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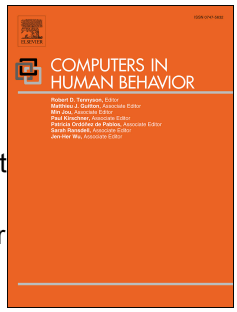

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Learning through Play:

The Impact of Web-based Games on Early Literacy Development

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1. Introduction

For the past three decades, experts have debated whether computers can support early literacy learning (McCarrick & Li, 2007; Plowman & Stephen, 2003). Seeing promise in educational game-based websites that potentially could widely disseminate lessons about literacy in engaging ways, scholars and content producers around the globe in countries such as Australia (e.g., Wolgemuth et al., 2013), Canada (e.g., Savage, Abrami, Hipps, & Deault, 2009; Savage et al., 2013), Finland (e.g., Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011), France (e.g., Magnan & Ecalle, 2006), Israel (e.g., Mioduser, Tur-Kaspa, & Leitner, 2000), Italy (e.g., Giacomo Dina et al., 2016), and the Netherlands (e.g., Segers & Verhoeven, 2003, 2005) created educational, literacy-themed computer games and websites for young children. In the U.S., where the present data were collected, the federal government has funded numerous initiatives aiming to utilize websites and other technology for supporting academic development (e.g., U.S. Department of Education, Office of Educational Technology, 2010). For example, the U.S. Ready To Learn (RTL) initiative provides $25 million annually for commercial screen media, including computer games, websites, and other new media, intended to promote early literacy among both general and low-income populations (Hurwitz, 2016).

Currently, the evidence is mixed as to whether educational computer games and websites can successfully promote early literacy (Torgerson, 2007), especially if played by young children at home outside of a school setting (Garrity, Piotrowski, McMenamin, & Linebarger, 2010). The present study is unique in the focus on early childhood and the use of a controlled experimental design (Tobias, Fletcher, Dai, & Wind, 2011; Torgerson, 2007) to determine whether a website

with a leveled series of literacy-themed games could promote early literacy when played at home.

1.1. Early Literacy Skills

Children who enter kindergarten without foundational early literacy skills remain at risk for reading difficulties throughout their schooling (Alexander, Entwisle, & Olson, 2007; Juel, 1988). Expert groups, including the National Reading Panel (2001) convened by the U.S. Congress have identified a number of foundational early literacy skills crucial to later literacy development; these skills have been promoted heavily in U.S. educational policy. As young children begin to learn to read, they first develop *concepts of print* or knowledge of print conventions (e.g., that text in English is read from left to right; Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), 2010), *alphabetic knowledge* or mastery of the names and printing of uppercase and then lowercase letters of the alphabet (Grant et al., 2012; Drouin, Horner & Sondergeld, 2012; NICHD, 2010; Pence Turnbull et al., 2010), and *phonemic awareness* or an understanding of language sounds, which is demonstrated through sub-skills such as rhyming and alliteration (Grant et al., 2012; National Reading Panel, 2000; Wagner et al., 1997). Children's ability to provide the sound(s) associated with each letter allows them to move on to more complex skills, such as *phonics,* or the ability to map letters and sounds, and spelling (Foulin, 2005; National Reading Panel, 2000). As children master these skills, they require fewer processing resources to name letters and sounds, which contributes to conventional reading success (Burgess & Lonigan, 1988; Foulin, 2005). Over time, children begin to develop *fluency* or the ability to read accurately, quickly, and expressively (National Reading Panel, 2000), and *comprehension* (National Reading Panel, 2000).

Unfortunately, these skills are often less developed among lower-SES children than their same-age higher-SES peers (Bradbury, Corak, Waldfogel, & Washbrook, 2015). All these early literacy skills are moderate to large predictors of conventional literacy, including reading comprehension, spelling, and writing, and have been demonstrated to be improved via intervention (see NICHD, 2010; National Reading Panel, 2000).

Throughout childhood, the child also grows his/her *vocabulary* (National Reading Panel, 2000). Vocabulary knowledge is important not only to the development of reading comprehension (Beck, McKeown, & Kucan, 2002; Stahl & Fairbanks, 1986) but also to general reading ability (Stanovich, Cunningham, & Feeman, 1984). It may be particularly important to identify interventions that support the vocabulary skills of children from low-income communities, given the findings from Hart & Risley's (2003) seminal study indicating that low-income children hear one-half to one-third fewer spoken words on a daily basis than children in more affluent households.

1.2. Educational Computer Games Supporting Literacy Development

1.2.1 Concerns about learning from media. Critics have questioned whether it is the best use of children's time to be using computers and other screen media (for reviews, see McCarrick & Li, 2007; Plowman & Stephen, 2003). Concerns have centered around whether that time might displace the time they have available to focus on learning or other developmentally enriching tasks (Neuman, 1995). Research with older children found that computer use facilitated independent reading time but inhibited study time and had mixed results on children's academic achievement, partially substantiating time-related concerns (Hofferth, 2010). Even if children only spend a small amount of time on the computer, other concerned parties worry that they might inadvertently be exposed to inappropriate content, such as sexual or violent videos or

advertisements (Plowman & Stephen, 2003). Aligned with these concerns, expert groups such as the American Academy of Pediatrics and National Institute for Care and Health Excellence in the U.K. have advocated placing strict limitations on young children's screen time (Blum-Ross & Livingstone, 2016). Although educational software exists that is intended to ensure the time children spend on the computer is fruitful, critics further contend that preschool-age children lack the abstract and symbolic reasoning capabilities to learn from information presented on a computer screen (McCarrick & Li, 2007). However, in light of a nearly fifty-year history underscoring that children ages 3 and above can learn from well-designed, curriculum-based television (Fisch, 2004), it logically follows that preschoolers might benefit from thoughtfully designed, literacy-themed computer games.

1.2.2. Theoretical background supporting learning from media. Contrasting the critics above, several theories, including frameworks by Fisch and Vygotsky, suggest that educational computer games and websites should be able to promote learning in literacy and other areas. Fisch's (2000; 2004; 2016) Capacity Model, a theoretical model originally intended to explicate learning from television, also has been applied to interactive media. The Capacity Model suggests that children have a limited amount of working memory resources that they can dedicate to screen media. As such, all features in a computer game or other media stimulus should work in tandem to promote the same learning goals and should be designed in a way to avoid distracting children from these goals (Fisch, 2000; 2004; 2016). To that end, the Capacity Model predicts learning from interactive media will be strongest when game mechanics reinforce learning goals (Fisch, 2016). For instance, a literacy-themed computer game ideally would require a child to physically click combinations of letters to blend words, as opposed to only allowing him/her to click frivolous hotspots unrelated to the game's educational lessons

(Guernsey & Levine, 2015). In a similar vein, the model specifies that a computer game will inhibit learning if gaming mechanics or sequences are unintuitive (Fisch, 2016). In other words, if it is challenging to click hotspots or unclear which hotspots to click, the child will focus on these technical issues at the expense of attending to educational lessons – a problem Fisch (2016) refers to as gameplay dominance.

