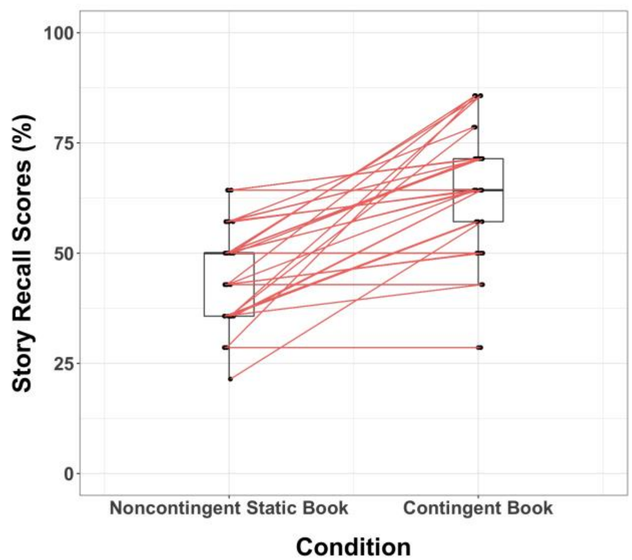

Figure 5. Paired box plot of recall scores in the noncontingent book and contingent book conditions. Data points were jittered in R by .02 to prevent overplotting (Team, 2018).

Engagement

Consistent with Experiment 1, the percentage of time children spent looking at the book condition out of total reading time did not significantly differ between the contingent book condition and the noncontingent static book condition, and there was a ceiling effect: children attended to the book throughout the entire reading session for both conditions (see Table 4, for mean reading time and mean looking time towards book conditions and the online supplemental material for the analyses on the effect of book condition on engagement).

Table 4

Recall and Engagement measures, by condition

Measure *M* (*SD*)	Noncontingent Static Book	Contingent Book
Story Recall Raw Scores	6.42 (1.52)	9.06 (1.98)
Story Recall (% of 14)	45.89% (10.87%)	64.72% (14.17%)
Total Reading Time (ms)	140433 (35567)	145900 (34098)
Total Looking Time at Book (ms)	136567 (35437)	143167 (33213)
Engagement (Looking/Reading Time %)	97.10% (3.65%)	98.18% (2.13%)

The Role of Individual Differences in Attention

With the goal of replicating results from Experiment 1, we examined whether the use of the contingent book might be especially useful for participants with less developed attention regulation. Recall difference scores ranged from 0.00% to 57.14%, with a mean of 18.83% (SD = 15.45%). Standardized z-scores of attention task distractors (M = 5.94; SD = 6.09) and time to complete the attention task (M = 169.29 *s*; SD = 33.08 *s*) created the composite variable of Distractibility (M =.50; SD =.75). Thirty-two participants returned to the laboratory and were administered the PPVT (M = 116.91, SD = 16.37). Higher Distractibility scores, $r(33) = .71$, 95% CI [9.16, 19.76], $p < .0005$ (see Figure 6A) were associated with how much children's story recall changed from using the contingent book condition, but verbal ability scores were not, $r(32) = -.04$, 95% CI [-.32, .39], $p = .83$ (see Figure 6B). There were three outliers with PPVT scores of 85, 83, and 65. With the removal of these outliers, there was still not a significant association between verbal ability scores and children's recall difference scores, $r(29) = .23$, 95% CI [-.23, .94], $p = .23$.

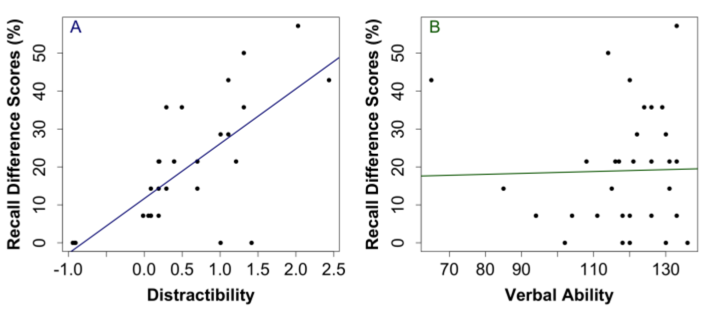

Figure 6. Scatterplots of correlations between recall difference scores and performance on the attention task and PPVT. (A) Greater Distractibility was associated with higher recall difference scores. (B) Verbal ability was not statistically associated with recall difference scores.

