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Computerized Electronic Features Direct Children's Attention to Print in Single- and Dual-Language e-Books

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There has been a rapid proliferation of electronic books in recent years. Given that dual-language books may impose extra cognitive load on children's information processing capacity, we investigated whether multimedia features in e-books (i.e., audio narration and tracking animation) were effective in directing preschoolers' attention to print in the target language. Seventy-one English-and-Mandarin speaking 4- to 6-year-olds were presented with single-language and dual-language e-books (with and without enhancing features) on a computer fitted with an eye tracker to read independently. Children attended more to their dominant language text than the other when reading dual-language texts silently but comparably in single-language texts. Most importantly, enhancing electronic features with synchronized dual-channel (visual and audio) inputs and attention-guiding cues effectively directed children's attention to print in both their dominant and nondominant languages. These findings provide important implications on how computerized electronic books affect children's attention to print and in turn support the development of children's emergent literacy.

Keywords: *reading, electronic books, bilingual education, attention to print*

Introduction

The proliferation of electronic books (e-books) in the market provides an impetus to examine the influence e-books have on children's language development. Unlike traditional paper versions of picture books, e-books for young readers have multimedia options such as sound effects, animation, and games in addition to pictures and text. There has been a debate on the acceptability of the use of technology in early childhood (Burnett, 2010; Rogowsky, Terwilliger, Young, & Kribbs, 2018) and the potential benefits to young children's developing literacy (Gong & Levy, 2009; Maynard, 2010). Importantly, some research has suggested that the presence of electronic features is distracting, and thus negatively affect children's understanding of higher level aspects like story content and sequence of story events (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013). Indeed, interactive features such as games are found to have diverted children's attention away from the text (de Jong & Bus, 2002). Cued animation and sound effects are also found to have an adverse effect on children's story recall (Trushell, Burrell, & Maitland, 2001; Trushell & Maitland, 2005; Trushell, Maitland, & Burrell, 2003). Other studies, however, suggest that children reading a digital book (e.g., CD-ROM story) exhibited better story recall (Pearman, 2008), improved verbal abilities (Johnston, 1997), better phonological awareness (Korat, 2009; Korat & Segal-Drori, 2016; Shamir, Korat, & Barbi, 2008; Woods, Pillinger, & Jackson, 2010), better comprehension of word meaning (Korat, 2009; Korat & Shamir, 2008; Roskos, Sullivan, Simpson, & Zuzolo, 2016), and improved letter reading skills (Gong & Levy, 2009; Talley, Lancy, & Lee, 1997) than their peers in a control group.

The varying effects of e-books on reading and comprehension found in previous research are largely dependent on how the various types of interactive features are incorporated into the e-books (Zucker, Moody, & McKenna, 2009). For instance, providing children with numerous multimedia options may place unnecessary burdens on their cognitive processing capacities. Research found that children who read e-books that had lesser interactive options were better at recalling the characters in the e-books and paid better attention to the story content compared with children who read e-books that had more interactive options (Wang & Yang, 2016). Similarly, interactive features that are incongruent with the text and require children to switch from processing one form of information to another place additional demands on children's information processing capacity and result in cognitive overload (Bus, Takacs, & Kegel, 2015).

However, according to the cognitive theory of multimedia learning (Mayer & Moreno, 2003), multimodal inputs in e-books can provide important connections between the visual and auditory channels (re: Paivio's, 1986, dual-coding theory). Interactive features that allow children to process

related information from different modalities could enhance children's comprehension (Bus et al., 2015). For example, picture animations and background music that are semantically related to the story content allow children to process the information in separate visual and auditory channels, leading to better learning and retention of information (Paivio, 1986). E-books that contain a combination of audio narration and a visual feature such as highlighting of words or finger-tracking animation (i.e., an animation pointing to and tracking the print as the words are read out loud) are found to provide better support in word recognition, word naming, and phonological awareness than traditional printed books (Karemaker, Pitchford, & O'Malley, 2010). Highlighting the words as they are read increases the saliency of the words, thereby reinforcing the auditory-visual connection of words (McKenna, Reinking, & Bradley, 2003). In traditional printed books, children were found to attend to a difficult text when an adult pointed to the words as the story was narrated, suggesting that finger tracking is an effective attention-orienting strategy even for difficult texts (Roy-Charland, Perron, Boulard, Chamberland, & Hoffman, 2015). This is in line with Betrancourt's (2005) attention-guiding principle that highlights the impact and importance of cueing in helping children process the information presented in e-books, thereby reducing extraneous cognitive load on the child. Well-designed e-books can tap into the various sensory channels and direct children's attention to the relevant details in ways that can help them better process information during storybook reading.

E-books also come in dual-language versions that have been developed to cater to the growing bilingual population. Majority of the world's population is bilingual and two thirds of the children are brought up in bilingual environments (Crystal, 1997; Semingson, Pole, & Tommerdahl, 2015). In the United States alone, the number of bilinguals has almost tripled in the past 30 years (Gándara & Escamilla, 2017). Almost a quarter of the population in the United States speak a second language at home, with the most common second language being Spanish, followed by Chinese, French, Tagalog, Vietnamese, and Korean (Gándara & Escamilla, 2017). Similarly, 54% of EU and 39% of U.K. citizens can take part in a conversation in a language other than their mother tongue (Eurobarometer, 2012). Thus, there is a lot of impetus to teach additional languages in schools right from the primary school level. There are important differences between the experiences of children learning a single language or dual languages in childhood, hence, it is important to consider bilingual education programs that are primarily designed to support students' development of biliteracy (i.e., the ability to read and write in two languages; Bauer & Gort, 2012; Dworin, 2003; Gándara & Escamilla, 2017; Pérez & Torres-Guzmán, 1996) from a bilingual perspective. These bilingual education programs often use two languages for instruction, including the use of dual language books, thus providing students with a means of learning other subjects while learning English and allowing these children to interact in two literate worlds (Moll & Dworin, 1996). Dual language books have story plots that are written in two languages.