The model further posits that children require a certain level of fine motor skills and familiarity with the computer and computer games in general to be able to benefit from educational computer programs (Fisch, 2016). It is not until between the ages of 3 and 4 that most children first begin using a mouse and computer independently (Calvert, Rideout, Woolard, Barr, & Strouse, 2005). Therefore, children younger than 4 might struggle to benefit from educational computer games, but those ages 4 and above might be capable of benefiting. Because young children are still developing self-regulation and executive function skills, a computer game should allow children to jump straight to gameplay or to learn the rules of the game as they play; children become frustrated sitting through long tutorials during which they cannot click the screen (Fisch, 2016).

Further, for the strongest possible learning, the Capacity Model suggests that educational lessons should be repeated across multiple contexts (e.g., multiple games that all promote phonemic awareness; Fisch, 2004). The Capacity Model also posits that games must be engaging, motivating, and playful, with the educational components embedded in the play – a notion shared by many other scholars, including some drawing from Vygotsky's Sociocultural tradition (McManis & Gunnewig, 2012; Plowman & Stephen, 2003; Yelland & Masters, 2007). Beyond the media content itself, the Capacity Model also suggests that parents can help mediate and support children's learning from media (Fisch, 2004), yet another tenet aligned with

Sociocultural theory, as described below.

Vygotsky's (1930–1934/1978) Sociocultural theory explains that humans use culturally meaningful tools to facilitate learning, problem-solving, and other sophisticated behaviors. Recently, scholars have argued that computer games serve as such a tool in the present-day (e.g., Plowman, McPake, & Stephen, 2008). Much like a caring teacher or caregiver, educational computer games can support children's learning by guiding them through increasingly challenging learning experiences that extend their existing knowledge, or, in Sociocultural terms, scaffold children through their "zone of proximal development" (McCarrick & Li, 2007; Yelland & Masters, 2007; Wartella et al., 2016). Ideally, computer games should begin the scaffolding process by presenting the child with content that is slightly more difficult than what he/she could do independently (Yelland & Masters, 2007) and become more challenging or "level up" automatically (Grant et al., 2012; McManis & Gunnewig, 2012), as research suggests this makes games more enjoyable and encourages sustained play (Educational Development Center & SRI International, 2012). Additionally, the computer program itself should provide corrective feedback, hints, and/or affective encouragement as additional means of scaffolding the child's performance (McManis & Gunnewig, 2012; Yelland & Masters, 2007). As a further means of scaffolding, it may be necessary for the computer game to demonstrate or model approaches to solving problems if a child seems stuck or for the program to allow the child to try to answer a question multiple times if his/her first answer is incorrect (Yelland & Masters, 2007). As the child becomes more competent at the skills targeted, ideally the game will decrease the level of scaffolding over time (Yelland & Masters, 2007).

Children have micro-interactions with computers within a broader sociocultural context. By playing computer games designed in the manner described above in a home environment,

children may receive explicit or discern implicit support from their caregivers that computers are an educational tool, which in turn can further enhance learning (Plowman et al., 2008). At a still higher level, a computer game can reinforce lessons children receive from outside sources (Wartella et al., 2016). For example, a computer game that disseminates lessons about pre-literacy in a manner aligned with national early learning standards may reinforce lessons children may be receiving in preschool. When made publicly available as a form of mass media, a computer game can broadly disseminate similar lessons to many children across a society.

Researchers at the Educational Development Center and SRI International (2012) have proposed additional game characteristics that may facilitate learning, positing that interactive media is more engaging when it allows the child to accrue points and achieve feelings of mastery (e.g., reaching the end of a leveled game; also see Ronimus & Lyytinen, 2015). Furthermore, McManis and Gunnewig (2012) recommended that games targeting young children refrain from the extensive use of written or complex verbal instructions and be simple enough that children can play relatively independently (also see Grant et al., 2012 and Plowman et al., 2008).

1.2.3. Extant game evaluations. Systematic reviews suggest that on average, literacy-themed computer games and websites produced in the late '90's and early 2000's only had small, arguably negligible effects on literacy development (Torgerson, 2007). Moreover, many prior evaluations relied on non-validated measures of learning (Hurwitz, 2016). Nevertheless, recent individual evaluations of more modern games have demonstrated positive results using robust measures, at least for children in early elementary school (i.e., kindergarten – 2nd grade). Prior research suggests such games can promote school-age children's alphabetic knowledge (e.g., Hintikka, Aro, & Lyytinen, 2005), phonemic awareness (e.g., Segers & Verhoeven, 2005), phonics (e.g., Saine et al., 2011; Savage et al., 2013), vocabulary (e.g., Segers & Verhoeven,

2003), fluency (e.g., Giacomo Dina et al., 2016; Saine et al., 2011), and comprehension (e.g., Savage et al., 2009). However, it is difficult to say if these findings about computer games' effectiveness would generalize to a slightly younger age group who may have only just recently mastered basic computer operational skills like using a mouse (Calvert et al., 2005).

Most research on literacy-themed websites and computer games has been conducted in school settings with older children (Hurwitz, 2016). However, conducting an evaluation of an educational computer game in a classroom setting may lack ecological validity. During early childhood, computers are primarily used in the classroom as a free play learning activity with little supervision or support (Chen & Change, 2006; Plowman & Stephen, 2003). Further, only about 1 in 5 of classroom teachers report having one computer per child (PBS LearningMedia, 2013), and oftentimes those computers do not have Internet access (Llorente, Pasnik, Penuel & Martin, 2010). Of those with access to any computers, approximately half of early childcare educators *never* use them for structured learning and more than 2 in 5 *never* use them for personal instruction (Blackwell, Wartella, Lauricella, & Robb, 2013). Thus, due to technology not being fully supported in early childhood classrooms, it was considered more valid to examine the impact of learning from computer games at home. After all, about 9 out of 10 families of young children have home computers and high-speed Internet, and in these households, children spend over an hour per week on the computer (Rideout, 2017). At home, they receive support in using the computer from a variety of relatives (Plowman et al., 2008). Given the prevalence and popularity of home computer play among youth in early childhood, it is important to examine the impact of this time use on young children's learning.

1.3. Current Study

This study aimed to evaluate whether an RTL-funded educational website could promote

learning for a diverse sample of young children when played in the home. The website used in the present study, *PBS KIDS Island* (hereafter referred to as *Island*), featured games based on the early childhood-targeted media properties *WordWorld, Super WHY!, Between the Lions, Sesame Street* and *Martha Speaks.* The *Island* was designed to reflect many of the Capacity Model, Sociocultural, and other design principles outlined above, and to promote early literacy in a manner aligned with National Reading Panel recommendations (2001). Previous research suggests that televised versions of these properties promote concepts of print, alphabetic knowledge, phonemic awareness, phonics, vocabulary, and fluency among both general and at-risk youth in preschool and early elementary school (Ball & Bogatz, 1970; Linebarger, Kosanic, Greenwood, & Doku, 2004; Linebarger, 2015; Linebarger, Moses, & McMenamin, 2010; Michael Cohen Group, 2009). Prior to this evaluation, a pilot study was conducted with a sample of 14 children to explore the potential for learning from an earlier version of the *Island.* It appeared as if children could learn from the website, but some content was edited to better support learning and engagement.