There were no statistically significant interactions (F_{change} = .39, df = 6, 25, p = .77) between Distractibility, age, and verbal ability and their effects on recall difference scores. Therefore, the final multiple regression analysis performed excluded the interaction terms as they were not significant. The additive model (F_{change} = 12.19, df = 3, 28, p < .0005) revealed that Distractibility (β = 17.57, t = 5.94, p < .0005, 95% CI [11.51, 23.64]) accounted for unique variance in changes in story recall using the contingent book, but verbal ability and age did not (all ps > .05; see Table 5). About 56.64% of the variability in recall difference scores is accounted for by taking the values of Distractibility, verbal ability, and age into account.

Table 5
Multiple Regression Analysis Predicting Changes in Recall from Contingent Condition

	β	*SE*	*t*	*p*	95% CI	*F*	*df*	R^2
Model				< 0.0005		12.19	3, 28	.566
Distractibility	17.57	2.96	5.94	< 0.0005	[11.51, 23.64]			
Verbal Ability	0.10	0.12	0.83	0.41	[-0.15, 0.35]			
Age	6.68	3.36	2.05	0.05	[-0.01, 13.37]			

Note. N = 32 for children who completed the PPVT

Discussion

Results from Experiment 1 revealed that children's recall scores were significantly higher in the contingent book condition compared to a noncontingent board book condition. These findings were replicated in Experiment 2 using a noncontingent electronic book condition, discarding the possibility that exposure to the contingent book was superior for children's story recall compared to the noncontingent board book due to the novel effect of being presented with an iPad. Findings from Experiment 2 also replicated the result from Experiment 1 that the contingent book was especially useful for children with less developed attention regulation.

Prior research has found verbal ability skills are associated with story recall (Bishop & Donlan, 2005), and although verbal ability was not found to be a significant predictor of how much children's recall changed from the contingent book condition, this finding does not indicate that vocabulary ability is completely unrelated to story recall. The books utilized in this study contained vocabulary that was designed to be comprehensible to all children in this age range. A plausible reason that individual differences in vocabulary knowledge were not predictive of how much children's recall benefited from the contingent book is because children's verbal ability skills were above the vocabulary level of the books and therefore, the vocabulary gains would not be as evident as the recall gains.

Children use salience cues like illumination and movement when learning content, and children's selective attention to salient features congruent with content predicts better learning (Moore, Angelopoulos, & Bennett, 1999; Scofield, Miller, & Hartin, 2011). It is plausible that animations congruent to the text enhanced children's story recall by orienting their attention to nonverbal information that matched the story narrative. Experiment 3 begins to explore this possibility by replicating Experiment 1 and 2 with the control condition of an animated book presentation in which congruent animations are deployed, but they do not respond contingently on the vocalizations of the child.

Experiment 3

The goal of this experiment was to assess the possibility that the results on children's story recall in Experiments 1 and 2 were solely because exposure to animations is superior to motionless images, perhaps due to salience cues. To do so, in this experiment participants were presented with both a contingent book condition and a noncontingent animated book control. In the animated book condition, the story-related animations are deployed for each page, but they do not respond contingently to the vocalizations of the child. If the effects observed in Experiment 1 and 2 are due to the contingent responsivity of the story (rather than the mere presence of animations), the recall advantage for the contingent condition should be reproduced in this experiment.

Method

Participants. All participants were recruited from the same pre-primary school as in Experiments 1 and 2, and none of these children participated in either Experiment 1 or Experiment 2. The study used a within-subject design with data from 22 children (11 males, 11 females) ages 3 to 5-years-old (*M* = 54.29 months, *SD* = 7.33 months). Four additional children were tested but excluded due to equipment failure. The sample size is smaller than the sample sizes in Experiments 1 and 2 because there were no children left in the pre-primary school to test and recruiting participants from different schools might introduce potential confounds.