Previous studies suggest that traditional dual language print books allow for reading skills to transfer from one language to another (Robertson, 2006; Sneddon, 2008b), raise children's metalinguistic awareness, and improve their graphophonemic skills and knowledge (Naqvi, Thorne, Pfitscher, Nordstokke, & McKeough, 2013; Sneddon, 2008a). Bilingual children who were read dual-language books gained more letter knowledge and graphophonemic knowledge in both languages than those who were only read in one language (Naqvi et al., 2013; Tsow, 1986). However, in a dual-language book, story plots are typically written in two languages and presented together within the same text. The two languages within the same text may compete for a child's attention and impose an increased cognitive load on the visual processing abilities, thus traditional dual-language print books can be a challenging resource for children compared with single-language books, especially in independent reading sessions where no other resources are available to help children in the reading process. This parallels e-books with multimedia features that exceeded the limited information processing capacity in children, which in turn can interfere with learning (DeStefano & LeFevre, 2007; Mayer & Moreno, 2003; Sweller, 2005). This extra cognitive load may lead to children reading the text in their dominant language and ignoring the nondominant (target) language when reading dual-language books independently, limiting the effectiveness of dual-language books in improving biliteracy.

Despite the growing availability and popularity of dual-language e-books in bilingual education programs—digital and printed copies of dual language books are now available in more than 40 languages (Semingson et al., 2015), little research has been conducted on the effectiveness of these dual-language e-books in promoting reading behavior or the nature of features in these dual-language books that affect children's biliteracy development. Given previous research that suggests that audio narration in e-books leads to better reading outcomes and finger-tracking animation increases monolingual children's interest in print (Justice, Pullen, & Pence, 2008), these multimedia features could be incorporated into electronic dual-language books to draw bilingual children's attention to the target languages. Digital versions of dual-language books with appropriate multimedia features, thus, have the potential to reduce cognitive load arising from matched dual-channel inputs and attention-guiding cues, thus allowing children to derive the same literacy benefits as traditional dual-language print books, and more. This is especially important in bilingual education programs that aim to increase children's interest in and usage of their second or less dominant language.

In this study, we set to test the hypothesis that presenting a dual language electronic book in visual and audio modalities with an attention-guiding cue in a contemporaneous way would reduce cognitive load and increase children's attention to print in the target language. Why is attention to print an important process in reading? Kim and Goetz (1995) suggested that word recognition is one of the most important components of reading to identify and make sense out of the words being read. Paying greater attention to print is posited to increase the pace at which children learn about the forms and functions of print (Justice & Ezell, 2004) and increase reading fluency (Rasinski, Reutzel, Chard, & Linan-Thompson, 2010), which in turn are associated with children's later word recognition, orthographic, and comprehension skills (e.g., Hammill, 2004; Piasta, Justice, McGinty, & Kaderavek, 2012). Past research showed that explicit nonverbal and verbal print references can direct and increase the proportion of children's fixations on print (e.g., Evans & Saint-Aubin, 2005; Justice et al., 2008; Justice, Skibbe, Canning, & Lankford, 2005). Thus, it stands to reason that multimedia features such as audio narration with finger-tracking animation in electronic dual language books would effectively draw children's attention to the print of the target languages, especially if the target language is their nondominant language competing for attention from the print of their dominant language, thereby potentially increasing the print knowledge of the language. The strengthening of the auditory-visual connection of the print would then potentially further contribute positively to biliteracy development.

By drawing on the cognitive theory of multimedia learning and the attention guiding principle, we specifically aim to investigate whether computerized multimodal enhancing features in single- and dual-language books, that is, audio narration and finger-tracking animation, are effective in directing bilingual 4- to 6-year-old preschoolers' attention to print in the target language, especially their less dominant language. This is the age range where the development of emerging literacy skills occurs and where past research examined the relationship between print knowledge and early reading skills (e.g., Bauer & Gort, 2012; Chall, 1996; Justice et al., 2008; Levy, Gong, Hessels, Evans, & Jared, 2006). We deduce our findings through an objective analysis of eye-tracking data as one direct indicator of attention and measure of reading (Bucher & Schumacher, 2006; Foster, Ardoin, & Binder, 2018; Kulke, Atkinson, & Braddick, 2016). When an individual looks at a particular portion of the text, he or she is deemed to be selectively attending to it. Selective attention is a precursor of what and how much of the information is stored and processed, especially in reading (Donsbach, 2004). Eye tracking has been used in novel word learning in adults and children (e.g., Weighall, Henderson, Barr, Cairney, & Gaskell, 2017), as well as e-book reading behavior in children (e.g., Sun, Loh, & Roberts, 2019; Takacs & Bus, 2016). It allows the direct comparison of attention to print and nonprint materials through fixation duration and proportional looking times (Wass, Smith, & Johnson, 2012). Thus, our *key dependent variable* of this study is the *average proportion looking time to the target text per page per child*. We measured the children's attention to print using an eye tracker as they were presented with dual-language books with enhancing features (audio narration and tracking animation) and without enhancing features (normal silent reading) in Study 1, and single-language books with and without enhancing features in Study 2. We hypothesized that adding enhancing electronic features to single- and dual-language books (i.e., audio narration with tracking animation) would help direct children's attention to the respective target.

Study 1

Method

Participants. Thirty-two English–Mandarin speaking bilingual kindergartners participated in this study (M_{age} = 5.48 years, *SD* = 0.49, range 4.53–6.37 years; 22 males, 10 females). Children were recruited from an English-Mandarin bilingual kindergarten in a middle-class neighborhood in Singapore. Kindergarten is a 2-year program in Singapore, where children could enroll in it from the year they are turning 5 years old to the year before they turn 7 years old (hence the age range of our participants). Parents were asked to fill up a language questionnaire with demographic and language background information such as order of language acquisition and language exposure duration. Children were reported to have English as their first language acquired and Mandarin as their second language acquired, and the average amount of exposure to English and Mandarin *at home* was 52.03% and 45.78%, respectively. In Singapore, about 74.3% of the population is Chinese, and there is a mandatory dual-language program from primary school (i.e., age 7 years) onward (Singapore Department of Statistics, 2016). Thus, preprimary schools in Singapore, including those who participated in the study, offer both English and Mandarin language lessons in preparation for entry to primary school.

Parents also reported their highest level of education obtained (from a scale of 0 to 5, i.e., "0" = no formal education, "2" = primary education, "3" = secondary education, "4" = university degree, and "5" = postgraduate degree). The average level of reported parental highest education was 4.23, *SD* = 0.60.