The purpose of this study was to formally determine whether the final version website with games based on these five media properties and played at home could meaningfully promote literacy development among low- and middle-SES preschool and kindergarten students. Children in this age range from low- to middle-income households may need extra literacy support prior to school entry (Alexander et al., 2007), possess the fine motor skills necessary to benefit from educational computer content (Calvert et al., 2005), and potentially be receiving complementary lessons from their preschool and kindergarten educators, who might be teaching towards the same learning goals (National Literacy Panel, 2001). We therefore predicted (Hypothesis 1) that children would learn early literacy skills from playing *Island.* Because of the Capacity Model

tenet about the importance of repetition (Fisch, 2004), we also predicted (Hypothesis 2) children who engaged with the website in general or games promoting specific skills most frequently would demonstrate stronger learning outcomes. Drawing from both Capacity Model and Sociocultural research, which suggest that children learn more from computer games when they receive explicit parent support, we also predicted (Hypothesis 3) learning might be enhanced if parents used complementary materials to further scaffold children's learning.

2. Method

2.1. Research Design

Researchers implemented a randomized control trial with assignment on the individual level. After pre-testing, children were randomly assigned for 8 weeks to play literacy-focused games on the *Island* website (RTL Group 1, n = 48), to play the *Island* games and engage with additional complementary books and activities with their parents (RTL Group 2, n =45), or to play a commercial website with puzzles and arts-themed games that did not focus on literacy (Control, n = 43). Because there were no significant differences between the two RTL groups and parents reported low use of the literacy support materials, we collapsed these two subgroups in subsequent analyses (n = 93). All research activities were approved by the university Institutional Review Board (IRB).

2.2. Participants

A total of 136 families participated in the study. Ninety-four children attended preschool (mean age = 4.86 years, SD = .47; 51 female) and forty-two attended kindergarten (mean age = 6.09 years, SD = .32; 20 female). Ages of child participants ranged from 4 to 6.83 years (mean age = 5.24 years, SD = .71). The sample included a mix of races and ethnicities, with child participants being Caucasian (27.9%), Hispanic (27.9%), African American (19.9%), Asian

(7.4%), and Other or Mixed (16.9%). We recruited families from 15 schools in a large Midwestern U.S. city. Because, as mentioned above, RTL aims in part to provide extra support to children from low-income backgrounds (CPB & PBS, 2011) and because of the dire need to better understand how to support low-income children's literacy development (Slavin et al., 2009), we made an effort to recruit from community preschools primarily serving a low-income population or from the local public schools, where on average 84.9% of students are considered low income. Across the sample, the mean family income was $56,635 ($43,932 adjusted for cost of living in the city where the study took place). We calculated an income-to-needs ratio for each family using reported income, cost of living in the city (American Chamber of Commerce Research, 2007), and family size. This ratio reflects family income relative to the U.S. federal poverty threshold. The median and mode income-to-needs ratio was 1.29. The U.S. federal government has determined that an income-to-needs ratio below 1.85 qualifies children for free or reduced lunch (Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), 2009); 61.8% of the participants in our study fell below this number. Despite efforts to target low-income schools, there was variance across the sample with the middle 50% of income-to-needs ratio falling between .85 and 3.18.

Parents were diverse in terms of educational attainment. Fifteen percent of the mothers had post-college degrees, 32% had college degrees, 31% percent completed some training after high school (some college, vocational school, or an associate's degree), 14% percent had a high school degree, and 7% had less than a high school degree. Most parents in the study were employed full-time (44.9% of mothers and 71.2% of fathers). The majority of parents were married (75%). On average, households consisted of 4.35 people with 2.38 children. Only one child from each family participated in the study. In the rare case in which there was more than

one child between the ages of four and six in the household, the oldest eligible child was enrolled in the study, in order to increase the number of kindergarten-aged participants in the study. All of the participants in the study had a working laptop or desktop computer with high-speed Internet access at home, as that was a requirement for participation. In addition, children had used a computer before and were able to use a mouse, said letters in English, and at least one parent was able to read English and complete online or phone surveys in English. Parents reported that the majority of children (86.7%) were able to navigate a website at least somewhat easily. We required families have a laptop or desktop to ensure that all children were accessing the same version of the website; *Island* was originally designed in Flash and not all components were compatible with all tablet computer operating systems. We also required this mastery of English because the RTL website was in English, and pilot research suggested that children who knew few letters in English found the site too difficult and quickly lost interest. Although parent support materials describing the *Island* are available on the site in Spanish, the actual environment and games are presented in written and spoken English.

We dropped an additional 24 families after the beginning of the study. Reasons included: did not use the website or played a few games and then stopped (n = 9), parents failed to complete surveys (n =7), computer no longer working (n = 5), left school prior to the post-test phase (n = 1), or did not want their child to use the computer/withdrew use as a form of punishment (n = 2). Dropped participants had fewer adults at home ($t(156)=-2.91$, p <.01) and lower household incomes ($t(155) = -2.89$, $p < .01$), but did not differ from study families in terms of any other demographic characteristics (i.e., gender, grade, ethnicity, employment status, parental education, and number of children).

2.3. Stimuli Website

Children in the RTL group played *PBS KIDS Island,* a website embedded with games created by PBS with support from the U.S. Department of Education's RTL initiative. The website and its games are directed toward children four- to six-years-old and aims to teach language and literacy skills aligned with recommendations from the National Reading Panel (2000). As mentioned previously, the game characters are drawn from five PBS RTL-funded properties targeting the same age group: *WordWorld, Super WHY!, Between the Lions, Sesame Street,* and *Martha Speaks.*

The RTL website allows children to build their own island amusement park by playing games that support literacy skills as well as games that support general cognitive skills. The games on the *Island* work on alphabetic knowledge (including letter identification and letter sequencing), phonemic awareness (including rhyming and alliteration), phonics, vocabulary, and reading.