Materials and Procedure

Procedure and apparatus were identical to those described in Experiments 1 and 2. The materials were nearly identical to the two previous experiments. The one difference was that the noncontingent control condition was an animated book. As in Experiments 1 and 2, children were read *Cat's Pajamas* and *Zoom City.* Children were read each story in the presentation of a noncontingent animated book or in the presentation of a contingent book. Condition and story order were randomly assigned and counterbalanced. The contingent and animated books were identical in pictures, text, platforms (Apple iPad 9.4 in x 6.6 in), and animations; however, while the contingent book's animations deployed contingently on children's vocalizations, the animated book's animations were deployed at the start of each page. Identical to Experiments 1 and 2, for the contingent book, the reader started each session by reading the first line of the story, and then said, “Now it’s your turn to read!” to the child. For the animated book, the animations were deployed, the reader read the first line of the story and then said, “Now it’s your turn to read!” to the child (see the online supplemental material for reader protocol).

Note that this is not the only control condition possible. For example, we could have chosen to have the animations deploy at the end of each page’s narration, or in response to the adult’s vocalizations rather than the child’s. While we explored these possibilities, pragmatic considerations and pilot testing favored page-initial animations. We pilot tested a condition in which the animations deployed contingently on the adult reader’s vocalizations, but determined that deploying the animations contingently on the adult reader’s vocalizations made the control condition too similar to the contingent book condition. That is, because children were inclined to immediately repeat after the reader, several of the animations appeared to respond contingently on children’s vocalizations by chance. Likewise, having the animations occur after the page was read was also too similar to the contingent book condition, because children often narrated slowly enough that they were still talking when the animations appeared at the end of the page. By having the animations deploy at the start of each page, it was possible to have a control book condition in which the relevant story information was highlighted without the animations appearing to respond contingently on children’s vocalizations.

Measures

Measures of story recall and attention were identical to the measures described in Experiment 1 and Experiment 2. Due to the time-intensive and laborious nature of coding children’s eye gaze fixations and recruiting children to return to the laboratory for an additional testing session, the engagement and vocabulary measures were not included in Experiment 3 because there were no effects of book condition on engagement and the multiple regression analyses revealed that PPVT performance lacked predictive power in Experiments 1 and 2.

Results

The same data analytic approach as in Experiment 1 and Experiment 2 was used with the one difference that the multiple regression analysis conducted did not include verbal ability as a predictor of recall difference scores, only Distractibility and age.

Story Recall

There was a main effect of book condition, in that children's recall scores were significantly higher in the contingent book condition (M = 59.42%, SE = 3.06%) compared to the noncontingent animated book condition (M = 45.13%, SE = 2.46%), $F(1, 17) = 39.97$; $p < .0005$; $\eta_p^2 = .70$. There was no main effect of order, $F(3, 17) = 3.05$, $p = .06$, or sex, $F(1, 17) = .23$, $p = .64$. There were also no significant interactions between any of these factors and story recall (all ps > .22). Follow-up pairwise comparisons after Bonferroni corrections revealed that on average, children scored 14.33% (SE = 2.27%) higher on the recall assessment in contingent book condition compared to the noncontingent book condition, 95% CI [9.55%, 19.11%], $p < .0005$. All but three participants exhibited higher recall scores using the contingent book compared to using the noncontingent animated book, two of which exhibited identical scores across conditions. The outcome for each condition of the recall measure followed a normal distribution and there was one outlier with a recall score of 100.00% in the contingent book condition. With the removal of this outlier, there was still evidence of a main effect of book condition on children's story recall, $F(1, 16) = 35.90$; $p < .0005$; $\eta_p^2 = .69$). Taken together, these results indicate that children's mean story recall scores using the contingent book were higher compared to the noncontingent animated book, regardless of the story or order in which the books were presented (see Figure 7, for paired box plot).

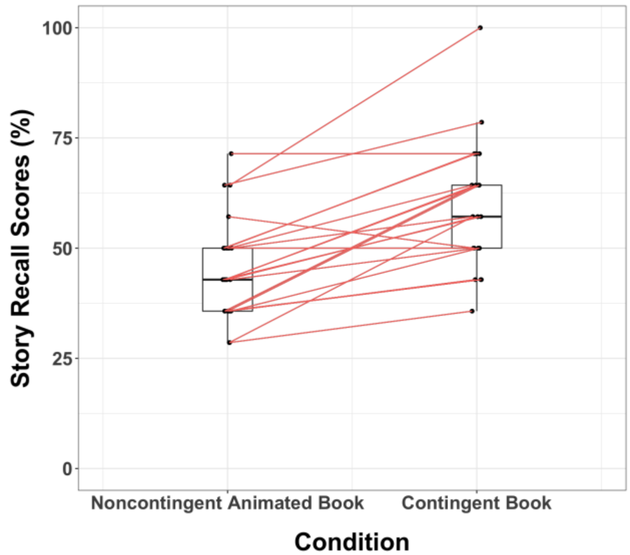

*Figure 7***.** Paired box plot of recall scores in the noncontingent book and contingent book conditions. Data points were jittered by .02 in R to prevent overplotting (Team, 2018).