Design. Children were asked to read dual-language (English-Mandarin) books presented in an electronic form (digitalized PowerPoint slides), self-paced, in this within-subjects design. There were two types of task: (1) a baseline task where children read a dual-language book silently on their own and (2) an experimental task where children read a dual-language book prerecorded with audio narration and text-tracking

animation in English and another prerecorded in Mandarin (order counterbalanced). Children always complete the baseline silent reading task first before the experimental enhanced reading task to avoid any carryover effects. Children's average looking time to the target text per page per child was the main variable of interest. Rectangular areas of interest (AOIs) were drawn over each English and Mandarin sentence with a border of approximately 0.5 to 1.0 cm on every page of the books. To measure attention to target sentences, fixation durations (i.e., looking time) to AOIs were extracted over the entire duration a child spent on a page. Proportion of looking time (PLT) to a target language in a page (i.e., $PLT_{English}$ or $PLT_{Mandarin}$) was calculated as the fixation duration to a target language sentence AOI over fixation duration to both language sentences. We then calculated the mean PLT to a target language by taking the sum of PLT of all the pages in the book and then averaging it. The mean PLT reflects the average preference of looking to a particular language sentence over another language sentence.

After reading each story, children answered two questions in each language. In the baseline task, children answered four comprehension questions after the story (two questions in each language, counterbalanced by language across participants). In the experimental task, children answered a total of four comprehension questions, of which two were for each (language) book. As previous studies found inconsistent effects of multimedia on children's story comprehension (e.g., Parish-Morris et al., 2013; Pearman, 2008), analysis of these comprehension questions in this study were largely exploratory.

In addition, children's reading ability was assessed using a modified reading ability test to control for their preexisting differences in English and Mandarin reading abilities specific to this set of e-books, as such differences may directly influence children's reading behavior in the study (Biemiller, 2003; Gong & Levy, 2009)—children who have a higher reading ability in English than Mandarin may tend to read English sentences more than Mandarin sentences when presented with both in the same text and vice versa. Parental report on language exposure of individual child and teachers' rating of reading difficulty of the books were also obtained to have a better understanding of the language background of the children as well as to ascertain that the books are at an appropriate reading level for these children.

Materials

E-Books. We adapted the brightly colored bilingual English-Mandarin Spot series by Eric Hill that comprise stories of comparable length, characterization, storyline, linguistic complexity, and illustrations (e.g., *Spot Stays Overnight, Spot Says Goodnight*, and *Spot Goes to the Park*). Other studies that examine print attention in preschoolers have used similar series of storybook in English (e.g., Justice et al., 2005). First, to assess the readability of the books for this population of children, the kindergarten teachers of the children who participated in the study were given the sentences from the books and were asked (1) how many children in their class would be able to read most of the words in the story, (2) how many of them would be able to understand the story if they were to read the story independently, and (3) if adults were to read the story to the children, how many of them would be able to understand the story (6-point scale: "1" = <10% to "6" = 90% or more). On average, the teachers rated about half of the children would be able to read most of the words in the story ($M = 3.55$, $SD = 0.26$), about three quarters of the children would be able to understand the story if they were to read the story independently ($M = 4.28$, $SD = 0.22$), and that most of the children would be able to understand the story if an adult were to read the story to them ($M = 5.53$, $SD = 0.25$). This suggests that the stories were pitched at an appropriate level for comprehension but yet remains reasonably challenging for independent reading for this group of children.

Each storybook had a total of 16 pages, with an average of 6.25 words per page. Each page was converted to an electronic form using a scanner.

Two types of e-books were created for each story:

a. *Silent dual-language e-books (baseline task).* The stories were presented as PowerPoint slides on a computer with no sound or visual add-ons (see Figure 1a). A child could control his reading pace by pressing a spacebar on the keyboard to flip to the next page, with a maximum duration of 22.17 seconds per page.
b. *Enhanced dual-language e-books (experimental task).* The stories were also presented as PowerPoint slides on a computer, but each sentence was "read" by a female native speaker (prerecorded) in either English or Mandarin with a "finger" tracking each sentence as the words were read (see Figure 1b). A child could stay on the page for a maximum of 22.17 seconds per page or press the spacebar to advance to the next page.

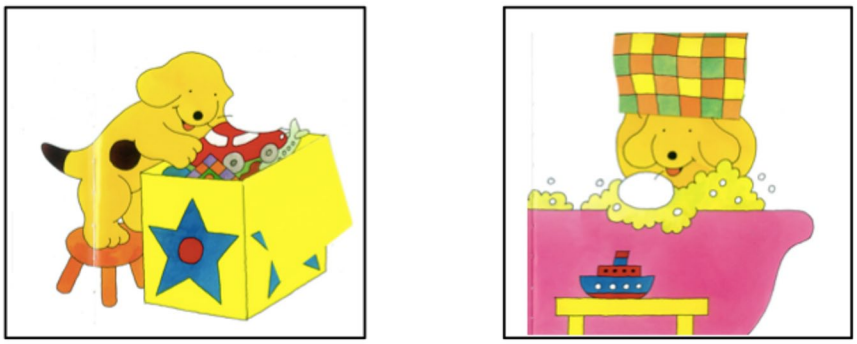
Comprehension test. After each story, children were asked questions about the characters or content of the story they just heard or read as an indication of how well they understood the story. For each book, four forced-choice questions (two in English and two in Mandarin) were derived based on the contents of the book (see the appendix, Table A1). For each question, the same female native speaker was recorded "asking" each question, and two pictures (of which one was the correct target) were displayed on the computer screen (see Figure 2). Children answered by pointing to one of the two pictures. The maximum score for the comprehension test in each language is 2 for each book.