There is a structured path through these games; children need to complete four games on one skill level before four games of the next level with more advanced literacy content become available in the form of new "amusement park rides" (initially, unavailable rides have 'under construction' signs and are not clickable). After playing all four games on the first level and then each of the four games on the next level, children continue to earn rides, until they complete eight levels. Games in higher levels present progressively more challenging learning content, with some concepts repeated across multiple levels (e.g., on levels 1 and 2 children can practice identifying letters and enhancing alphabet knowledge in a bingo game. Levels 4 to 6 promote more advanced phonemic awareness skills with different rhyming games, as well as games where children can practice blending different sounds like "wr" and "ap" to make a new word of

their two sounds, like “wrap”). Games are relatively short, straightforward, and focused on the target learning content. For instance, in a vocabulary-themed game, children are instructed to take digital pictures of target words. For the most part, games deliver playing instructions verbally and have large, easy-to-click hotspots. The games also provide corrective feedback and allow for multiple guesses if children give an incorrect answer (e.g., the Big Bad Wolf steps closer to the forefront of the screen each time the child incorrectly identifies a target letter of the alphabet in one game). There were eight sequenced levels for a total of 32 games, some of which supported multiple skills: 11 letter identification (six focused on uppercase letters), five rhyming, two letter sequencing, four alliteration, three phonics, two phonemic awareness, five vocabulary and six comprehension (see supplementary materials for descriptions of the full set of games). For each game they complete, children receive tickets which can be redeemed for prizes to personalize the gameplay space.

The control website featured games inspired by other popular children’s television shows not funded by RTL, such as *Bob the Builder* and *Roary the Racecar*. The suite included 66 games children could play in any order, such as memory games requiring children to choose matching digital cards featuring characters from *Angelina Ballerina* from a deck of cards “facing” down, complete puzzles of scenes of Pingu and his friends, “paint” machines featured on *Bob the Builder*, and create songs by clicking pieces of Fireman Sam’s fire truck (e.g., clicking on the truck’s siren to make trumpet-like noise). The games did not focus on pre-literacy skills or advance in a leveled fashion.

2.4. Measures

In this study, parents were surveyed six times over the course of the 8-week intervention and children completed a series of pre- and post-intervention assessments yielding 12 different

scores (see Table 1). Pre-literacy measures were chosen to assess the skills demonstrated and practiced on the RTL website and identified to support children in developing literacy (National Reading Panel, 2000). When possible and for all but three cases, we used standardized measures of early literacy that are predictive of later reading success. When standardized assessments were not available or not considered adequate to assess learning from the website, researchers developed website-specific measures. Psychometrics on one of our standardized measures, the Phonological Awareness Literacy Screening PreK assessment (PALS-PreK), had reliabilities in norming studies ranging from .74 to .94 (Invernizzi, Sullivan, & Meier, 2004). Psychometric assessments on our other standardized measure, the Get Ready to Read!-Revised (GRTR-R) Screening Tool, had an internal consistency reliability of .88, test-retest reliability of .73, and has demonstrated predictive validity and classification accuracy (Lonigan & Wilson, 2008, Wilson & Lonigan, 2009, Wilson & Lonigan, 2010).

2.4.1. Child measures. We assessed *Letter Identification and Letter Sound Knowledge* using the PALS-PreK Alphabet Knowledge Task and the PALS-PreK Letter Sounds Task (Invernizzi, et al., 2004). These tasks included three different activities: a) identification of the 26 uppercase letters; b) identification of the 26 lowercase letters; and c) identification of the sounds associated with 23 letters and 3 digraphs (i.e., a combination of two letters representing one sound). To begin, children are shown all 26 uppercase letters, in random order, and are asked to identify each, one by one. If the child correctly identifies 16 uppercase letters, he/she is eligible to proceed to the lowercase letters task, which repeats the same procedure for the 26 lowercase letters. If a child correctly identifies 9 lowercase letters, he/she may proceed to the Letter Sounds portion of the tasks, which repeats the procedure yet again for 23 letters and 3 digraphs (ch, sh and th). We gathered three types of scores: the number of letters or sounds a

child could correctly identify, eligibility to complete the task identifying lowercase letter names or letter sounds, and fluency scores (i.e., the number of seconds it took to identify one letter or sound for each of the three tasks). We assessed *Letter Sequencing* using a researcher-developed instrument inspired by an *Island* game which asks children to identify which letter came next in the alphabet sequence when the letter was replaced by a silly word, such as cheeseburger. Researchers asked children to identify four letters; they received two points if they identified it correctly on their first attempt, and one point if they identified it correctly on their second attempt (after hearing the researcher sing the alphabet song, replacing the silly word with their first, incorrect response). A second attempt was provided to children as this assessment was modeled after the *Island* game that offers a second chance. Children could receive a total of eight points on this measure.

We evaluated *Alliteration,* a measure of phonological sensitivity, using the PALS-PreK Beginning Sound Awareness subtest. This test asks children to identify the sound at the beginning of words, shown on small laminated cards with black and white line drawings on them. We used four picture cards as samples, and each card on the measure had a word that began with the letters s, b, or m. As children identified the beginning sounds, the researcher sorted the cards into stacks according to their beginning sounds. There were ten test items, each worth one point.

We assessed *Rhyming* with the PALS-PreK Rhyme Awareness test, which asks children to identify a picture that rhymes with a target word when given three choices, using simple black and white line drawings (e.g., “This is a mop. These pictures are top, bike, can. Find the picture that rhymes with mop.”). There were ten test items, each worth one point.

Phonics were evaluated using another researcher-developed tool. This measure was

based on an *Island* game in which a PBS character guides children through spelling a word. The measure asked children to identify the letter that made a specific sound (e.g., "find the letter that makes the 'buh' sound"), going through each letter to spell a three or four letter word. The assessment asked children to spell three words by identifying a total of 10 letters which were each worth two points if correct on the first try and one point if correct on the second try, for a total of 20 possible points. Again, children were given a second chance because the model game for the assessment did.

We measured *Vocabulary* with a researcher-developed instrument designed to assess participants' knowledge of 20 target words, measuring receptive vocabulary knowledge of website-specific terms. The procedure for selecting the 20 target words included coding all of the target words introduced in 4 website vocabulary-themed games for grade level, as indicated by the Living Word Vocabulary: The Words We Know: A National Vocabulary Inventory (Dale & O'Rourke, 1981). The words ranged from grade 2 to 16. When all of the words were coded, we randomly selected 20 words from grades 2 to 4 to reflect the overall population of target words likely to be accessible but not already known to preschool and kindergarten children. Furthermore, researchers selected words based on their ability to be pictorially represented. We modeled the specific test after the Peabody Picture Vocabulary Test-4 (PPVT-4; Dunn & Dunn, 2007), a norm-referenced receptive vocabulary test validated for children as young as 2.5 years old. As such, four choices were presented in the form of color photographs for each vocabulary word. The child was asked to point to the correct picture of a word (e.g., "Show me *snoozing*", "Show me *mustache*"). There was one sample question and 20 test questions each worth one point.

The *Get Ready to Read!-Revised Screener (GRTR-R)* consists of 25 items that primarily

assess concepts of print, phonics, and phonemic awareness. For each item, children are shown a page with 4 pictures. The researcher reads aloud the test question and the child answers by pointing to one of the four pictures. Children were given a score of a (1) for every correct answer provided and a (0) for every incorrect answer provided, with a maximum score of 25 points. Sample items include: "These are pictures of a book; find the one that shows that back of the book," an item showing four letters "find the one that makes the sss sound," and an item with four pictures "this is ball, and these pictures are zebra, shoe, wall, leaf. Does ball sound like zebra, shoe, ball, or leaf? Find the one that rhymes with ball."