The Role of Individual Differences in Attention

Recall difference scores ranged from -7.14% to 35.71%, with a mean of 14.29% (*SD* = 10.80%). Standardized z-scores of attention task distractors (*M* = 2.36; *SD* = 3.26) and time to complete the attention task (*M* = 108.66 *s*; *SD* = 62.94 *s*) created the composite variable of Distractibility (*M* =-.41; *SD* =.79). The multiple regression analysis showed no significant interactions (F_{change} = 0.00003, *df* = 3, 18, *p* = 1.0) between Distractibility and age and their effects on recall difference scores (β = -.02, *t* = -.01, *p* = 1.0). Therefore, the final multiple regression analysis performed excluded the interaction term as it was not significant. The additive model (F_{change} = 8.46, *df* = 2, 19, R^2 = .47, *p* = 0.002) revealed that Distractibility (β = 9.02, *t* = 3.95, *p* = .0009, 95% CI [4.24, 13.81]) accounted for unique variance in changes in recall using the contingent book, but age did not (β = -2.86, *t* = -.97, *p* = .35, 95% CI [-9.04, 3.32]). There were no outliers. About 47.10% of the variability in recall difference scores is accounted for by taking the values of Distractibility and age into account. The contingent book was especially helpful for children with less developed attentional control: as children's measure of Distractibility increased, they showed more benefit in recall from using the contingent book (see Figure 8).

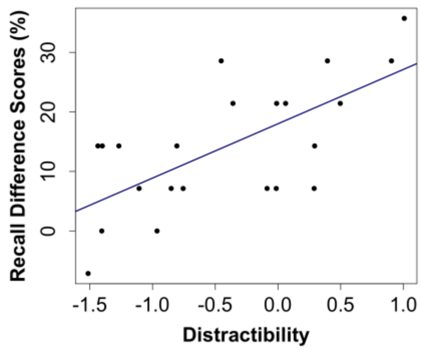

Figure 8. Scatterplot of correlation between recall difference scores and performance on the attention task: greater Distractibility was associated with higher recall difference scores.

Animations that respond contingently may improve story recall beyond animations alone because even when animations direct attention to relevant story information, the salient cues are not effective unless they are in sync with the child. Contingent responsivity in adult-child interactions enhances learning because following a child's vocalizations with relevant responses adapts to the child's current focus of attention and encourages children to continue engaging throughout the reading experience; whereas animations that come beforehand do not give children immediate and appropriate feedback that match the child's communicative attempts that would foster understanding of the story content.

A plausible possibility age was never a significant predictor of how much children's story recall gained from the contingent book condition is because age is correlated with Distractibility, so age in and of itself is not a strong predictor. Collapsing the data across all 3 experiments, the results indicate that children's Distractibility is associated with age ($r(90) = -.26$ $p = .05$). Consistent with prior research, younger children exhibited less developed attention regulation

(Rueda, Posner, & Rothbart, 2005; see Figure 9)

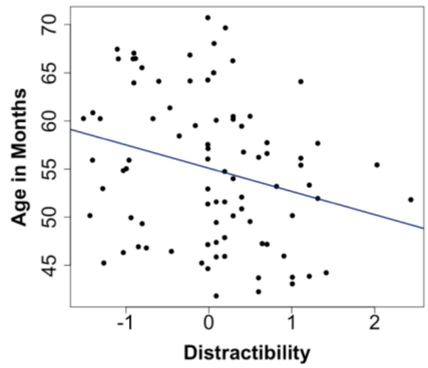

Figure 9. Scatterplot of correlation between age in months and attention regulation across all three experiments

Although attention is correlated with age, the multiple regression analysis in each experiment revealed age was not the main mechanism driving the effects. A plausible reason that individual differences in age were not predictive of how much children's recall benefited from the contingent book is because cognitive constructs and processes evolve over time and age does not have a strong effect because all of the variance associated with age is instead partialled into the underlying process investigated: attention regulation.