Reading ability test. Word Recognition Tests in English and Mandarin were constructed to collect information about the children's preexisting English and Mandarin reading

(a)

(b)

FIGURE 1. *Sample pages of (a) a silent e-book and (b) an enhanced e-book.*



"What did Spot do before he went to bed?"/ "小玻睡觉前做了些什么？"

FIGURE 2. *Example of a comprehension question.*

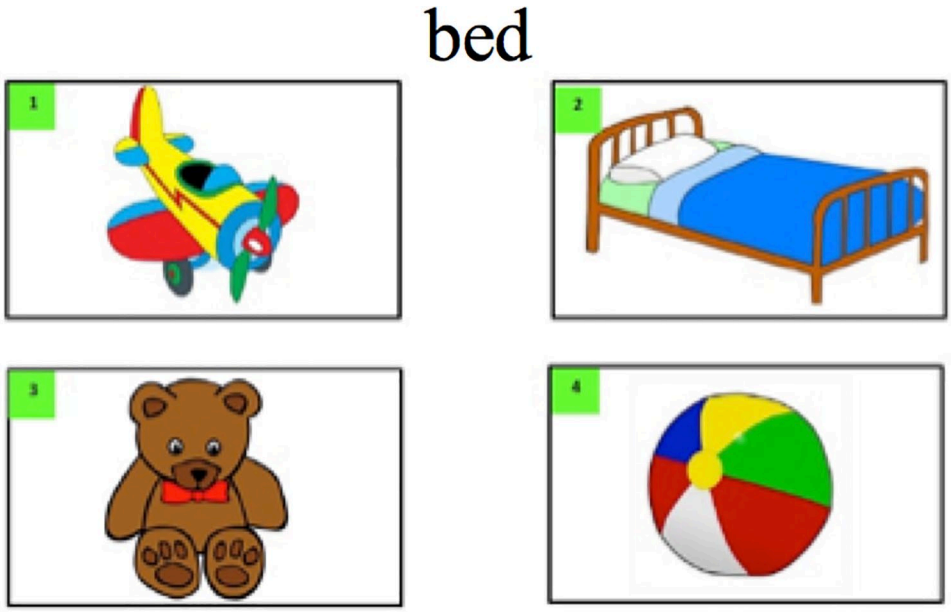


FIGURE 3. *Example of an item from the Word Recognition Test.*

abilities. Words from the e-books were first extracted and distributed to the kindergarten teachers who then indicated the words that a typical child of this age would likely be able to read or not independently. Twenty words were selected for each language: 10 were those indicated by the kindergarten teachers that children typical of this age would likely not be able to read (four words from each book—six nouns, two verbs, and two adjectives/other in total), and 10 (matched) were from the remaining words that the children would likely be able to read (see the appendix, Table A2). In addition, one simple word in each language, "cat" and "一" ("one"), were used as practice trials to familiarize the children with the test procedure. The test was constructed to resemble a standard receptive picture-vocabulary test, where each word was presented with four pictures (one of which is the correct target; see Figure 3). Children were asked to point to the picture that represents the word. Children were not required to read the word out aloud. This is important because children may recognize and know a particular word but yet not know how to pronounce it. No feedback was provided. The items were presented as a 21.0 cm by 29.7 cm ring-bound book. For each child, the range of possible scores for their reading ability is 0 to 20 for each language.

Procedure. Children took part in the study individually in a room located within their child care center. Children first completed the Word Recognition Test. The experimenter guided each child through two practice trials before the test trials (English practice trial was always presented first). All children answered the practice trial questions in both languages correctly. Half of the children received trials in English first and the other half received trials in Mandarin first.

This was followed by the baseline reading task and the experimental reading task during which a dual-language book was presented on a computer screen fitted with a Tobii TX300 eye tracker. Children were told to read a story presented on the computer screen silently and to press the spacebar to turn the page. Once they finished reading a story, they would be asked a few questions about it. Children were first asked to read two practice slides silently, one each in English and Mandarin, that showed (1) the main character Spot with a sentence, "Hello, my name is Spot/*你好！我是小玻*" and (2) Spot and a white rectangle with a sentence, "I like white color/*我喜欢白色*." This was followed by a practice test slide with one white rectangle and one red rectangle displayed side-by-side, and a prerecorded female voice asking (in English followed by Mandarin), "Which color does Spot like/他喜欢什么颜色?" Children were asked to respond by pointing to one of the two pictures. All children answered this question in both languages correctly. Children then proceeded to read a dual-language book silently (baseline task) and answered four comprehension questions after the story (two questions in each language, counterbalanced by language across participants). This was followed by reading two dual-language books (experimental task), one prerecorded with a female voice reading in English with the English sentences concurrently tracked by a pointing animation, and another prerecorded with a female voice reading a different book in Mandarin, simultaneously tracked by a pointing animation on the Mandarin sentences, order counterbalanced across participants. Children had to answer two comprehension questions after each story in the language that was consistent with the recorded speaker. Children were randomly assigned to any of the titles to minimize any

TABLE 1
Means of Reading Ability and Comprehension Scores for Studies 1 and 2

	Study 1, *M* (*SD*)	Study 2, *M* (*SD*)
Reading ability (out of 20)		
English	11.69 (5.80)	14.95 (4.38)
Mandarin	11.00 (3.88)	11.41 (3.43)
Comprehension scores (out of 2)		
Baseline dual language (English questions)	1.53 (0.67)	1.61 (0.64)
Baseline dual language (Mandarin questions)	1.63 (0.66)	1.50 (0.73)
Baseline English language (English questions)	—	1.69 (0.63)
Baseline Mandarin-language book (Mandarin questions)	—	1.39 (0.70)
Experimental enhanced reading (English questions)	1.81 (0.54)	1.79 (0.47)
Experimental enhanced reading (Mandarin questions)	1.75 (0.44)	1.46 (0.82)

potential confound in the number of words or the difficulty of vocabulary words distributed in each story and children's background knowledge of the story. The experimenter only spoke in English throughout the entire session.

Results

We hypothesized that (1) children look longer at English sentences (dominant language) than Mandarin sentences (less dominant language) when asked to read a dual-language book independently and (2) children look longer at the respective target language sentences highlighted by the enhancing multimedia features than the nontarget language sentences.

Reading Ability and Comprehension Scores. Means and standard deviations of reading abilities and comprehension scores are shown in Table 1. For reading ability, a paired-samples *t* test revealed that children scored similarly in the English reading test and the Mandarin reading test, $t(31) = 0.69$, $p = .50$; $d = 0.14$. Children's English and Mandarin reading abilities were comparable; thus, subsequent analyses did not control for a difference in children's English and Mandarin reading scores. However, age may be an important developmental variable in reading. For example, Crone and Whitehurst (1999) found that the oldest children in preschool and kindergarten had significantly better literacy skills than those who were younger by 10 months. In our sample, we found a significant effect of age on English reading scores, $t(30) = 3.19$, $p = .003$, but not on Mandarin reading scores, $t(30) = .72$, $p = .48$ (median split; Young group = 4.53–5.56 years; Old group = 5.59–6.37 years; difference between the oldest in the Old group and the oldest in the Young group is 10 months). Since the development of literacy skills may not be linear by age, we followed previous studies and included age group (median split) as a between-subject variable in subsequent analyses.