2.4.2. Parent questionnaires. After recruiting and screening parents at schools, members of the research team hand-delivered surveys to them. Parents returned the initial family demographic survey to their child's teacher or by mail. Those who did not respond to requests to return the initial survey were given the option to complete the survey over the phone or online. Parents completed five additional surveys over the course of the study, primarily focusing on their child's usage of the study websites, as well as other educational websites. Parents completed surveys over the phone or online at regular intervals of approximately every 1.5 weeks, in relation to the child's start date in the study and depending on their availability. After children were post-tested, parents completed a final post-intervention survey.

2.5. Procedure

After receiving parental consent, trained interviewers conducted pre-test assessments in schools using the measures described above. Each session took 15 to 30 minutes. Immediately following the pre-test, researchers gave participating families a letter with their assigned website and called parents within a few days to ensure receipt of the letter and answer any questions they may have had about using the website. In both groups, children were encouraged to use the

website 4 times per week for approximately one hour per week for approximately 8 weeks (*M* = 7.71, *SD* =.62 weeks). Teachers were not made aware of the stimuli websites and were not informed of children's condition assignment. As far as we are aware, children did not play either the RTL or control website in school.

Researchers assigned child participants in the RTL group a username and password so that usage data on which games were played and how often could be tracked using PBS's parent tracking software. Participants' email addresses, which were used to log in to the *Island*, were provided to PBS (with parental consent) so they could track use by these children. Daily tracking information provided by PBS included the date of the last login, level reached, total number of games played, number of plays for each game, tickets earned for completing games, tickets redeemed, prizes bought, and rides built. We used these data to confirm the continued participation of children in the study as well as to assist with technical problems. Comparable information was not available for the control group because their assigned website did not require a login, so website usage was assessed via weekly parent surveys. After the intervention period, trained researchers again assessed children's early literacy skills at school using the same battery of assessments. Finally, after completing the post-test assessments, we provided children with a book and stickers and gave parents $100 for their participation. Children in all groups participated in the same pre-test and post-test activities. Schools were also given a small monetary donation for allowing us to recruit families and conduct on-site interviews with children.

2.6. Analytical Approach

Early literacy skill gains were tested using Analysis of Covariance (ANCOVA) models to evaluate differences between conditions. We controlled for initial group differences related to

children's academic outcomes (Duncan & Murnane, 2011) as measured by the child's pre-test literacy ability, child's age at pre-test, and family differences as assessed by a composite measure which was formed by z-score transforming and then summing adjusted income, mother's age and mother's education, with scores ranging from -4.19 to 5.65 (M = 0, SD = 2.25). We tested for interactions between condition and the family difference composite, as well as each of the indicators comprising this composite. There were no significant interactions, and therefore we control for family differences without including any interaction terms in our final models. Although children were randomly assigned to condition within each school, we also included school as a random factor to account for the possibility that children may have been more receptive to the intervention lessons if the schools' teaching philosophy complemented the curriculum (Savage et al., 2013) and for the possibility that results may have varied had we sampled from a different set of schools. For these analyses, we report significant effects associated with Condition, age, school, and parent composite. During initial analyses, we also examined gender as a potential between-subjects grouping factor but it was not included in final models because it was unrelated to any of the outcome variables and did not interact with condition.

Preliminary checks were conducted to ensure that there was no violation of the assumptions of linearity, normality, homogeneity of regression slopes, homogeneity of variances, and reliable measurement of the covariate. Identification of uppercase and lowercase letters, alliteration, phonics, letter sequencing, and GRTR-R required transformation (inverse and reflect) in order to meet the requirements of ANCOVA because these variables were negatively skewed. The reported results were largely similar to those conducted without transformations. Outliers were removed (three or fewer cases per measure) when person-level assumptions were

violated. See Table 1 for unadjusted means ± standard deviations for each outcome variable.

3. Results

3.1. Intervention Use

Fidelity of implementation in this evaluation concerned website usage to ensure study manipulation occurred. We assessed website usage via weekly parent surveys for both conditions as well as tracking data for children in the RTL group only.

3.1.1. Parents' reports of children's website use. Parents' responses about how long their children spent using the study websites in the week or two prior to each survey were compiled and averaged to determine mean time using each of the websites per week. Parents' reported that children in each condition used their assigned website for an average of about 40 minutes per week (Control M = 42.44, SD=21.03, RTL group M = 39.09, SD = 18.60).

As required by the intervention, there were significant differences in usage of the assigned websites: Control t (42) = 11.57, $p < .001$ and RTL: t (92) = -19.51, $p < .001$. This degree of compliance is consistent with previous children's television evaluation research (e.g., Linebarger & Piotrowski, 2009). Further, children spent very little time using their non-assigned site: seven children in the control group[1] and twelve children in the RTL group reported a small amount of time using the other site. Thus, consistent with the intervention requirements, children primarily focused on their assigned website.

3.1.2. Island tracking data. Tracking data were available for 91 participants from the RTL group. We were unable to obtain tracking data for two of the study participants as PBS was unable to track their logins over the course of the intervention. However, parents indicated that

[1] The RTL website was publicly available at the time of data collection. As such, control group parents who were aware of *Island* could create their own accounts. Control parents did not provide researchers or PBS their login information for detailed tracking but did report on their use of the website in the parent survey.

these two children did continue using the website throughout the 8-week study period, and therefore parent reported usage data, where available, was used in these cases. For one of the two participants, researchers were able to login to the account to confirm continued usage of the site and corroborate parents' survey data.

3.1.2.1. Website usage. Overall, children in the RTL group logged into the site an average of 22.70 times (*SD*=12.14) over the course of the intervention. Thus, children logged into the site an average of 3.44 times per week (*SD* = 1.91) for bouts of 11.36 minutes. Each week, children played an average of 14.40 out of 32 games (*SD* = 12.46).

Level reached. The RTL website has eight levels. All children reached at least level three, which primarily promoted alphabetic knowledge with additional phonemic awareness and phonics activities. Participants reached the remaining five levels at rates of 96.70%, 90.11%, 80.22%, 69.23% and 64.84%, respectively for each level. Thus, nearly two-thirds of children reached level eight. Level reached did not differ significantly by age or grade (preschool, kindergarten).

3.2. Literacy Outcomes by Condition

3.2.1. Letter identification. Alphabetic Knowledge was assessed with four scores: how many of the 26 uppercase letters children identified, average time per uppercase letter named, how many of the 26 lowercase letters children identified and average time per lowercase letter named. With the exception of lowercase letter naming, these scores (i.e., uppercase letter scores, uppercase fluency, lowercase fluency, see Table 1) did not vary by condition.