General Discussion

These data provide the first, to our knowledge, systematic analysis of whether contingent responsivity on children's utterances from a digital book could support children's learning. There were significant differences in story recall, with nearly all children exhibiting higher recall scores from the contingent book compared to a noncontingent board book. Our findings were strengthened when these results were replicated in a second experiment comparing the use of the contingent book with a noncontingent static book, discarding the possibility that exposure to the contingent book was superior to the board book due to the novel effect of a digital device. Furthermore, it was shown that the animations were not driving the effect in a follow-up control experiment comparing the use of the contingent book with a noncontingent animated book.

Similar to the effects contingent responsivity from adults have on children during shared book reading, when each of the children's vocalizations was returned with reinforced guidance to appropriate story content, this enabled children to later reproduce a better understanding about the story. The present findings extend those of previous studies in three ways. First, this is one of the first studies that investigated the effects of contingent responsivity from a digital book on story recall with a focus on individual differences in attention regulation. Second, the present experiment highlighted the specific nature of the contingent responses that is helpful for learning: children receiving a contingent response upon repeating the text. Third, the findings extend our knowledge of how preschool-aged children learn from contingent responsivity instilled in an e-book compared to how preschool children learn from various other book contexts.

Children spent approximately the same amount of time focusing their eye gaze fixation on both contingent and noncontingent book presentations. The lack of variability in engagement with both conditions for Experiments 1 and 2 could be due to the secluded testing room environment. It is possible that children rarely shifted their eye gaze elsewhere from the book presentations because the testing room was absent of other stimuli, and therefore children were less likely to disengage from the task. A future research question to explore is whether children's gaze fixations towards the books would be more variable if children were immersed in a more ecologically valid environment such as a classroom, library, or home.

We hypothesized that children who attend to more distractors and take longer to complete the attention task (i.e., children with less developed attention regulation skills) would exhibit greater recall gains from the contingent book. Our findings support this hypothesis: the contingent responsivity was especially useful for children with the highest Distractibility scores.

Results also showed that the associations between Distractibility and changes in recall from the contingent book were largely not due to variance shared with verbal ability. Children's attention regulation is a significant predictor of academic achievement not only when they enter formal schooling, but continue to predict academic success until several years later in development (Franceschini et al., 2012; McClelland et al., 2007). While prior research has found that interactive features are distracting and detract from learning, caregiver behavior characterized by appropriately high levels of responsiveness has been found to buffer poor attention regulation in children (Graziano, Calkins, & Keane, 2011). The interesting finding in the differential impact of attention regulation for the contingent book advances current theories of the beneficial effects from contingent responsivity on young children's learning from *a digital device*. The novelty of these findings is that this study investigated individual differences in attention regulation in predicting story recall in the context of the interaction with various designs of e-books, a topic that is understudied. Although this study clearly exhibits a contingent responsivity advantage on story recall for children with less developed attention regulation, it does not address specific hypotheses regarding this advantage. Two plausible overlapping hypotheses that support this advantage are the role of positive reinforcement learning and attention regulation, and the role of associative learning and attention regulation.

Contingent use of positive reinforcement and visual cues reduce attention regulation problems (Becker et al., 1967; Lunkenheimer, et al., 2008; Posavac, Sheridan, & Posavac, 1999). The comprehension of word-referent relations increases when adults provide actions considered to be positive to children (i.e., attention, praise, following their lead) contingent upon characteristics of the child's vocalizations (Whitehurst, 1988). The contingent responsivity advantage in e-books on story recall for children with less developed attention regulation could potentially be elicited engagement through positive reinforcement: children's responses are required for progress through the story, e-books uniquely respond to children's responses, and acknowledgement and rewards through a contingent response from the book occur when children answer correctly (Troseth, Russo, & Strouse, 2016). Contingent responsivity also encourages children to be active rather than passive participants, and children's learning is optimized when they are engaged rather than distracted (Dore et al., 2018). Following a child's vocalizations with relevant responses adapts to the child's current focus of attention and encourages children to continue engaging throughout the reading experience; whereas currently available e-books and interacting with books alone do not give children immediate and appropriate feedback that match the child's communicative attempts that would foster understanding of the story content. The contingent responses upon repeating the story text may provide children with feelings of accomplishment, and the animations activating contingent on children's vocalizations may serve as positive reinforcement, which in turn enhance learning (Troseth, Russo, & Strouse, 2016).