For comprehension test, a 2 (Condition: Baseline vs. Experimental) × 2 (Age Group: Young vs. Old) × 2 (Question Language: English vs. Mandarin) repeated-measures analysis of variance (ANOVA) revealed a marginally significant main effect of Condition, $F(1, 30) = 3.82$, $p = .060$, partial $\eta^2 = .11$. Children's average comprehension scores for the experimental reading sessions per language ($M = 1.78$, $SE = 0.07$) were trending to be higher than their average comprehension scores from the baseline reading sessions ($M = 1.58$, $SE = 0.10$). No other significant differences were found (ps > .35).

TABLE 2
Mean Proportion of Looking Times Between English and Mandarin Sentences Toward Target Language in Silent Dual-Language Condition in Study 1 and Study 2

	Overall Mean (*SD*)	
	Study 1	Study 2
Study 1		
Silent dual language		
English sentences	0.64 (0.27)	0.74 (0.19)
Mandarin sentences	0.36 (0.27)	0.26 (0.19)

Attention to Target Sentences. Two children had missing data in the baseline reading task because of equipment failure. The average duration a child spent on a page was 7.95 seconds ($SD = 4.24$) for baseline task, 8.96 seconds ($SD = 1.99$) for experimental task in English, and 9.43 seconds ($SD = 2.63$) for experimental task in Mandarin.

Baseline reading (dual language). A 2 (Text Language: PLTE vs. PLTM) × 2 (Age-Group: Young vs. Old) repeated-measures ANOVA revealed a significant effect, $F(1, 29) = 7.97$, $p = .009$, partial $\eta^2 = .222$. Children looked proportionately significantly longer at English sentences than Mandarin sentences during the baseline task across age groups (see Table 2).

TABLE 3
Mean Proportion of Looking Times Between English and Mandarin Sentences Toward Target Language During and Post-Animation in Enhanced Dual-Language Conditions in Study 1

	Overall Mean (*SD*)	
	During Animation	Post-Animation
Enhanced English dual language		
English sentences	0.86 (0.16)	0.76 (0.26)
Mandarin sentences	0.14 (0.16)	0.24 (0.26)
Enhanced Mandarin dual language		
English sentences	0.28 (0.21)	0.56 (0.22)
Mandarin sentences	0.72 (0.21)	0.44 (0.22)

Experimental reading (English). To investigate the effect of animation alone (during the animation phase) as well as to dissociate the possible confound of an after effect of reduced attention when the animation ended (post-animation phase), we examined the mean PLTE and PLTM for each page over two time periods: (1) from beginning to the end of animation (i.e., animation phase) and (2) remaining duration until the child advanced to the next page (i.e., post-animation phase; see Table 3).

A 2 (Text Language: PLTE vs. PLTM) × 2 (Phase: Animation vs. Post-animation) × 2 (Age Group: Young vs. Old) repeated-measures ANOVA was conducted to investigate children's PLT to the target (English) language. Results revealed a significant main effect of Text Language, $F(1, 30) = 85.95$, $p < .001$, partial $\eta^2 = .74$. Children's PLTE was significantly longer than PLTM when a finger-pointing animation tracked the English sentences while a voice read the sentences out loud. This is qualified by a significant interaction effect between Text Language and Phase, $F(1, 30) = 7.18$, $p = .012$, partial $\eta^2 = .19$. Further analyses revealed that PLT to the target (English) text was significantly higher than PLT to the Mandarin text in both the animation phase and the post-animation phase, $t(31)$s > 2.62, ps < .014, ds > 0.45, but PLT to the Mandarin text increased significantly after the guided reading to English text has ended compared with during animation, $t(31) = -2.62$, $p = .014$, $d = 0.45$. No other significant results were found.

Experimental reading (Mandarin). Similarly, a 2 (Text Language: PLTE vs. PLTM) × 2 (Phase: Animation vs. Post-animation) × 2 (Age Group: Young vs. Old) × repeated-measures ANOVA was conducted to investigate children's PLT to the target (Mandarin) language (see Table 4) for the experimental reading session in Mandarin. One child did not look at any English or Mandarin AOIs after the animation ended, thus there was no post-animation data for this particular child. Results revealed a near significant main effect of Text Language, $F(1, 29) = 3.98$, $p = .056$, partial $\eta^2 = .12$.

TABLE 4
Mean Proportion of Looking Times Toward Target Sentences in Silent Single Language Condition in Study 2

	Overall Mean (*SD*)
Silent single English	
English sentences	0.27 (0.22)
Others[a]	0.73 (0.22)
Silent single Mandarin	
Mandarin sentences	0.20 (0.20)
Others[a]	0.80 (0.20)

[a]"Others" refer to areas on the page not defined as an area of interest.

Children looked longer at the Mandarin sentences than English sentences when there was a voice reading and a finger animation pointing to the Mandarin sentences. Importantly, there was a significant interaction effect between Text Language and Phase, $F(1, 29) = 97.43$, $p < .001$, partial $\eta^2 = .77$. Further analyses revealed that children's PLT to the target (Mandarin) text was significantly higher than PLT to the English text during animation phase, $t(30) > 5.83$, $p < .001$, $d = 2.06$, but this difference was no longer significant after the animation ended, $t(30) = 1.62$, $p = .12$, $d = 0.58$. In fact, children looked more at the English text than Mandarin text post-animation compared with during animation, $t(30) = -9.90$, $p < .001$, $d = 1.27$. No other significant results were found.