Lowercase letter scores were analyzed in two ways: 1) with only those children eligible to complete the tasks and 2) assigning those who were not eligible scores of 0 (*n*=11 at pre-test). In both cases, there was a significant difference between the two conditions, so results were

reported with the full sample. Children in the RTL group named more lowercase letters than those in the control condition, F (1, 115) = 4.75, $p < .05$, partial $\eta^2 = .040$. Not surprisingly, child's age was also a significant predictor of lowercase letter naming, F (1, 115) = 8.94, $p < .01$, partial $\eta^2 = .072$.

3.2.2. Letter sound knowledge. Letter sound knowledge (i.e., identification of phonemes) was analyzed in two ways: 1) with only those children eligible to complete the task and 2) assigning those who were not eligible scores of 0 (n=11 at pre-test). Results again were reported with the full sample because these two techniques did not impact the findings. Both how many of the 26 letter sounds children identified and average time per letter sound named were assessed. Letter sound performance significantly increased over time, resulting in a greater number of identified sounds at the post-test for the RTL group when compared with control group performance, F (1, 109) = 5.80, $p < .02$, partial $\eta^2 = .050$. At the post-test, participants in the RTL group knew more letter sounds compared with control group participants.

For letter sound fluency, time per letter was counted as 15 seconds for children who were slower than 15 s (which was approximately 15% of those eligible to complete the task) to meet normality requirements of ANCOVA. Children in the RTL group identified letter sounds more rapidly than children in the control group, F (1, 90) = 8.60, $p < .01$, partial $\eta^2 = .087$. School was also a significant predictor of letter sound fluency, F (13, 90) =2.06, $p < .05$, partial $\eta^2 = .229$, suggesting some schools were especially effective at promoting this skill.

3.2.3. Letter sequencing. Compared to the control group, children in the RTL group demonstrated more correctly sequenced letters at the post-test, F (1, 116) = 5.22, $p < .03$, partial $\eta^2 = .043$. Out of eight target items, RTL group participants identified 6.88 letters at the post-test while control participants identified only 6.07 letters. Children's age (F (1, 116) = 4.38, $p<.05$,

partial η^2=.036) and school (F (14, 116) =2.08, p<.05, partial η^2=.201) were also significant predictors of letter sequencing.

3.2.4. Alliteration. There was a statistically significant difference in post-intervention alliteration between the RTL and control groups, F (1, 111) = 21.02, p <.001, partial η^2 = .159. Children in the RTL group identified more beginning sounds than children in the control group.

3.2.5. Rhyming. Despite higher rhyme awareness post-intervention scores for children in the RTL group than in the control group, after pre-intervention adjustments there was not a statistically significant difference between groups, F (1, 117) = 1.48, p =.226, partial η^2 = .012.

3.2.6. Phonics. Condition was a significant predictor of phonics, F (1, 116) = 10.08, p = .002, partial η^2 = .080. Out of 20 possible points, children in the RTL group scored higher than the Control Group.

3.2.7. Vocabulary. There was a statistically significant difference in post-intervention vocabulary between the RTL and control conditions, F (1, 115) = 7.77, p < .01, partial η^2 = .063. On average, children in the RTL group reported more vocabulary words compared with children in the control condition. Child's age was also a significant predictor of vocabulary post-test scores, F (1, 115) = 4.16, p < .05, partial η^2 = .035.

3.2.8. Get Ready to Read! Revised Screener (GRTR-R). Children's concepts of print, phonics, and phonemic awareness skills as measured by the *GRTR-R* screener were higher in the RTL group than in the control group, F (1, 117) = 4.95, p < .03, partial η^2 = .041.

3.3. Literacy Outcomes Predicted by Game Play (RTL group only)

To see if there was a relation between the RTL group's engagement with the website and learning, multiple regression was used to assess the ability of time or type of game play to predict literacy outcomes, after controlling for child's pre-test literacy ability, child's age, school,

and parent composite. There were no significant relations between parents' reports of children's overall time playing on the *Island* or tracking of number of games played per level. However, number of times playing games promoting specific skills were, in some cases, predictive of corresponding learning outcomes. It was found playing phonics games[2] was predictive of letter sound knowledge ($\beta = .11$, $t = 2.09$, $p < .05$), letter sound fluency ($\beta = -.14$, $t = -2.43$, $p < .02$), and phonics (B = .11, $t = 1.85$, p .= .068). Playing uppercase letter games[3] was predictive of uppercase letter knowledge ($\beta = .22$, $t = 3.11$, $p < .01$) and letter sequencing ($\beta = .19$, $t = 2.01$, $p < .05$). In other words, children who played more phonics and uppercase letter games demonstrated stronger performance for some outcomes. There were no other significant relations between gaming content and the related outcome.

4. Discussion

In this study, use of the RTL website predicted growth of young children's early literacy skills, with RTL group children showing improvements on eight of 12 assessments (supporting Hypothesis 1). Specifically, the RTL group scored significantly higher on lowercase letter identification, letter sound awareness, letter sound fluency, letter sequencing, alliteration, phonics, vocabulary, and the GRTR-R general literacy assessment. Children in the intervention group also outperformed children in the control group on the other four assessments, although not to a significant degree. Uppercase letter knowledge was also significantly related to time spent playing games focused on uppercase letters (providing some support for Hypothesis 2). Thus, this study suggests that web-based games specifically designed to teach early literacy skills

[2] Phonics games included *Princess Presto's Spelling Game, Princess Presto's Create Your Own Superhero* and *Spectacular Sounds Bingo.*

[3] Uppercase letter games included *Theo's Puzzles (1 +2), Alpha Pig's Bricks, Alpha Pig's Lickety Letter Bingo, ABCD Watermelon* and *Princess Presto's Bingo.*

following recommendations of the National Reading Panel (2000) can be effective when played by preschool and kindergarten-age children in a home setting with only limited direct parental support. Below, some possible implications and explanations regarding these results are discussed.

Phonemic awareness and letter knowledge are two of the best predictors at school-entry of children's reading abilities during the first two years of instruction (National Reading Panel, 2000). Thus, it is quite meaningful that children in the RTL group showed gains in these areas. Among the significant results, effects were biggest for alliteration (a phonemic awareness sub-skill) and phonics. Children's ability to identify and fluently name phonemes also improved. These findings were also supported by improvements for children in the RTL group on the GRTR-R screener, which includes measures of phonics, phonemic awareness and letter knowledge. Use of the RTL website was also associated with small improvements in lowercase letter naming, and playing uppercase letter games was associated with improved uppercase letter knowledge.