Children scored lower on the attention task because these children's ability to selectively attend to relevant information while suppressing irrelevant, extraneous information is less efficient. Many storybook designs for young children integrate colorful visuals and decorational illustrations. Although the inclusion of entertaining visuals in children's reading materials have enormous potential to engage children—if children are not given the appropriate guidance to the content related to the story text—these additional visuals might be counterproductive if they distract children from processing the narrative (e.g., exploring pictures of cats when they should be focusing on pictures of cars). Children verbalizing a word with contingent feedback to the matching referent guides children's attention to story-relevant features that may improve encoding, storage, and retention of material, and thereby facilitate subsequent retrieval and use

(Schunk, 1986). The contingent animations that are synced with children's vocalizations signify to children the relevant material related to the story they should attend to, and help them develop a better understanding of the story because the animations in the contingent book match the simultaneously pronounced story text. Children may encode the vocalized words and associated animations to form a unitary representation of the story content (Baker, Olson, & Behrmann, 2004). The actions of the contingent book and the children are coordinated and in sync with one another: the children vocalize, and the contingent book responds with referents that match those vocalizations. Because the animations in the contingent book match the simultaneously pronounced story text, the children are not forced to constantly switch between exploring the entertaining visuals in the storybooks and processing the story narrative. Instead, the visuals helped integrate nonverbal information and language. This contingent responsivity may be especially useful for children with less developed attention regulation because it encourages children to focus on relevant story content that matches their words, leading to better attention to the main story elements and therefore higher levels of story recall. Greater attention difficulties in early childhood have been found to predict more use of mobile media alone (Levine et al., 2019). Thus, contingent responsivity in e-books modeled on quality adult-child interactions might be especially useful for children with less developed attention regulation who are prone to using digital media by themselves. These results highlight the role individual differences in attention regulation play in learning outcomes in the context of child-to-digital book interactions and should be taken into account when establishing design standards for educational media.

Children performed better in the contingent book condition across all ages in our experiments. The developmental trajectory for the effectiveness of contingent responsivity in digital books might change with a variety of age ranges. For younger children ages 1- to 2-years old who are developing their language production skills, the effects of contingent responsivity on story recall might not be as effective because developmentally, this age group is still learning to produce vocalizations. Attention regulation skills display protracted development and are still developing during the time when children begin formal schooling (Fisher & Kloos, 2016). Contingent responsivity in e-books may continue to be helpful for beginning readers ages 6- to 8-years old, who are in the process of learning how to read. A recent detailed analysis of 100 of the most popular books for beginning readers indicated that books targeting this age group commonly contain design features that increase attentional competition for young children: on average, 86.56% of a book’s pages contained extraneous illustrations irrelevant to the story narrative, and attention allocation towards extraneous details were found to be negatively associated with children’s ability to recall key story details (Godwin, Eng, Murray, & Fisher, in press). Therefore, contingent responsivity in e-books may be helpful for beginning readers ages 6- to 8-years old, who are also commonly exposed to extensively embellished storybooks and whose attention regulation skills are still developing. The contingent responsivity may become less useful for older children ages 9- to 11-years old, who are starting to transition to chapter books without illustrations and whose attention regulation and reading skills are more developed.