In summary, while Singapore bilingual children would choose to look at English sentences rather than Mandarin sentences when given a dual-language book to read independently in a baseline (silent-reading) task, enhancing multimedia features such as audio narration and tracking animation were effective in drawing children's attention to the print of the target sentences in a dual-language book. However, it is possible that the effectiveness of multimedia features in a dual language is due to something special about presenting two languages within the same text per se. To tease this apart, we conducted Study 2 to examine the following questions: (1) Can we replicate the English language bias found in the baseline task (silent reading of dual-language e-books) in Study 1 on a different population of children? (2) Do children still prefer reading English books to Mandarin books when only one language text is presented in the book (silent reading of single language e-books)? and (3) Are multimedia features effective in drawing children's attention to print in the absence of a competing language?

Study 2

Study 2 was similar in design as Study 1 except that, instead of one silent dual-language book as the baseline task and two enhanced dual-language books as the experimental task, children were presented with one silent

dual-language book ("Baseline dual") to replicate Study 1 baseline task) and two silent single-language books ("Baseline single"—one each in English and Mandarin) to serve as baseline tasks for single-language book, and two enhanced single-language books ("Experimental"—one each in English and Mandarin) as the experimental task.

We would expect that when reading a book printed in only one language silently (i.e., no competing language), contrary to reading dual-language books, children would spend a comparable amount of time on the text in either languages. In addition, we would also expect that the same enhancing multimedia features in Study 1 (i.e., audio narration and tracking animation) would be effective in increasing children's attention to the print in single-language books as well, even for those printed in their less dominant language (i.e., Mandarin).

Method

Participants. A different group of 39 English-Mandarin bilingual preschoolers participated in this study (M_{age} = 5.26 years, *SD* = 0.51, range 4.24–6.28 years; 18 males, 21 females). They were recruited from a bilingual childcare center in a middle-class neighborhood. The same language questionnaire used in Study 1 was given to parents. The children were reported to have English as their first language and Mandarin as their second language (average amount of exposure *at home* in English and Mandarin was 56.53% and 43.46%, respectively). The average level of reported parental education was 3.63, *SD* = 0.92 (from a scale of 0 to 5).

Design. The design of Study 2 is largely similar to Study 1. However, in Study 1, we were interested in whether enhancing multimedia features were effective in directing children's attention to the target language text in a book where texts in two different languages were competing for attention at the same time (i.e., a dual-language book). Our main variable of interest was thus the mean PLT to a target language in a page, that is, the mean fixation duration to a target language sentence AOI over fixation duration to both language sentences. In Study 2, however, we were mainly interested in whether the English language bias found in the baseline task in Study 1 would be replicated in Study 2 on a different population of children, as well as whether a similar heightened attention to print would be achieved in a single-language book with multimedia features compared with one without. Thus, in Study 2, our main variables of interest include (1) the comparison of the mean PTL to English text versus Mandarin text in the baseline dual-language book as per Study 1, (2) the comparison of the mean PLTE and PLTM over two time periods in the experimental single-language books: animation phase and post-animation phase, and (3) the comparison of the *mean total fixation duration* over the entire duration a child spent per page in the baseline single-language books versus the experimental single-language books.

Materials. Much of the materials were similar to Study 1 with the exception that in the single-language e-books, only sentences of one language appeared in each book. In the experimental condition, the same animation ("reading" and "finger" tracking) from Study 1 was used. Two additional books, *Spot Goes to School* and *Spot's First Christmas*, were included in Study 2 as children had to read five books (one Baseline-Dual, two Baseline-Single, and two Experimental-Single; stories counterbalanced). The comprehension test and the reading ability tests were similar as those in Study 1.

Procedure. The procedure and instructions for the sessions remained the same as Study 1.

Results

Reading Ability and Comprehension Scores. Means and standard deviations of reading abilities and comprehension scores are found in Table 1. Eight children had missing data for the comprehension task: one had missing data in all conditions due to equipment failure and seven did not answer the questions in time (one in baseline English task, three in baseline Mandarin task, one in experimental Mandarin task, and one in both baseline single-language tasks).

For reading ability, a paired-samples *t* test revealed that children scored significantly higher in their English reading test than Mandarin reading test, $t(38) = 5.57$, $p < .001$; $d = 0.91$. Children in Study 2, in general, had better reading ability in English than in Mandarin. We decided to control for a difference in children's English and Mandarin reading scores (ReadDiff) in subsequent analyses, since those who had comparably better reading ability in English than Mandarin may direct their attention to the English text more than those who had equivalent reading ability in both English and Mandarin (e.g., Biemiller, 2011; Gong & Levy, 2009). No significant relationship between age and reading scores was found (*p*s > .87).

For comprehension test, a 2 (Condition: Baseline Single Language vs. Experimental Single Language) × 2 (Question Language: English vs. Mandarin) repeated-measures analysis of covariance (ANCOVA) with ReadDiff as a covariate revealed no significant main effects after controlling for differences in reading ability, Fs(1, 28) < .96, *p*s > .34, partial $\eta^2 < .032$.

Attention to Target Sentences. As per Study 1, rectangular AOIs were drawn over each English and Mandarin sentence with a border of approximately 0.5 to 1.0 cm on every page of the books. Fixation durations to the sentences were extracted over the entire duration a child spent on a page. One child had missing data for the baseline dual language

task, one had missing data in baseline single-language tasks, and another had missing data in experimental single-language tasks. Two other children had missing data in three tasks (one had missing data in both baseline single-language tasks and baseline dual-language task, while the other had missing data in both baseline single-language tasks and experimental Mandarin-only task). No child had missing data in more than three conditions. Missing data were due to either equipment failure or the child's lack of attention to the screen. On average, children spent 5.94 seconds on each page per book (*SD* = 3.17) for baseline dual-language reading task, 5.09 seconds (*SD* = 3.58) for baseline English reading task, 4.38 seconds (*SD* = 3.16) for baseline Mandarin reading task, 6.57 seconds (*SD* = 3.25) for experimental English reading task, and 6.86 seconds (*SD* = 2.73) for experimental Mandarin reading task.

Do children in Study 2 also prefer to read English text to Mandarin text given a dual-language book to read on their own? As per Study 1, PLTE and PLTM were calculated. A repeated measures ANCOVA revealed a significant effect of Text Language (PLTE vs. PLTM) after ReadDiff was controlled for, $F(1, 36) = 28.14$, $p < .001$, partial $\eta^2 = .44$ (see Table 2). Replicating the results of Study 1, children in Study 2 looked significantly longer at English sentences than Mandarin sentences when reading a dual-language book silently. No other interaction effects were found.