The RTL website may have facilitated this foundational learning by presenting the information richly and in context, with game mechanics that often required children to focus on intended educational lessons (Fisch, 2004). For example, one alliteration-focused game tasked players with creating pizza toppings beginning with certain phonemes (e.g., "The first pizza is a letter R pizza. Find [click on] toppings that start with the letter R. R makes the Ruh sound"). The website also repeated most learning lessons across multiple games, to help children encode the material in an abstract manner (Fisch, 2004). The analysis on literacy outcomes by game type indicates that repetition mattered for some game types emphasizing more fundamental literacy skills (in particular phonics and uppercase letters) but not other more advanced early literacy

skills, partially supporting Hypothesis 2. This may suggest that, while valuable, repetition might only be necessary to a point or in certain circumstances (e.g., if a child is in need of more basic support), or be less important than other aspects of game design. Some of the games promoting well-learned skills (and others) also provided instant feedback as to whether or not the response was correct, in a way that was non-judgmental and encouraging, which may have been a contributing factor (McManis & Gunnewig, 2012; Yelland & Masters, 2007). Nevertheless, some of the games that seemed to successfully promote early literacy were fairly open-ended with no opportunities for the computer to provide feedback. While it is certainly valuable for games to provide opportunities for children to actively engage with learning material (Fisch, 2016) and receive corrective feedback (Yelland & Masters, 2007), preschool-age children might experience just as much enjoyment and learning from a select number of more open-ended and passive games. Together, these findings suggest a combination of game design characteristics may have promoted young children's phonemic awareness, phonics, and letter knowledge, although it may not be necessary for game designers to implement every best practice in every game. Further empirical research is necessary to determine the optimal level of repetition, interactivity, and corrective feedback needed to promote learning among children in preschool and kindergarten.

Children also demonstrated moderate gains in learning vocabulary words from the RTL website. One reason for these gains may be that many of the games attempted to teach users through direct, explicit instruction, which is an effective technique for word learning and reading comprehension (e.g., Beck et al., 2002; Stahl & Fairbanks, 1986), and by also situating vocabulary instruction in rich contexts with familiar media characters (Fisch, 2004). Because having a strong vocabulary is integral to the development of later reading skills (e.g., Beck et al.,

2002; Stanovich et al., 1984) and because children from low-income households may be in particular need of support in this area (Hart & Risley, 2003), these findings are encouraging and extend previous data indicating that television promotes children's vocabulary development (Moses, Linebarger, Wainwright & Brod, 2010).

Although use of the RTL website was effective at improving many skills, it had no effect on letter naming fluency and rhyming measures. However, this is unsurprising when closely considering the games and participating children. Fluency is a particularly challenging reading skill that children do not usually focus on in school until at least first grade (Grant et al., 2012). Fluency is typically promoted through oral practice activities (National Reading Panel, 2010), which were not part of the *Island* website. Thus, it may be unrealistic for preschool and kindergarten children to gain fluency, as it might have been beyond what the children in our sample could have reasonably gained through the games on the *Island*. In Sociocultural terms, fluency may be beyond the sample's zone of proximal development (Vygotsky, 1930–1934/1978). In contrast, even though rhyming skills were heavily featured in the website and repeated across many games, pre-test data showed that many participants already mastered these skills with scores above the expected spring developmental ranges (i.e., between 5 and 7 rhymes for preschool children), which may have led to ceiling effects. Children typically begin acquiring rhyming skills around age three (Grant et al., 2012); therefore, it is logical that many of the 4- to 6-year-old participants already had strong skills in rhyming. Collectively, these findings underscore the importance of beginning learning sequences with content that is just above children's current level of mastery, as per Sociocultural theory (Yelland & Masters, 2007).

Beyond the specific focus on letters, phonemes, and vocabulary, the interactive nature of computer and web-based games may be key to learning. As noted previously, research shows

that computer games that become more challenging over time scaffold children through their zone of proximal development in a way that promotes successive learning of increasingly difficult lessons (McManis & Gunnewig, 2012) and a sense of self-efficacy and enjoyment (Educational Development Center & SRI International, 2012). The *Island* embodies this design principle as it adds new "rides" with more challenging games as children complete initial, simpler games. Interactivity along these lines enhances children's engagement and motivation, which in turn enhances retention (Cordova & Lepper, 1996). In a similar vein, children's positive attitudes towards literacy and learning engendered through positive media engagement may have downstream positive effects on children's attitudes towards literacy in formal school settings (Fisch, 2004).

Critics have lambasted educational websites and computer games for only having a small impact on children's early literacy (Torgerson, 2007), and noted that evaluation studies typically assess learning with nonvalidated measures (Anderson & Collins, 1988; Hurwitz, 2016). On the contrary, in the present study, children who played the RTL games demonstrated benefits across multiple key early literacy skills assessed via numerous validated measures and assessments designed to emulate validated assessments. Moreover, these children were able to play the intervention website consistently without veering off and accessing age-inappropriate content. Likewise, this study demonstrates that these results generalize to the home context, and to children as young as four, extending the growing body of evidence that was previously largely conducted in schools with a slightly older sample (e.g., Giacomo Dina et al., 2016; Saine et al., 2011). It also is important that the research utilized a randomized experimental-control group design, as much of the controversy regarding whether technology can be an effective tool for young children's literacy learning is due to the lack of rigorous research (Torgerson, 2007).

Children who succeed in developing pre-literacy skills prior to or during kindergarten may be set up on a positive trajectory to do well in school across subject areas. For instance, early reading has been demonstrated to be an important predictor of mathematics achievement (Grimm, 2008). With the implementation of educational policy such as No Child Left Behind and Common Core State Standards (CCSS), there has been a move towards an *integrated curriculum*, where teachers use informational texts like newspapers and trade manuals to allow children to explore science and social studies, while also developing their foundational literacy skills. Studies have shown that integrating science with literature increases both interest (Madrazo, 1997) and comprehension (Rice, 2002). Similarly, incorporating informational texts into social studies curriculum supports a richer understanding of history and social studies concepts (Gunning, 2012). Difficulties with early reading skills, therefore, may exact a toll on children's performance in mathematics, science, and social studies, as well as on their self-confidence, motivation, and subsequent reading achievement (e.g., Kaniuka, 2010). Thus, it is important that free resources, such as the *Island* website, can serve as tools to support early literacy development, which in turn may help ensure longer-term academic success.

Nonetheless, these findings should be interpreted carefully as the use of the RTL website via an in-home intervention may not only indicate use of the web-based games but also imply overall supportive family environments (Plowman & Stephens, 2003). We know that adult mediation is important to young children's learning (Klein & Alony, 1993; McManis & Gunnewig, 2012; Nir-Gal & Klein, 2004), and research on web-based learning indicates that parents are interested in learning about and engaging with kids' informal learning from media (e.g., Roberts, Chung & Parks, 2016). It is for these reasons that the Capacity Model highlights the potential benefits of parental mediation in extending learning from media (Fisch, 2004).