A limitation to this study is that the recall assessment primarily focused on questions that require children to recall story information through identification and description. Although the main outcome measure in this study mainly focused on the recall of key story events, recent research has found that early childhood teachers use recall questions as the primary instructional strategy for comprehension in school settings and tend to ask lower-order literal questions that elicit one word responses from children (Truong, Ebisuzaki, & Carlson, 2018; Walsh & Hodge, 2018), increasing the generalizability of these findings. The recall of more story elements may reflect a coherent narrative structure because prior research has shown that the ability to recall, retell, and describe key story events in early childhood is not only associated with global reading skills, but it is also a strong predictor of later reading comprehension (Kendeou, Van den Broek, White, & Lynch, 2009; Reese, Suggate, Long, & Schaughency, 2010; Storch & Whitehurst, 2002; Suggate, Schaughency, McAnally, & Reese, 2018). Children's story recall competency indicates a complex mix of children's understanding of stories, mastery of pragmatics, syntax, and semantics (Suggate et al., 2018). Central to comprehension in the context of reading is the construction of a coherent mental representation of the text that enables readers to identify relations between text elements (Kendeou et al., 2009). Several story recall questions utilized in the study were designed to require understanding of the book's text and not just the illustrations. For example, in *Cat's Pajamas* the storyline is that the main characters are walking down the street and outside the moon is big, the night is hot, and the cats hear a growl from a dog. One of the story recall questions inquired, "Was the night cold or hot?" The book does not depict the night's temperature through any images and the temperature at night is generally associated with cold rather than hot. To get the answer correct, children needed to construct the setting and connect the story elements of the hot temperature with nighttime, and scored better on this question in the contingent book condition. Furthermore, the most significant difference between children with reading disabilities and children with typical reading skills has been found to be performance on story retelling, showing that the recall of story elements is a useful context for identifying strengths and weaknesses in children's competency in understanding story narratives (Westerveld & Gillon, 2010). Prior research also shows that preschool children make inferences and use rudimentary network representations of the events in narratives to recall key events in the narrative, and story recall relates to the use of complex syntax, making story recall an essential skill for communicating effectively with others by organizing the story details remembered coherently and meaningfully (Bishop & Donlan, 2005; Lynch et al., 2008). While the current study cannot make direct conclusions on the effect of contingent responsivity from an e-book on children's global story comprehension skills, the contingent responsivity did improve children's ability to recall key story details, a predictor of overall comprehension.

Studies have found that numerous parents report not sharing digital device play with their young children, and 72% of top-selling paid apps in the Education category of the iTunes Store target preschool-aged children, and apps for the preschool age category have exhibited the greatest growth compared to all other age groups (Radesky & Christakis, 2016; Shuler, 2012). Future studies conducted with children from low socioeconomic (SES) households, second language learners, and children with attention deficits may validate our findings and give us a more thorough understanding of the effects of the contingent book for a diverse range of children. SES is a variable of particular pragmatic (as well as theoretical) concern. Due to decreasing costs, marketing strategies, and subsidies by providers mobile media such as smartphones, iPads, and tablets are more accessible—even for low SES children. In 2011, 73% of higher income families owned a mobile device compared to the 34% of lower income families; in 2017, the percentages rose to 99% for higher income families and 96% for lower income families (Rideout, 2017). While the digital divide is closing, the amount of mobile media use and parental co-engagement with media still differs between low SES and high SES households. The daily screen time use of children ages 0 to 8 from lower SES households is on average, 3 hours and 29 minutes, compared to the average 1 hour and 50 minutes of children from higher SES households (Rideout, 2017). This means that children from lower SES households almost spend twice as much time in front of a screen compared to children from higher SES households, and this exposure is also more likely to be unsupervised by a parent (Radesky & Christakis, 2016). Children's use of the target words interacting with the book alone or without appropriate adult guidance may not be as consistent unless the book interacts in the manner adults were instructed to in the current study. However, given that young children may interact with digital devices alone, contingent responsivity functionality in e-books may be practical for times in which adults are unavailable and when children are reading alone, and might even be more beneficial than hardcopy, static, and animated books as evidenced by the results from this study. Because experimenters were trained to do the bare minimum of simply reading the text aloud to children with minimal interaction—and the contingent book led to increased story recall—we hypothesize that similar results would be reproduced if prompts and the narration were coming from the contingent book while children interact with the book alone or without the presence of an adult.

Media use by preschool children may not be by itself the critical concern; however, poorly designed educational devices might be. If a caregiver were reading a book to a child, it would seem almost obvious that stopping the child in the middle of the page to play a game or make an irrelevant noise would interrupt the flow of the story and distract the child from understanding the narrative. Yet, this structure is how many interactive digital books are designed: with tactile puzzles, memory tasks, or entertaining sound effects and animations activated spontaneously on the story pages in ways that are not central to the narrative (Vaala, Ly, & Levine, 2015). When well-deployed and designed, features in technology have the potential to enrich, not hinder learning experiences for children.

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