Do children in Study 2 prefer to read an English-only book to a Mandarin-only on their own? Since there was only one language text in the book, we computed the PLT to the text per page not with the other language (as in dual-language books) but with the total amount of time spent looking at the page (i.e., total fixation duration per page). The mean PLTE and PLTM for each of the two single-language books were then calculated over each page (see Table 4). A repeated-measures ANCOVA revealed a non-significant effect of Book Type (silent reading English book vs. silent reading Mandarin book) after controlling for ReadDiff, $F(1, 32) = .19$, $p = .67$, partial $\eta^2 = .006$. This suggests that without a competing language within the same page, children spent comparable amount of time reading text from an English-only book and text from a Mandarin-only book.

Are multimedia features effective in drawing children's attention to print in single-language books? Two types of analyses were conducted. First, we compared the mean total fixation duration over the entire duration a child spent per page in the baseline single-language books with the experimental single-language books. This is to examine whether overall, children spent more time looking at books with enhanced features than those without. A 2 (Condition: Baseline vs. Experimental) × 2 (Book Type: English vs. Mandarin) ANCOVA showed that the effect of Condition was significant after controlling for ReadDiff, $F(1, 30) = 4.36$, $p = .045$, partial $\eta^2 = .13$. Children spent a significantly larger amount of time on enhanced single-language books ($M = 6.74$, $SE = 0.44$) compared with silent single-language books ($M = 4.79$, $SE = 0.56$). No other significant effects were found (ps > .30).

TABLE 5
Mean Proportion of Looking Times Toward Target Sentences During and Post-Animation in Study 2

	Overall Mean (*SD*)	
	During Animation	Post-Animation
Enhanced single English		
English sentences	0.30 (0.14)	0.13 (0.09)
Others[a]	0.70 (0.14)	0.87 (0.09)
Enhanced single Mandarin		
Mandarin sentences	0.31 (0.17)	0.15 (0.09)
Others[a]	0.69 (0.17)	0.85 (0.09)

[a]"Others" refer to areas on the page not defined as an area of interest.

Second, we analyzed the mean PLTE and PLTM for each page over two time periods in enhanced single-language books: animation phase and post-animation phase. A 2 (Book Type: enhanced English vs. enhanced Mandarin) × 2 (Prepost: during animation vs. post-animation) ANCOVA revealed a significant main effect of pre–post after controlling for ReadDiff, $F(1, 33) = 47.09$, $p < .001$, partial $\eta^2 = .59$ (see Table 5). Children looked significantly longer at the sentences during the animation phase compared with the post-animation phase. No other effects were found (ps > .17, partial η^2s < .056). This suggests that the audio narration and finger-tracking animation were effective in drawing children's attention to the print in both English and Mandarin single-language books.

General Discussion

This study aimed to examine the contributions of the multimedia-learning framework to the reading behavior (attention to print) of bilingual preschoolers, especially in a challenging dual-language reading context. As expected, bilingual children looked more at English sentences than at Mandarin sentences in a silent dual-language book in both Studies 1 and 2. When there was no competing language within the same text (Study 2—silent single-language), children spent comparable amount of time reading the text in the respective languages. More important, we found that the addition of multimodal features was effective in directing bilingual children's attention to the respective target

language. In Study 1, children looked longer at the target language in a dual-language book when there was an audio narration and tracking animation of the target text than when asked to read the book on their own silently, even when the target language was Mandarin, the less dominant language. In Study 2, children spent more time looking at single-language books with the enhanced features than those without. Thus, in both studies, children spent more time looking at the e-books with multimedia features than those without. Although we found a trend in an increase in story comprehension in the enhanced reading compared with silent reading condition in dual-language books, no significant effects in single-language books were found.

In a complex task with competing demands, such as a dual-language book that features parallel text, children may only attend to specific text due to limited resources (e.g., attend to their dominant language text and ignore the other). Our findings suggest that taking into consideration the cognitive theory of multimedia learning as well as the attention-guiding principle when designing an e-book can help guide children in the reading task (Betrancourt, 2005; Mayer & Moreno, 2003; Paivio, 1986). The matched dual-channel inputs, that is, visual input and audio narration, help children better integrate information and reduce cognitive overload. The tracking animation on the text helps guide children's attention to the target text and mitigates their limited capacity to process two sources of information at any one point in time. These findings are consistent with studies on single-language traditional print books and single-language e-books where similar print referencing and animation were found to increase children's attention to print (Justice et al., 2008; Sun et al., 2019). Attention to print has a positive correlation with the development of literacy skills, such as print awareness, word recognition, and comprehension skills (e.g., Hammill, 2004; Justice & Ezell, 2004; Piasta et al., 2012). Reading development research has shown that children at the emergent stage would start by mapping the meaning via sound with letters (Byrne, 1998), and then gradually learning how to decode words to finally being able to read correctly and fluently (Nation, 2009; Share, 1995, 2008). Thus, appropriate multimedia features embedded in computerized books that facilitate dual-channel input processing can help map children's attention to a target language text (e.g., the less dominant language) and support the development of children's literacy skills in that language.

Our findings have important implications on modern educational initiatives that support children's emergent literacy in two languages. Dual-language e-books with appropriate multimedia features that support bilingual children's emergent literacy skills can be implemented in bilingual education programs in many countries. Previous studies suggest that shared reading between mother and child using traditional dual-language print books appears to have a positive effect on children's metalinguistic awareness, graphophonemic skills and knowledge, and literacy skills (e.g., Robertson, 2006; Sneddon, 2008a, 2008b). However, even with shared reading, it might be challenging for children to develop orthographic or print-specific skills if the shared reading process predominantly focuses on the nonprint aspects of the book (e.g., illustrations, nouns, story content) without additional explicit references to print (Evans & Saint-Aubin, 2005; Justice et al., 2005; Roy-Charland, Saint-Aubin, & Evans, 2007). Thus, there is a need to consider the use of more explicit teaching methods with young children that increase their attention to print. Digital versions of dual-language books with appropriate multimedia features would thus allow children to gain the ability to read independently with effective guidance from explicit print referencing. We suggest that e-books, with the appropriate multimedia features, could provide an alternative pathway to enhance the reading process and encourage independent reading, thus complementing the traditional reading process with explicit attention to print (see Justice et al., 2008, for a discussion on the how exposure to print referencing for as few as 4 weeks can accelerate children's print knowledge on the magnitude of large effects).