Despite parents' general interest, previous research suggests their actual involvement in children's educational website play is low (Ronimus & Lyytinen, 2015). Our informal conversations with parents likewise suggest that although most parents of children in the RTL group helped with the use of the website initially, it is unlikely they were actively mediating children's website use throughout the course of the intervention. Likewise, because the games adhered to production recommendations suggesting that children should be able to play educational websites relatively independently (e.g., McManis & Gunnewig, 2012; Plowman et al., 2008), parents may not have perceived a need to supplement children's play. In other words, parents may have conveyed tacit support for the use of *Island* as an educational tool, as per the Sociocultural theory (Plowman & Stephen, 2003) but likely were not the main causal mechanism explaining the present pattern of results.

Despite the importance of parental involvement in children's learning, we found that Hypothesis 3 was not supported, and the use of additional parental support activities in one of the intervention groups did not have a significant impact on outcomes, contrasting Capacity Model predictions (Fisch, 2004). This finding is similar to other interventions that rely on parents or teachers to implement material they may not feel they need (e.g., Garrity et al., 2010; Pasnik et al., 2015). In addition, the supplemental materials were not developed by RTL, and as such, may not have seemed as connected to the website as well as if they contained the same characters and curricular focus (Piotrowski, Jennings, & Linebarger, 2012). Finally, time constraints may have limited the time parents had to engage in these exercises, as most worked full time and had children in school full time. In the final survey, parents who had access to support materials reported rarely looking at the activity booklet (Mo = 4 and Md = 4 times over the course of the full intervention). Reasons included not having time to use the support materials ("We didn't

have time to work on these two activities."), that they were too easy ("He already had mastered these activities and was at a higher skill level.") or too hard ("It was not her level, I guess it was hard for her so it did not interest her."). The fact that children learned despite limited explicit parental mediation may be encouraging for busy working parents, who desire educational opportunities for their children, such as the web-based games on the *Island*, which led to gains even with minimal parental assistance.

4.1. Limitations and Suggestions for Future Research

Although the overall pattern of results is highly encouraging, it is important to note a few limitations when considering these findings. Because all children in the intervention group played the same set of leveled, literacy-focused games with tacit parental support, it is difficult to identify which of these elements or combinations of elements led to the positive effects observed in this study. In addition, all of the children in this study were attending school, which may limit the generalizability of results. Although only letter sequencing and speed of naming letter sounds were significantly related to children's school, children's relatively high uppercase letter scores across the sample were likely due in part to the quality of programs attended. Further research may be able to explore whether results are replicable in children who are not enrolled in academic preschool programs. Further, the sample of children in this study was not representative of children in the country across the U.S., but it was generally representative of the children in the city where the research took place. The study was conducted in a large Midwestern city, with children who were, for the most part, from low-income to middle class families with access to computers with Internet access at home. Therefore, the effectiveness of the website may not generalize to children from other backgrounds or in other regions. Additionally, there may be third variables (e.g., children's motivation to read or involvement in

the *Island* website) that we did not measure but that did account for or contribute to the observed differences in the outcomes. Future research could address these issues.

Future research could also systematically explore two- and three-year-olds' learning from educational websites like the *Island*. Children younger than four were not included in the study, as younger children, especially low SES children, typically have limited computer skills (e.g., Saçkes, Trundle & Bell, 2011) and are not able to navigate websites on their own (Calvert et al., 2005). However, as the penetration of tablets and smart-devices in families of young children is catching up to and surpassing that of more traditional computers (Rideout, 2017), and as developers increasingly version content for multiple operating systems, it may become feasible to version efficacious websites like *Island* for mobile devices, which can be more user-friendly for young children (Michael Cohen Group, 2011).

4.2. Conclusions

Rather than being a distractor that takes away time young children might better invest in developing literacy skills (see Neuman, 1995), this study provides evidence that an educational website developed with support from RTL, *PBS KIDS Island*, can impact the pre-literacy skills of 4- to 6-year-olds, especially in the domains of phonological awareness, phonics, and vocabulary, key predictors of later reading success (National Reading Panel, 2000). Given widespread availability and use of home computers with Internet access among children of this age group and the frequency with which computer games are played (Rideout, 2017), this study provides encouraging news about the potential for educational technology to effect low-to middle-income children's learning and school readiness, even with minimal direct parent involvement, and reflects positively on initiatives like RTL. Children with fewer high-quality educational materials and experiences are at significant risk for later reading failure, and may

benefit from such interventions which are free (e.g., Anderson et al., 2001), can be implemented with minimal direct parental oversight, and are available to all those with access to a computer and the Internet. Further, given the connections between reading skills and other academic outcomes (e.g., Fite, 2002), it is clear that assisting children in learning to read around the time they enter formal schooling is crucial to academic success. This study extends the growing body of literature that children can and do learn key early literacy skills from developmentally appropriate websites (e.g., Saine et al., 2011), uniquely demonstrating that even children as young as preschool- and kindergarten-age can learn from websites at home.

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Table 1

Pretest and Posttest Means and Standard Deviations by Condition for Effects of Website Use on Literacy Outcomes

		Control		Intervention	
	N	Pre-Test	Post-Test	Pre-Test	Post-Test
Uppercase letter knowledge	136	22.93 (5.6)	23.33 (5.29)	23.04 (6.01)	24.04 (4.52)
Uppercase letter naming fluency	134	3.27 (4.95)	1.70 (0.87)	3.19 (5.73)	1.53 (0.71)
Lowercase letter knowledge*	134	20.79 (6.70)	20.74 (7.77)	20.80 (7.68)	21. 89 (6.68)
Lowercase letter naming fluency	123	3.69 (3.76)	3.30 (3.37)	3.43 (4.35)	2.55 (2.50)
Letter sound awareness*	128	12.72 (9.29)	14.28 (7.69)	14.69 (8.90)	17.70 (7.49)
Letter sound fluency**	108	7.35 (4.65)	5.98 (4.29)	6.13 (4.80)	4.02 (3.25)
Letter sequencing*	135	6.05 (1.93)	6.07 (2.10)	6.00 (1.90)	6.88 (1.41)
Alliteration**	133	7.61 (2.98)	7.54 (3.54)	7.35 (3.06)	8.60 (2.65)
Rhyming	136	6.40 (2.72)	6.98 (2.76)	7.04 (2.87)	7.97 (2.44)
Phonics*	136	15.95 (5.36)	16.58 (4.74)	16.03 (5.63)	17.93 (3.72)
Vocabulary*	134	14.19 (3.29)	15.09 (3.01)	14.90 (2.90)	16. 52 (2.14)
Get Ready to Read! (GRTR-R)*	136	18.90 (3.74)	20.02 (4.07)	19.44 (4.44)	21.43 (3.56)

Note. Means and standard deviations in parentheses. The Experimental group outperformed the Control group on the assessments denoted with asterisks (*$p < .05$, **$p < .01$)

Highlights:

- Young children used a literacy-focused or a control website at home for 8 weeks.
- Both groups completed pre- and post-tests of pre-literacy skills.
- Treatment group children showed more gains on nearly all pre-literacy outcomes.