An important consideration to note is that we did not study children's attention when only a visual input or only an audio input was provided. Our enhanced condition combined an audio input (narration) with visual input (finger animation). It may be important to examine if one of the input channels alone would be sufficient to create a similar increased attention to print, or that it is the synergistic display of inputs from two different modalities that is the key to increasing attention to print. A recent study by Sun et al. (2019) on single-language e-books suggested that it is the combined provision of explicit print referencing in audio and visual that has a significant effect on attention to print (fixation duration), target word production, and storytelling. Future studies should consider examining the separate effects of each input channel on attention to print in dual-language e-books.

Interestingly, children's story comprehension improved in the enhanced conditions in dual-language books (Study 1), but not single-language books (Study 2). This finding is in congruence with some studies (e.g., Nayak & Sylva, 2013), but contradicts other studies showing that multimedia features like animations help children understand the stories better (e.g., Piasta et al., 2012). One reason for the discrepancy in findings between Study 1 and Study 2 could have been due to the fact that dual-language books impose a much higher load on children to pay attention to print in the target language as compared with single-language books where children have to attend to only one language. Therefore, the multimedia features may have helped children in selectively attending to the target language in the cognitively demanding dual-language books, thereby boosting story comprehension. However, as the cognitive load for single-language books is

already low, such features may not be needed to facilitate story comprehension, even if they do increase attention to print. An alternative explanation, and a noted limitation of the current study, is that our comprehension questions focused mainly on simple literal content and did not test higher order reading comprehension that is important for an interactive reader, such as inference, prediction, evaluation, or personal responses of events and characters (e.g., Day & Jeong-suk, 2005; Nuttall, 1996). Our two choice-based comprehension questions for each story might have been too simple and not robust enough to accurately examine whether multimedia features did enhance children's more complex understanding of the stories. We also noted that we did not include a more elaborated measure or set of measures of reading ability. To do that, we need to include versions of the same measures in both English and Mandarin. Future studies could possibly include standardized measures of reading ability with their equivalent Mandarin (or other language) versions and design a series of more difficult questions to test whether the addition of multimedia features would improve children's story comprehension in single and dual-language e-books.

One consideration relating to picture book reading is the influence of cultural elements. Cultural values and norms are commonly reflected in the thematic content of storybooks set in a particular cultural context (Miller, Wiley, Fung, & Liang, 1997; Tsai, Louie, Chen, & Uchida, 2007; Zheng, 1997). Our study used stories set in a western cultural context (i.e., "Spot the dog") with Asian children, although they were the official English-Mandarin books of the series. It is possible that children in our study might have found English sentences describing characters set in a western context more culturally compatible compared with Mandarin sentences (Vogt, Jordan, & Tharp, 1987), and thus tended to look more at English sentences than Mandarin sentences in a "Spot the dog" book. Further research on how the cultural setting of a storybook influences children's attention to a particular language in dual-language books would yield interesting insights into the interplay of culture and multimedia features on biliteracy development.

Exposing children to technologies at an early age has been controversial (Rogowsky et al., 2018). Skeptics have raised questions on the appropriateness of the use of technology in early childhood settings, citing concerns that such experiences may reduce the amount of social interaction a child engages in (Burnett, 2010). However, while such concerns are valid in the context of social development, such concerns must not overshadow the potential benefits that e-books bring to young children's developing literacy. For example, children who do not respond well to traditional print may find e-books on computers or tablets particularly helpful (Maynard, 2010). Multimedia features like audio narration and tracking animation that e-books often have are a means for beginning readers to engage with the text. Importantly, e-books allow for individual exploration, as there is no longer a need for an adult to narrate the book to the child (Gong & Levy, 2009). More research on how computer technology can be infused in preschool curriculum and how teachers can make use of technology in a meaningful, student-focused manner is essential to effectively support children's emerging literacy skills.

The current study is one of the first to examine the comparative use of multimedia features in computerized dual-language e-books versus single-language e-books. We found empirical support of the hypothesis that guided multimodal inputs provide important connections between the audio and visual channels, which facilitate information processing, especially during a storybook reading task that challenges the children's limited cognitive capacity. Coupled with synchronized print referencing, these multimodal features facilitated the orientation of children's attention to target language, even if these features may not necessarily increase children's comprehension in such books. It is important to note that language and literacy development is a continuous process and we should examine and document it beyond a brief test using more sophisticated measures and documentation of change over time. Nevertheless, our findings suggest the benefit of using computer technology that consider dual-channel inputs matched with attention-guiding cues, and the potential of using such multimedia features in current language programs to support children's literacy, especially in their less dominant language, as today's societies are becoming increasingly bilingual.

Appendix

TABLE A1
List of Comprehension Questions

Book	Questions
Spot Stays Overnight	What did Spot forget to bring to Steve's house? 小玻忘了带什么东西去史蒂夫的家？ What was Spot doing when his mum came to see him? 妈妈来找小玻时，小玻正在做什么？
Spot Says Goodnight	What did Spot do before he went to bed? 小玻睡觉前做了些什么？ Whom did Spot say goodnight to? 小玻跟谁说 "晚安"？
Spot Goes to the Park	What did Spot bring to the park? 小玻带什么东西去公园？ Who helped Spot to bring the ball back from the pond? 谁帮忙把球送回给小玻？
Spot Goes to School	What was Spot doing when it's time to sing? 该唱歌的时候，小玻在做什么？ What did Spot bring to show to his class? 小玻带什么东西去学校？
Spot's First Christmas	Who came to Spot's house on Christmas Eve? 圣诞夜那晚，谁去了小玻的家？ What did Spot get from Father Christmas? 圣诞老人送什么礼物给小玻？

TABLE A2
List of Words Used in the Word Recognition Test

English Words	Duck, Play, Bed, Dad, Bag, Door, Happy, Ball, Sing, Look
	Splash, Swing, Bath, Clean, Slide, Tyre, Brush, Collar, Bone, Little
Mandarin Words	小，妈妈，爸爸，好，开心，家，早上，老，小姐，上
	追，拿，困，干净，梯，袋，礼物，刷子，故事，骨头

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